Australian Research Data Commons

ARDC Digital Research Capabilities & Skills Framework

THE FRAMEWORK AND ITS COMPONENTS

v1 - Consultations (2021-2023)

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Australian Research Data Commons

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Acknowledgement of Country

We acknowledge the traditional custodians throughout Australia and their continuing connection to, and deep knowledge of, the land and waters. We pay our respects to Elders both past and present.

Australian Research Data Commons

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1. SUMMARY

The ARDC's Digital Research Capabilities and Skills Framework, released in 2022, provides a structure for training programs to develop essential and advanced digital research skills. It aims to help researchers and professionals identify the necessary skills they need to leverage emerging opportunities in data management, data analysis, data linking, AI, and machine learning. The framework aligns with technological advancements and encourages ongoing discussion and contributions to evolve the coverage of digital research skills.

The framework focuses on digital research skills, excluding broader professional skills, and is intended for a wide range of stakeholders. It provides a structured approach for project teams and organisations to develop and enhance their digital research skills through six main components: a skills taxonomy, a skills glossary, a list of generalised roles, roles and skills-related profiles, learning paths, and a skills and roles matrix. The skills taxonomy classifies digital research skills into four capability families: Governance, Data, Software, and Digital Research Infrastructure Management. It provides a standard terminology for identifying and describing these skills.

The ARDC Skilled Workforce Development team will refine and expand the Skills Framework to keep it relevant. The team will gather feedback, build role profiles and learning paths, share resources, and monitor implementations. The ARDC invites contributions from universities, research organisations, industry partners, and policymakers to help shape the framework into the future. Stakeholders can get involved by sharing use cases, collaborating on refinements, and participating in discussions on best practices and future directions.

2. INTRODUCTION

In this paper, the Australian Research Data Commons (ARDC) presents a detailed and updated view of its *Digital Research Capabilities and Skills Framework* (Skills Framework) which was released through the Open Science Foundation (OSF) in 2022.

The Skills Framework provides a relevant structure for training programs and curricula development to aid in upskilling and equipping researchers, data scientists, research software engineers, data architects, data engineers, and others with essential foundational and advanced digital research skills. It guides these groups in acquiring the necessary skills and knowledge to tackle innovative research methods, services, and tools, and to leverage emerging opportunities in data management, data analysis, data linking, AI, and machine learning.

The Skills Framework is designed to align digital research skill sets with rapid technological advancements and expanding data sources. Although not yet comprehensive, it currently covers essential digital research skills across the breadth of research disciplines and domains. Skills frameworks

that offer deeper expertise within specific research fields can integrate seamlessly to extend their own and the ARDC's skills framework.

As this work evolves, we encourage ongoing discussion on the content of this paper and the ARDC Skills Framework. We extend our thanks to all current contributors for their insights and active engagement during targeted consultations, successive ARDC Skills Summits, and serendipitous conversations. Your invaluable input and feedback have been crucial in shaping the Skills Framework for the benefit of the research sector.

3. BACKGROUND

3.1. What is a Skills Framework?

Skills frameworks help organisations, projects and teams identify relevant roles, key capabilities and necessary skills needed for effective performance. They can also define competencies to assess the application of those skills at various experience levels.

These frameworks highlight existing and emerging skills, roles, job profiles and learning pathways, providing the toolkit for upskilling individuals and addressing skills gaps[1]. Using an accepted and standardised terminology, they support the design of training programs and resources for skills and career enhancement and serve as a mechanism for workforce planning, transformation, and change management[2].

3.2. What is Digital Research?

Digital research refers to the use of digital tools and technologies to collect, manage, analyse, and interpret research data. These approaches are transforming the research landscape by enhancing efficiency, fostering collaboration, and increasing accessibility.

Some examples of emerging technologies in digital research include:

- using artificial intelligence (AI) and machine learning (ML) to analyse large or complex datasets, identify patterns and make predictions
- collecting real-time data from various sources using Internet of Things (IoT) devices
- transferring and processing data in non-traditional ways, faster and more efficiently using quantum computing.

[1] *Singapore Government. "Skills Frameworks." Skills future. [website] (Updated 22 July 2024). https://www.skillsfuture.gov.sg/skills-framework, accessed 13 October 2024.*

[2] *Plummer, D., Kearney, S., Monagle, A., Collins, H., Perry, V., Moulds, A., Mroczka, M., Robertson, J., Smith, T., Trewavas, S., & Lewis, C. (2021). Skills and Competency Framework - Supporting the development and adoption of the Information Management Framework (IMF) and the National Digital Twin. CDBB. https://doi.org/10.17863/CAM.65347*

As noted by UK Research and Innovation, "Digital research infrastructure allows us to work with data and computation efficiently and securely across all research and innovation challenges"[3]. To make the most effective use of this digital research infrastructure, being responsive to rapid technological advances and societal shifts requires continuous updating of digital research skills[4].

3.3. Why Create a Digital Research Capabilities and Skills Framework?

Policy development,public investment in digital research infrastructure and advancements in commercial offerings, has enabled greater access to more data being generated and made available through data enabled research and the emergence of new technologies, methods and digital tools. The promise and benefits for researchers, and society as a whole, are more innovation and improvements in the rate, transparency and reproducibility of research. The realisation of these benefits is predicated on matching increases in the data and digital research skills of our research workforce. Without a highly capable workforce, investments in digital research infrastructure will be under-exploited. The lack of requisite skills to effectively apply and leverage these new methods and technologies results in researchers' underutilisation of digital research infrastructure, reducing research efficiency and inhibiting their global competitiveness.

The Skills framework presented in this paper serves as a crucial enabler for developing a highly skilled digital research infrastructure (DRI) workforce and equally skilled Australian researchers, highly capable in their use of DRI. This framework aims to identify the skills and levels of experience needed across a range of relevant roles, helping the research sector assess and resolve any gaps in digital research skills, while setting out skills expectations for people involved in designing, developing and deploying DRI.

3.4. Why the ARDC?

The ARDC is Australia's leading facility for research data infrastructure. We facilitate access to research datasets and tools from academia, industry and government for all Australian researchers.

Our mission is to accelerate research and innovation by driving excellence in the creation, analysis and retention of high-quality data assets. As such, we run programs and form partnerships that ensure Australian researchers are internationally competitive through their use of high-quality infrastructure including data assets, platforms, policies, people and skills[5].

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[3] *UK Research and Innovation (UKRI). (2024). Digital research infrastructure. [website] (Updated 24 September 2024). https://www.ukri.org/what-we-do/creating-world-class-research-and-innovation-infrastructure/digital-research-infrastructure/, accessed 5 October 2024.*

[4] *Department of Education (Cmth). National Digital Research Infrastructure Strategy. [website] (23 July 2024). https://www.education.gov.au/national-research-infrastructure/resources/national-digital-research-infrastructure-strategy, accessed 11 November 2024.*

[5] *The Australian Research Data Commons (ARDC). 'About us - ARDC' [website] (2024). https://ardc.edu.au/about-us/, accessed 12 November 2024.*

The ARDC is delivering leading-edge digital research infrastructure through 3 Thematic Research Data Commons underpinned by national compute ecosystems, services for discovery, linkage and interoperability of data and a national hub of expertise.

We provide national leadership in DRI. DRI does not run on technological systems and architectures alone. As previously mentioned, expertise and skills are necessary not only for researchers and other infrastructure users to maximise the benefits of these platforms, services and tools, there are also essential digital research skills for the workforce who manage and deploy DRI.

After significant consultation with the training community, partners, institutions and other research performing organisations, and a review of existing data skills-related frameworks, the ARDC commenced work on developing the Skills Framework.

The ARDC designed the framework to help the research sector unpack and understand the skills that researchers and DRI providers need to work with research data, build capability, and improve the development and delivery of digital research skills training. The Skills Framework identifies the essential knowledge, skills and experience levels needed to work effectively in digital research, and the organisations currently best positioned to develop and deliver skills training, which is outlined in more detail in section 5.2.7. below.

The Skills Framework will continue to evolve and grow. New skills will be added as innovative technologies, methods and tools emerge. We encourage all those involved in digital skills training and recruitment to help us expand and build upon the framework to ensure researchers and research support professionals have pathways to improve their digital research skills.

4. ABOUT THE DIGITAL RESEARCH CAPABILITIES & SKILLS FRAMEWORK

4.1. What Does the Skills Framework Help Us Do?

The range of capabilities needed for effective digital research is varied. Digital research capabilities encompass data and digital research infrastructure governance, the principles and practice of FAIR, CARE and open research, research data management and curation, the use of data platforms and infrastructures, data generation, analysis, statistics, visualisation and modelling techniques, software development, digital research infrastructure management and more.

The Skills Framework serves multiple strategic, operational and descriptive purposes, focusing on skills and workforce development within the digital research ecosystem. By identifying the necessary capabilities and skills, we can uncover:

- how current skill sets within the research workforce align with national strategic objectives

- what skills will be required in the future, considering evolving technological and societal trends
- which skills are essential for data-enabled research to keep Australian researchers competitive
- who are the current providers and determining who within the sector is best positioned to offer future skills training. Are there overlaps and duplications? Are there gaps where future investments in skills development are needed?
- how a structured and coordinated approach to digital research skills development can enhance research workforce performance and effectiveness
- what metrics to use in assessing performance based on required skills
- which clearly defined skills are needed for various roles within the research workforce and identification of cross-cutting, fundamental capabilities and skills
- how to address siloed skills and training initiatives, finding ways to bring trainers together to build partnerships that improve collaboration and avoid the duplication in resource-intensive training development
- what a common language looks like that readily identifies, defines and categorises skills across different roles and levels
- what are the gaps between current skills and those required, enabling targeted interventions and investments to address the gaps.

4.2. The Framework's Scope and Limitations

The ARDC Capabilities and Skills Framework focuses on digital research and data-related skills. Skills such as communication, collaboration, change management and other professional skills are also often required for data stewardship, data generation/use, research software engineering and infrastructure management but are outside the scope of this framework.

The ARDC Capabilities and Skills Framework currently focuses on high-level capabilities and skills. As the Framework matures, tools and more specific technologies, such as R, Python, MatLab, Tableau, Tensorflow and Regex, may also be represented.

4.3. Who Can Use the Framework?

This framework is for anyone who wants to understand the skills needed to work with research data, build capability and improve current skills development offerings across their organisations and the research sector.

It is designed to inform a diverse range of stakeholders including research communities, higher education institutions, research-performing organisations, research infrastructure providers, policy makers and training providers.

4.4. How to Use the ARDC Digital Research Capabilities and Skills Framework

As a guide, we recommend the following steps for using this Framework:

1. Review the framework, recognising the skills covered relate specifically to digital research skills and directly enable digital research and support digital research infrastructures.
2. Set a clear vision and goals for what you want to achieve by using the framework – is it to:
    a. address organisational digital research capability gaps,
    b. upskill your researchers in digital research capabilities and skills,
    c. assist in framing curriculum development for universities, and other digital research skills training providers,
    d. create learning paths to skills and expertise in data collection, data management and data analysis,
    e. help funders, peak bodies, and training providers to prioritise the development of new training across the research sector.
3. Collect existing skills and training data – what existing information do you already have about roles, capabilities and skills.
4. Collect new data – using the role profile template and Skills/Roles Matrix competency levels, develop profiles for the roles needed by individuals or teams, identify skills and competency levels required to understand roles and skills gaps.
5. Establish a baseline by analysing the data you've collected.
6. Develop a customised skills and training framework.
7. Review and finalise training plans and paths – develop your own role-based learning paths to close any local skills gaps.
8. Contribute your training materials, resources, role profiles, and learning paths to the Digital Research Skills Australasia (DReSA) training registry. This will help avoid duplicating effort and provide a more comprehensive national perspective on digital research skills training.

Integrate your framework with other skills frameworks (where possible) to add to a nationally coordinated approach to digital research skills training.

5. THE DIGITAL RESEARCH CAPABILITIES & SKILLS FRAMEWORK AND ITS COMPONENTS

5.1. How the Framework is Organised

The ARDC Digital Research Capabilities and Skills Framework is made up of 6 main components as outlined in Figure 1.

The Framework incorporates the following components:

1. A skills taxonomy at high and detailed levels covering 4 high level capability families; Governance, Data, Software and Digital Research Infrastructure Management.
2. A skills glossary with definitions and descriptions of relevant skills terms. The glossary acts as a companion reference tool to the skills taxonomy.
3. A list of 6 generalised data and digital research roles and their purpose.
4. Roles and skills-related profiles for identifying digital research and data-related organisational roles and the skills required to perform these roles effectively.
5. Learning paths that provide a structured and topic-targeted bundle of skills development activities and resources to ensure those in data and digital research roles achieve their learning objectives.
6. The skills and roles matrix highlights the key roles and corresponding digital research skills, what level of experience and proficiency is required and which organisations are best placed to provide the relevant training.

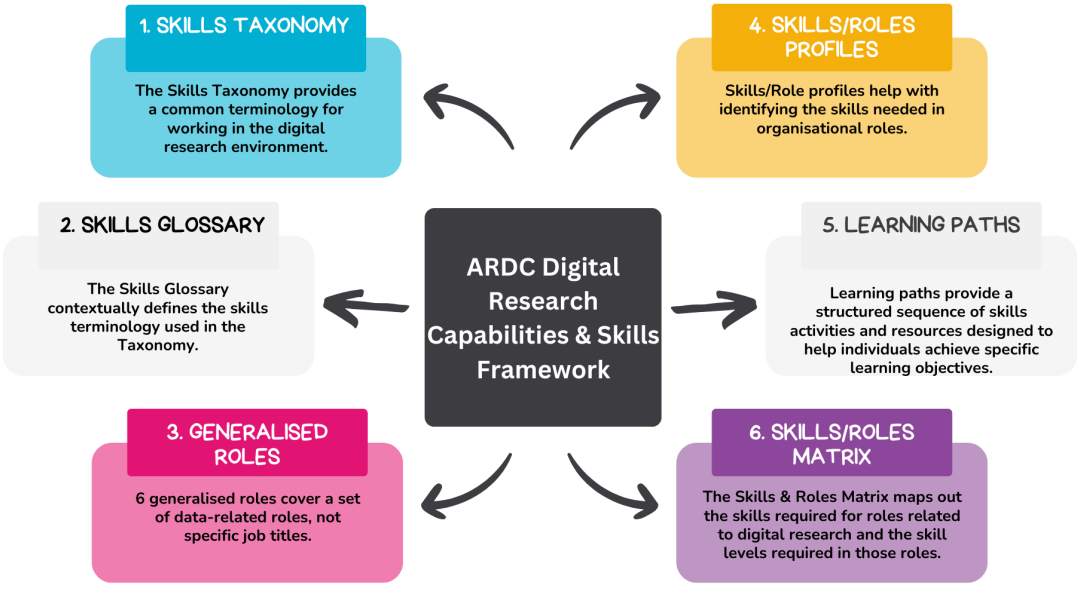


Figure 1: How the ARDC Digital Research Capabilities & Skills Framework is organised

5.2. The Skills Taxonomy

The Skills taxonomy provides high and detailed levels of classification for digital research skills within the following groupings: Governance, Data, Software and Digital Research Infrastructure Management capability families. This is an Australian skills taxonomy for working in digital research environments which aims to provide a standard terminology for identifying and describing digital research skills.

5.2.1. High Level Taxonomy

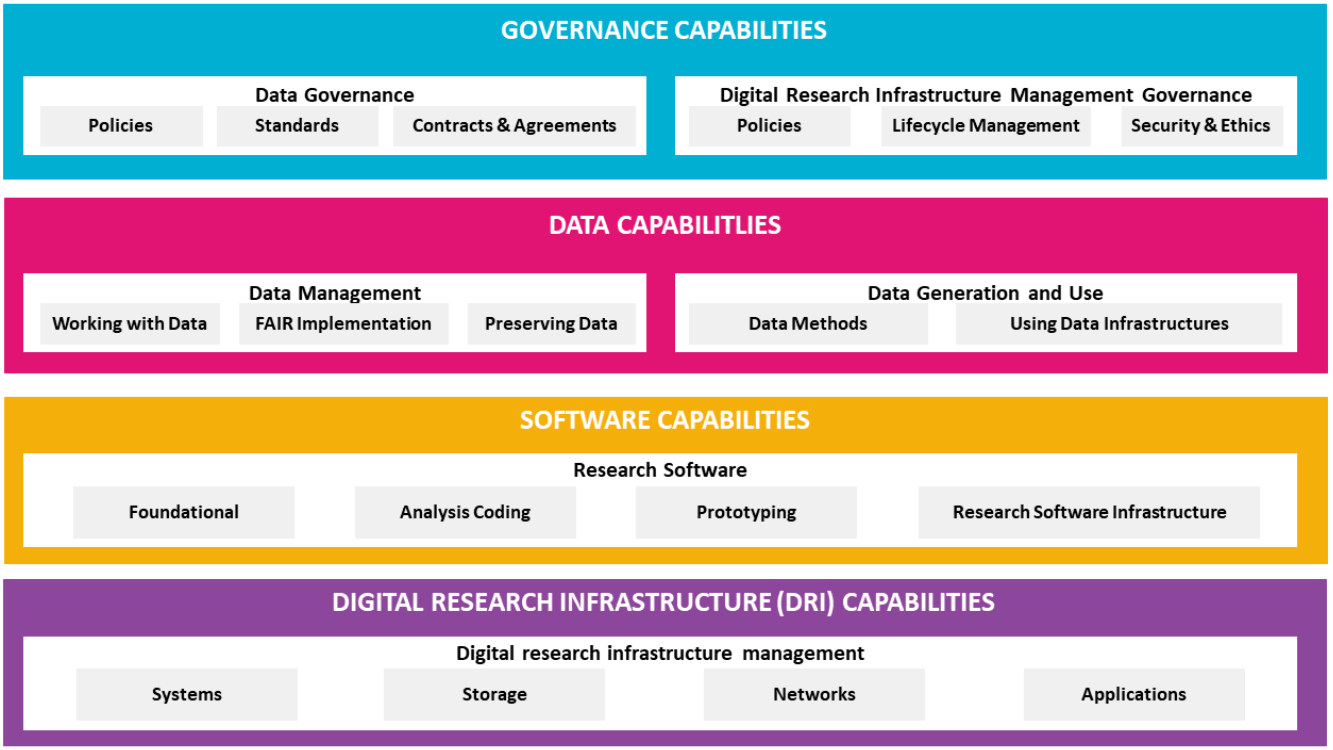


Figure 2: The ARDC Capabilities and Skills Framework focuses on capabilities and skills related to digital research

5.2.2. Detailed Taxonomic View

There are 6 levels or tiers of categorisation within the Skills Taxonomy. To understand the various levels, there are definitions of each level's categorisation term, classification codes, and examples for each level outlined in Table 1.

Definition of categorisation terms

- **Level 1: Capability family** - A broad category that includes a range of related capabilities that share goals or functions and is the highest level of the taxonomy.
- **Level 2: Capability cluster** - A more specific grouping within a capability family, consisting of closely related capabilities. Nested within capability families, capability clusters describe capabilities that work together to achieve specific outcomes.

- **Level 3: Capability** - The ability or capacity of an individual to perform a specific task or function effectively. A capability encompasses a combination of skills, knowledge, experience, and behaviours that enable a person to achieve desired outcomes in their role.
- **Level 4: Skills family** - A broad category that includes a range of related skills that share common characteristics or purposes.
- **Level 5: Skills cluster** - A more specific grouping within a skills family, consisting of closely related skills. Nested within skills families, skill clusters describe skills that are often used to perform particular tasks.
- **Level 6: Skill** - An individual ability or expertise that a person acquires through training or experience. The fundamental elements within clusters and families, representing specific proficiencies or talents. Skills are the building blocks of capabilities.

Classification codes

- **Governance** - Data governance (**D-DG**), Digital Research Infrastructure governance (**D-DRIG**)
- **Data** - Data Management (**D-DM**), Data Generation & Use (**D-DGU**)
- **Software -** Research Software (**S-RS**)
- **Digital Research Infrastructure Management -** Digital Research Infrastructure Management **(DRI-DRIM)**

Table 1. The structure of the detailed digital research skills taxonomy

Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
CAPABILITY FAMILY	**CAPABILITY CLUSTER**	**CAPABILITY**	**SKILL FAMILY**	**SKILL CLUSTER**	**SKILL**
Governance	G-DG: **Data governance**	G-DG/P: **Policies**	G-DG/P/IP: **Institutional policies**		
Data	D-DGU: **Data generation & use**	D-DGU/DM: **Data methods**	D-DGU/DM/D: **Data analysis**	D-DGU/DM/DA/ML: **Machine Learning**	D-DGU/DM/DA/ML/SL: **Supervised learning**
Software	S-RS: **Research software**	S-RS/RSI: **Research software infrastructure**	S-RS/RSI/RSE: **Research software engineering**	S-RS/RSI/RSE/: **Encapsulation**	S-RS/RSI/RSE/E/MDR: **Modular design for reusability**
DRI Management	DRI-DRIM: **Digital research infrastructure management**	DRI-DRIM/SM: **Systems management**	DRI-DRIM/SM/BR: **Backup recovery**		

Table 2. The digital research skills taxonomy in detail

Governance - Capability family				
CAPABILITY CLUSTER	**CAPABILITY**	**SKILL FAMILY**	**SKILL CLUSTER**	**SKILL**
G-DG: **Data governance**	G-DG/FRM: **Foundational - Research methodologies & practices**			
	G-DG/P: **Policies**	G-DG/P/IP: **Institutional policies**		
		G-DG/P/FPP: **Funder & publisher policies**		
		G-DG/P/GPL: **Government policies & legislation**		
	G-DG/S: **Standards**	G-DG/S/DS: **Data standards (generic and community-specific)**		
		G-DG/S/IP: **Intellectual property**		
		G-DG/S/RI: **Research integrity**		
	G-DG/CA: **Contracts / Agreements**	G-DG/CA/DS: **Data sharing**		
		G-DG/CA/DT: **Data transfer**		
		G-DG/CA/DL: **Data linkage**		
G-DRIG: **Digital Research Infrastructure Governance**	G-DRIG/P: **Policies**	G-DRIG/P/NRIS: **NRI strategies, roadmaps & decadal plans**		
		G-DRIG/P/AUP: **Access & use policies**		
		G-DRIG/P/RSP: **Risk & security policies**		
		G-DRIG/P/TT: **Technology transfer & IPR**		
	G-DRIG/LM: **Lifecycle management**	G-DRIG/LM/IP: **Initiation & planning**		

Governance - Capability family				
CAPABILITY CLUSTER	**CAPABILITY**	**SKILL FAMILY**	**SKILL CLUSTER**	**SKILL**
		G-DRIG/LM/DB: **Design & build**		
		G-DRIG/LM/OM: **Operation & maintenance**		
		G-DRIG/LM/IR: **Impact reporting**		
		G-DRIG/LM/EOL: **End-of-life of infrastructure**		
	G-DRIG/SE: **Security & ethics**	G-DRIG/SE/BC: **Business continuity including sustainability planning**		
		G-DRIG/SE/CS: **Cyber security, including crisis response and disaster recovery procedures**		
		G-DRIG/SE/PL: **Privacy & legal obligations**		

Data - Capability family

CAPABILITY CLUSTER	CAPABILITY	SKILL FAMILY	SKILL CLUSTER	SKILL
D-DM: **Data Management**	D-DM/FRM: **Foundational - Research methodologies and practices**			
	D-DM/WD: **Working with data**	D-DM/WD/DMP: **Planning for data management**		
		D-DM/WD/HSD: **Handling sensitive data**		
		D-DM/WD/ASD: **Accessing & storing data**		
		D-DM/WD/DV: **Data versioning**		
		D-DM/WD/DP: **Data pre-processing**	D-DM/WD/DP/DE**: Data engineering**	D-DM/WD/DP/DE/SD: **Structured data**
				D-DM/WD/DP/DE/T: **Text**
				D-DM/WD/DP/DE/I: **Image**
			D-DM/WD/DP/DC: **Data cleaning**	
			D-DM/WD/DP/SD**: Sampling data**	
			D-DM/WD/DP/DT: **Data transformation**	
		D-DM/WD/DQ: **Data quality**		
		D-DM/WD/DII**: Data integration & interoperability**		
		D-DM/WD/CC: **Categorising & classifying**		
		D-DM/WD/DF: **Data flows**		
		D-DM/WD/CT: **Citing & tracking**		

Data - Capability family				
CAPABILITY CLUSTER	**CAPABILITY**	**SKILL FAMILY**	**SKILL CLUSTER**	**SKILL**
	D-DM/FI: **FAIR implementation**	D-DM/FI/FO: **FAIR outputs**	D-DM/FI/FO/MDS: **Metadata schema & standards**	
			D-DM/FI/FO/PID: **Persistent identifiers (PIDs)**	
			D-DM/FI/FO/OF: **Open formats**	
			D-DM/FI/FO/DV: **Data versioning**	
		D-DM/FI/DR: **Discovery & reuse**	D-DM/FI/DR/RDP: **Repositories & discovery portals**	
			D-DM/FI/DR/P: **Provenance**	
			D-DM/FI/DR/AC: **Access conditions**	
			D-DM/FI/DR/L: **Licensing**	
		D-DM/FI/FTA: **FAIR technical architectures**	D-DM/FI/FTA/SCP: **Standardised communications protocols**	
			D-DM/FI/FTA/VOS: **Vocabulary/ontology systems**	
	D-DM/PD: **Preserving data**	D-DM/PD/MD: **Moving data**		
		D-DM/PD/DS: **Data security (long term)**		
		D-DM/PD/RMD: **Reference & master data**		
		D-DM/PD/DW: **Data warehousing & business intelligence**		
		D-DM/PD/AP: **Archiving & publishing**		
		D-DM/PD/ASD: **Appraising, selecting & disposal**		

Data - Capability family				
CAPABILITY CLUSTER	**CAPABILITY**	**SKILL FAMILY**	**SKILL CLUSTER**	**SKILL**
		D-DM/PD/RDI: **Retention & discovery infrastructures**		
D-DGU: **Data generation & use**	D-DGU/DM: **Data methods**	D-DGU/DM/DCA: **Data collection & acquisition**		
		D-DGU/DM/CDA: **Compilation, derivation & aggregation**		
		D-DGU/DM/DA: **Data analysis**	D-DGU/DM/DA/TSA: **Time-series analysis**	
			D-DGU/DM/DA/HGD: **Handling geospatial data**	
			D-DGU/DM/DA/SI: **Statistical inference**	
			D-DGU/DM/DA/ALM: **Advanced linear modelling**	
			D-DGU/DM/DA/UP: **Uncertainty propagation**	
			D-DGU/DM/DA/SA: **Spatial analysis**	
			D-DGU/DM/DA/SW: **Scientific workflows**	
			D-DGU/DM/DA/NM: **Nonlinear modelling**	
			D-DGU/DM/DA/QA: **Qualitative analysis**	
			D-DGU/DM/DA/BT: **Bayesian techniques**	
			D-DGU/DM/DA/MA: **Meta-analysis & systematic reviews**	

Data - Capability family				
CAPABILITY CLUSTER	**CAPABILITY**	**SKILL FAMILY**	**SKILL CLUSTER**	**SKILL**
			D-DGU/DM/DA/SM: **Simulation modelling**	
			D-DGU/DM/DA/ML: **Machine Learning**	D-DGU/DM/DA/ML/SL: **Supervised learning**
				D-DGU/DM/DA/ML/USL: **Unsupervised learning**
				D-DGU/DM/DA/ML/RL: **Reinforcement learning**
				D-DGU/DM/DA/ML/AI: **AI, unstructured & big data**
		D-DGU/DM/DVS: **Data visualisation & storytelling**	D-DGU/DM/DVS/VL: **Visual literacy and graphical principles**	
			D-DGU/DM/DVS/IV: **Interactive visualisations**	
			D-DGU/DM/DVS/2D: **2D & 3D visualisation**	
			D-DGU/DM/DVS/VSL: **Visualisation services and libraries**	
			D-DGU/DM/DVS/VT: **Visualisation tools**	
			D-DGU/DM/DVS/WVT: **Web visualisation tools and techniques**	

Data - Capability family				
CAPABILITY CLUSTER	**CAPABILITY**	**SKILL FAMILY**	**SKILL CLUSTER**	**SKILL**
		D-DGU/DM/RR: **Reproducibility & replication**		
	D-DGU/UDI: **Using data infrastructure**	D-DGU/UDI/DRP: **Data repositories & portal**		
		D-DGU/UDI/PFR: **Platforms / facilities / resources**		
		D-DGU/UDI/AM: **Access management**		
		D-DGU/UDI/CIT: **Citation & impact tracking**		

Software - Capability family

CAPABILITY CLUSTER	CAPABILITY	SKILL FAMILY	SKILL CLUSTER	SKILL
S-RS: **Research software**	S-RS/F: **Foundational**	S-RS/F/RMP: **Research methodologies and practices**		
		S-RS/F/CT: **Computational thinking**		
	S-RS/AC: **Analysis coding**	S-RS/AC/PS: **Programming & scripting**		
		S-RS/AC/CT: **Collaborative tools, e.g. GitHub**		
		S-RS/AC/D: **Documentation**		
		S-RS/AC/CR: **Code review**		
		S-RS/AC/VC: **Versioning code**		
	S-RS/P: **Prototyping**	S-RS/P/RG: **Requirements gathering, analysis and validation**		
		S-RS/P/SD: **Specifications development and system design**		
		S-RS/P/LD: **Libraries & documentation**		
		S-RS/P/PDD: **Prototype development & deployment**		
	S-RS/RSI: **Research software infrastructure**	S-RS/RSI/RSE: **Research software engineering**	S-RS/RSI/RSE/E: **Encapsulation**	S-RS/RSI/RSE/E/MDR: **Modular design for reusability**
				S-RS/RSI/RSE/E/IPG: **Interfaces -programming, graphical & web services**
			S-RS/RSI/RSE/A: **Abstraction**	S-RS/RSI/RSE/A/ADD: **Algorithm design and development**

Software - Capability family

CAPABILITY CLUSTER	CAPABILITY	SKILL FAMILY	SKILL CLUSTER	SKILL
				S-RS/RSI/RSE/A/DS: **Data structures**
				S-RS/RSI/RSE/A/CW: **Computational workflows**
				S-RS/RSI/RSE/A/DSL: **Domain-specific languages**
			S-RS/RSI/RSE/PO: **Performance optimisation**	S-RS/RSI/RSE/PO/CFL: **Compiled and/or functional languages**
				S-RS/RSI/RSE/PO/P: **Parallelisation**
				S-RS/RSI/RSE/PO/HPCD: **HPC Development, Code Optimisation, Compilers**
				S-RS/RSI/RSE/PO/GPUP: **GPU programming**
			S-RS/RSI/RSE/I: **Integrity**	S-RS/RSI/RSE/I/UT: **Unit Testing & Other Testing Paradigms**
				S-RS/RSI/RSE/I/NS: **Numerical Stability**
				S-RS/RSI/RSE/I/VC: **Version control**
				S-RS/RSI/RSE/I/DDSU: **Documentation – Design, Specifications, Usage**
		S-RS/RSI/DRT: **Deployment & release techniques**		
		S-RS/RSI/AIOM: **Applications integration, operation & migration**		
		S-RS/RSI/C: **Containerisation**		

Digital Research Infrastructure Management - Capability family

CAPABILITY CLUSTER	CAPABILITY	SKILL FAMILY	SKILL CLUSTER	SKILL
DRI-DRIM: **Digital research infrastructure management**	DRI-DRIM/SM: **Systems management**	DRI-DRIM/SM/SCP: **Systems capacity planning**		
		DRI-DRIM/SM/DRB: **Disaster recovery & backups**		
		DRI-DRIM/SM/SA: **System administration**		
		DRI-DRIM/SM/ALM: **Asset lifecycle management**		
		DRI-DRIM/SM/HSDM: **Helpdesk & service desk management**		
	DRI-DRIM/NM: **Network management**	DRI-DRIM/NM/NA: **Network administration**		
		DRI-DRIM/NM/NM: **Network maintenance**		
		DRI-DRIM/NM/NO: **Network operations**		
		DRI-DRIM/NM/NP: **Network provisioning**		
		DRI-DRIM/NM/NS: **Network security**		
	DRI-DRIM/SM: **Storage management**	DRI-DRIM/SM/SCP: **Storage capacity planning**		
		DRI-DRIM/SM/SP: **Storage protocols**		

Digital Research Infrastructure Management - Capability family				
CAPABILITY CLUSTER	**CAPABILITY**	**SKILL FAMILY**	**SKILL CLUSTER**	**SKILL**
		DRI-DRIM/SM/AM: **Asset management**		
		DRI-DRIM/SM/BR: **Backup recovery**		
	DRI-DRIM/AM: **Application management**	DRI-DRIM/AM/AL: **Application lifecycle**		
		DRI-DRIM/AM/AP**: Application performance**		
		DRI-DRIM/AM/AS: **Application service**		
		DRI-DRIM/AM/ACM**: Application configuration management**		

5.3. ARDC Skills Framework - Glossary

The glossary contextually defines the skills terminology used in the Skills Framework.

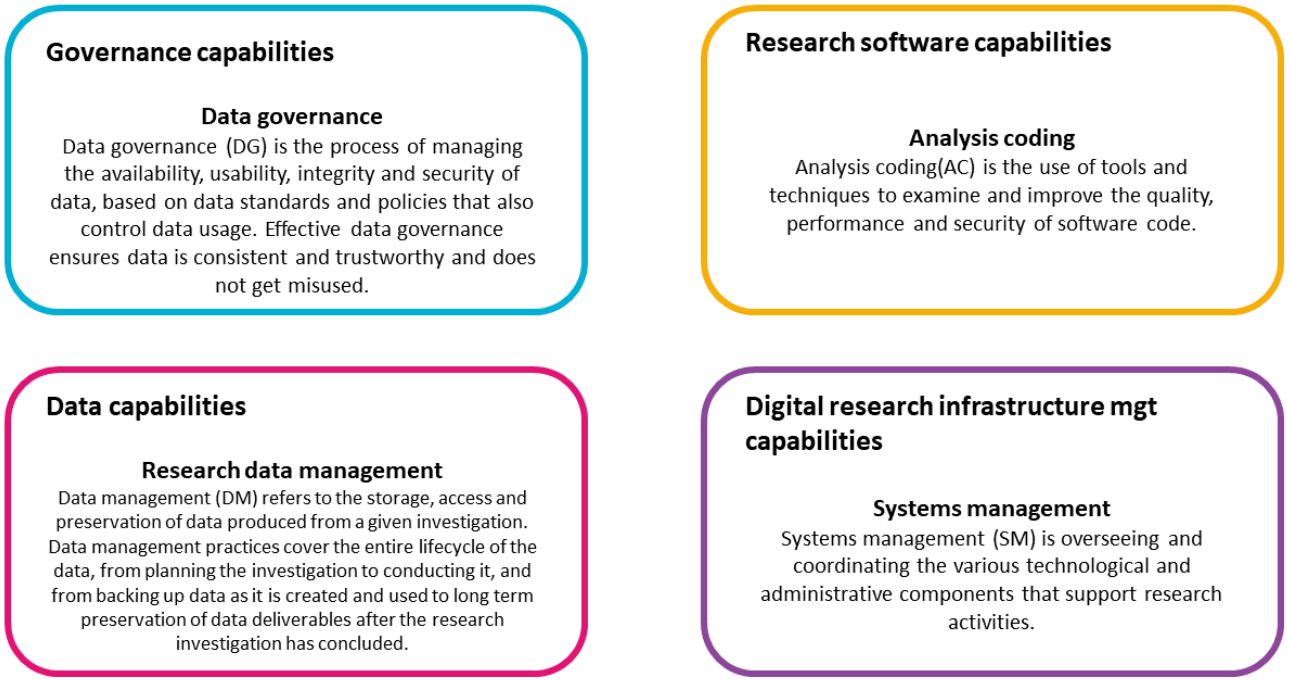


Figure 3: Example definitions of glossary terms

5.4. Generalised Digital Research Roles

Currently, six generalised roles are identified in the ARDC Skills Framework. Generalised roles refer to role families rather than specific job titles. Roles also do not always map one-to-one to an individual. Individuals performing a role may take on other roles within their organisation, or parts of the role may be performed by multiple people. Many people working and supporting research often cover more than one of these roles in their day-to-day activities. It's rare for these roles to be specifically dedicated, except possibly in larger organisations or on large scale projects where there is a greater need for data specialists.

Table 3. Generalised digital research roles

Role	Definition
Data Owner	Data owner refers to those who not only have possession of but also have responsibility for data. The control of data includes not just the ability to access, create, modify, package, derive benefit from, sell or remove data, but also the right to assign access privileges to others.

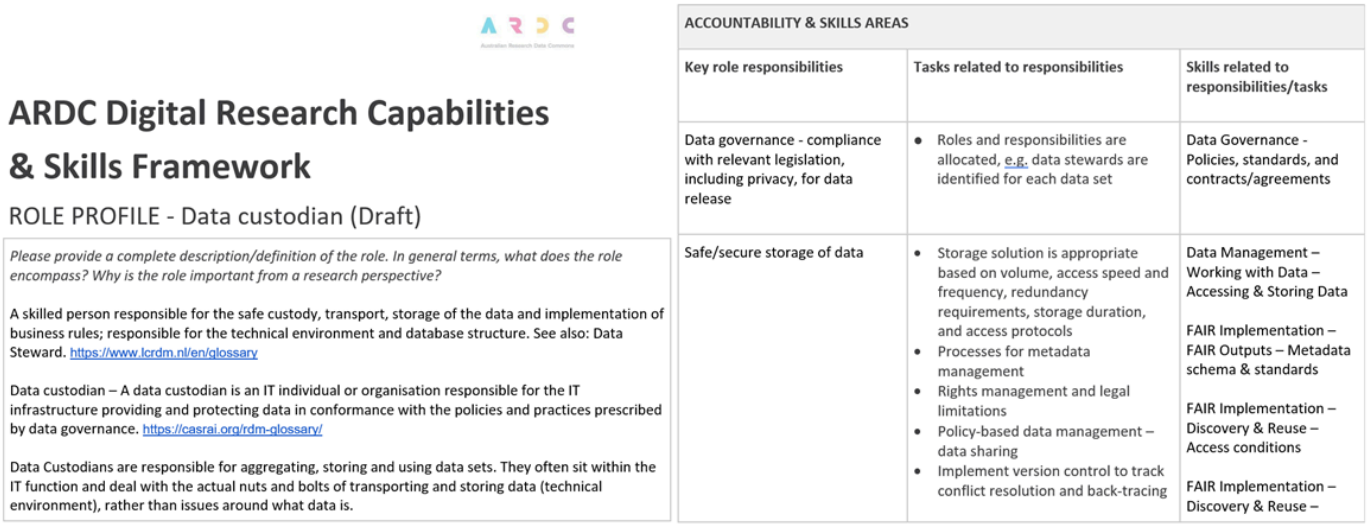
Data Governance (manager)	Defines the availability, usability, integrity and security of data, based on data standards and policies that also control data usage. Effective data governance ensures that data and data use are consistent and trustworthy and generate benefit for the data owner(s).
Data Steward	A person responsible for keeping the quality, integrity, and access arrangements of data and metadata in a manner that is consistent with applicable law, institutional policy, and individual permissions. Data stewardship implies professional and careful treatment of data throughout all stages of a research process. A data steward aims to guarantee that data is appropriately treated at all stages of the research cycle (i.e. design, collection, processing, analysis, preservation, data sharing and reuse). https://www.lcrdm.nl/en/glossary
Data User / Generator	Generates, accesses and/or analyses data to derive a conclusion within a data governance framework that benefits from the tools, resources, skills and workflows provided by data stewards. These processes may result in data ownership.
Research Software Engineer	Research software engineer (RSE) - A growing number of people in academia combine expertise in programming with an intricate understanding of research. These RSEs may start off as researchers who spend time developing software to progress their research or they may come from a more conventional software-development background and are drawn to research by the challenge of using software to further research. https://www.lcrdm.nl/en/glossary
Digital Research Infrastructure Manager	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. Digital skills for FAIR and Open Science - https://op.europa.eu/en/publication-detail/-/publication/af7f7807-6ce1-11eb-aeb5-01aa75ed71a1/language-en/format-PDF/source-1906942

5.5. Skills/Roles Profiles

Skills-aligned role profiles are an essential tool and component of any skills framework. They provide a comprehensive overview of a specific role in an organisation or team, its key responsibilities, tasks and skills requirements. They can be used to identify skills gaps and aid the design of targeted training programs. Role profiles help assemble teams with complementary skills and expertise. They are also useful in the allocation of resources and tasks based on each individual's capabilities.

The ARDC Role Profile template covers:

- the role title and operational level
- a description of the role's purpose
- accountability and skills areas - key responsibilities, tasks and related skills
- who collaborates with this role



ARDC Digital Research Capabilities & Skills Framework

ROLE PROFILE - Data custodian (Draft)

Please provide a complete description/definition of the role. In general terms, what does the role encompass? Why is the role important from a research perspective?

A skilled person responsible for the safe custody, transport, storage of the data and implementation of business rules; responsible for the technical environment and database structure. See also: Data Steward. https://www.lcrdm.nl/en/glossary

Data custodian – A data custodian is an IT individual or organisation responsible for the IT infrastructure providing and protecting data in conformance with the policies and practices prescribed by data governance. https://casrai.org/rdm-glossary/

Data Custodians are responsible for aggregating, storing and using data sets. They often sit within the IT function and deal with the actual nuts and bolts of transporting and storing data (technical environment), rather than issues around what data is.

ACCOUNTABILITY & SKILLS AREAS		
Key role responsibilities	**Tasks related to responsibilities**	**Skills related to responsibilities/tasks**
Data governance - compliance with relevant legislation, including privacy, for data release	• Roles and responsibilities are allocated, e.g. data stewards are identified for each data set	Data Governance - Policies, standards, and contracts/agreements
Safe/secure storage of data	• Storage solution is appropriate based on volume, access speed and frequency, redundancy requirements, storage duration, and access protocols • Processes for metadata management • Rights management and legal limitations • Policy-based data management – data sharing • Implement version control to track conflict resolution and back-tracing	Data Management – Working with Data – Accessing & Storing Data FAIR Implementation – FAIR Outputs – Metadata schema & standards FAIR Implementation – Discovery & Reuse – Access conditions FAIR Implementation – Discovery & Reuse –

Figure 4. Snippets from the ARDC role profile of a data custodian

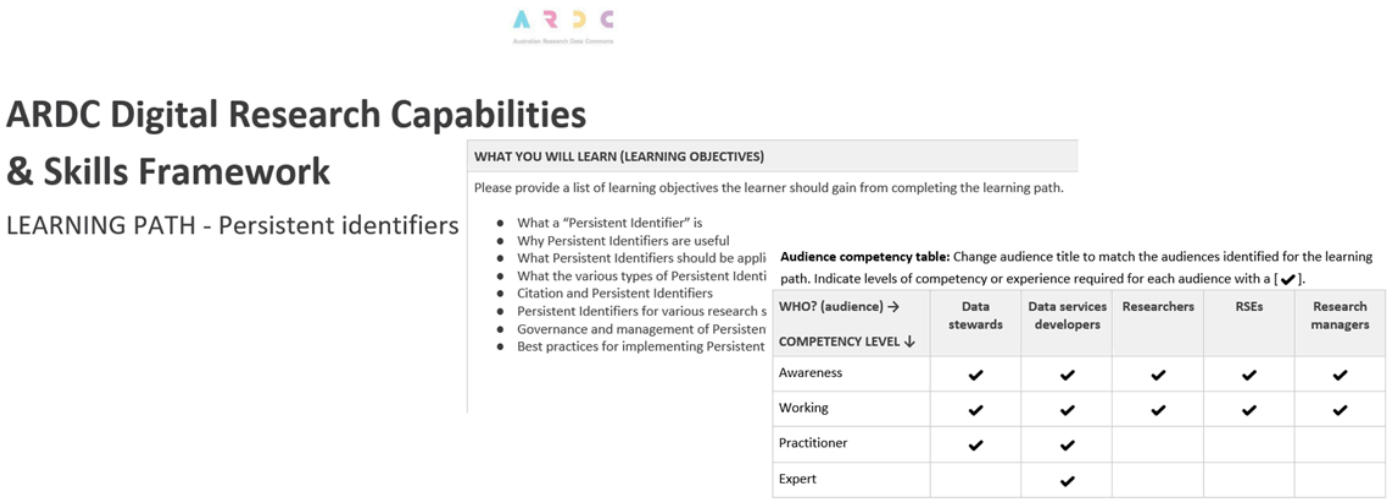
5.6. Learning Paths

In the context of the ARDC Skills framework, learning paths provide a structured collection of training and knowledge resources and activities bundled in a way to help individuals build topic-specific knowledge or skills. They provide a clear roadmap, navigating and progressing learners through a series of steps to achieve their learning objectives. Each step incrementally builds on the previous level's competencies and expertise.

The ARDC Learning Path template provides an audience competency table that matches the level of need for relevant digital research roles. The template can be customised to suit the skills level needed for data and digital research roles.

The ARDC learning path template covers:

- expected time for completing the learning
- a description of the topic area
- a description of the learning path
- skill levels corresponding to the knowledge requirements for a role
    - Level 1-Awareness
    - Level 2-Working
    - Level 3-Practitioner
    - Level 4-Expert
- learning objectives
- who the learning path is targeting
- audience competency table
- systems requirements and/or prerequisites
- links to training coursework, materials and resources for each skill level



ARDC Digital Research Capabilities & Skills Framework

LEARNING PATH - Persistent identifiers

WHAT YOU WILL LEARN (LEARNING OBJECTIVES)

Please provide a list of learning objectives the learner should gain from completing the learning path.

- What a "Persistent Identifier" is
- Why Persistent Identifiers are useful
- What Persistent Identifiers should be appli
- What the various types of Persistent Identi
- Citation and Persistent Identifiers
- Persistent Identifiers for various research s
- Governance and management of Persisten
- Best practices for implementing Persistent

Audience competency table: Change audience title to match the audiences identified for the learning path. Indicate levels of competency or experience required for each audience with a [✔].

WHO? (audience) → / COMPETENCY LEVEL ↓	Data stewards	Data services developers	Researchers	RSEs	Research managers
Awareness	✔	✔	✔	✔	✔
Working	✔	✔	✔	✔	✔
Practitioner	✔	✔			
Expert		✔			

Figure 5: Snippets from the ARDC learning path for persistent identifiers

5.7. Skills/Data Roles Matrix

The Digital Research Skills/Roles Matrix outlines the essential digital research skills and roles, specifying the required competency levels and the organisations best equipped to provide the necessary training. This matrix aligns specific skills, such as data analysis, data management, and data ethics, with roles like Data Analyst, Data Scientist, Data Engineer, and Research Data Manager. It also details the competency levels needed for each role to ensure success in their respective positions.

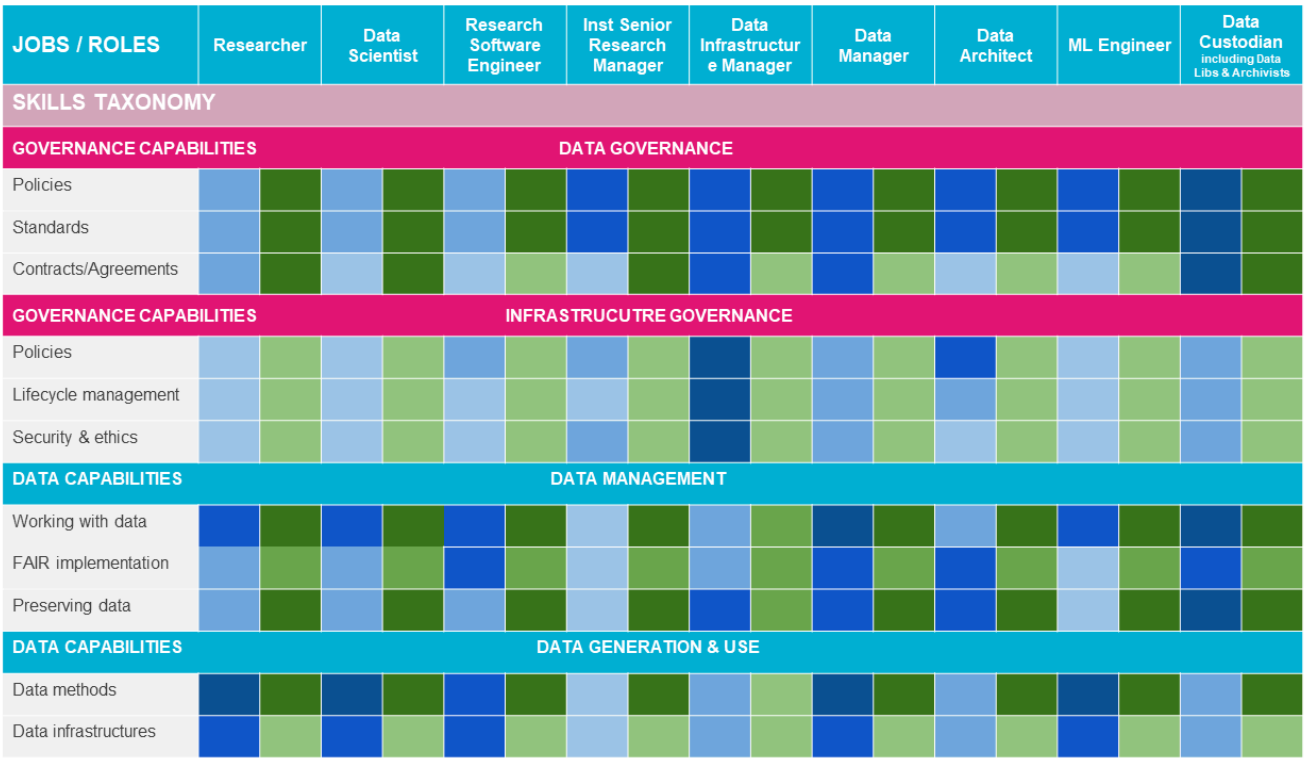
The competency levels cover basic awareness to expert levels:

- Awareness - Background understanding - you know about the skill and have an appreciation of how it is applied in a practical situation.
- Working - Functional command - you can apply your knowledge and experience of the skill, including tools and techniques. You can adopt those most appropriate for the situation.
- Practitioner - In depth proficiency - you know how to share your knowledge and experience of this skill with others, including tools and techniques. You can define those most appropriate for the situation.
- Expert - Recognised authority - you have extensive and substantial training, practical experience and applied knowledge including generation of new practice, methods and tools. You are a recognised specialist in the skill and can lead or guide others in following best practice[6].

“Well-positioned” entities for delivering training include the groupings:

- Universities - identified as having the sole responsibility for providing skills development activities
- Universities/ARDC - both organisations have responsibility for providing skills development activities based on audience and need
- Universities/NCRIS/ARDC - these organisations may share responsibility and in some cases work collaboratively on the delivery of skills development activities
- ARDC - identified as having sole responsibility for providing skills development activities, particularly related to the platforms, services, tools and products developed and delivered by the ARDC or supported through partnered projects

[6] *Plummer, D., Kearney, S., Monagle, A., Collins, H., Perry, V., Moulds, A., Smith, T., Lloyd, C., & Lewis, C. (n.d.). Developing a Capability Enhancement Programme: Supporting the development and adoption of the Information Management Framework (IMF) and National Digital Twin (NDT). CBDD.* https://digitaltwinhub.co.uk/download/capability-enhancement-programme/



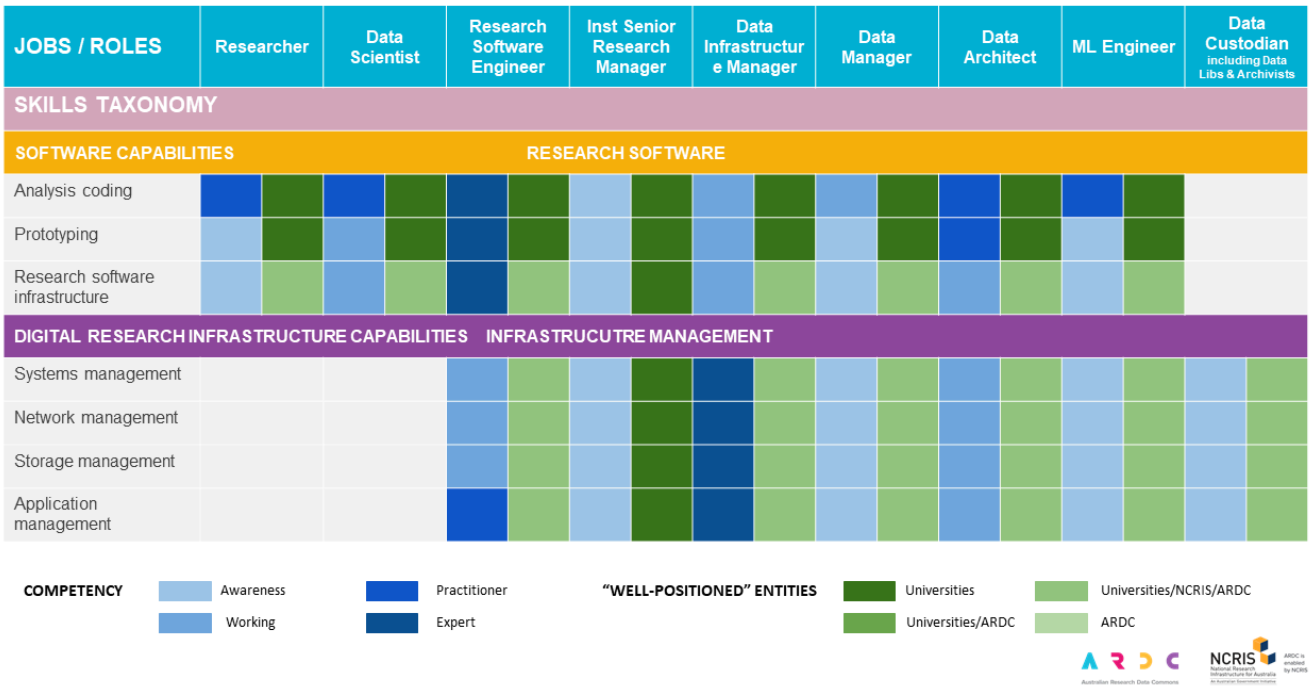


Figure 6: The Skills Framework - Skills/Roles Matrix

5.8. How the components work together

The diagram below (Figure 4) illustrates how each of the components of the Skills Framework interconnect.

- The Skills Taxonomy (#1) and Glossary (#2) work together to organise digital research skills into clusters and families, offering structure, definitions and a unified terminology.
- The Glossary (#2) provides the definitions for roles including the six Generalised Roles (#3).
- Generalised Role definitions (#3) help inform the development of Role Profiles (#4).
- Based on a role's responsibilities as outlined in a Role Profile (#4), the Skills Taxonomy (#1) helps to identify the capabilities and skills needed for a specific role, informing the development of Learning Paths (#5).
- The Skills/Roles Matrix (#6) identifies the required experience levels for each role and corresponding skill. This information helps to develop Learning Paths (#5), outlining the experience levels needed for individuals in specific roles or those aspiring to them to acquire the necessary skills for effective performance.
- The Skills/Roles Matrix (#6) also indicates the best placed organisations to deliver the required training.

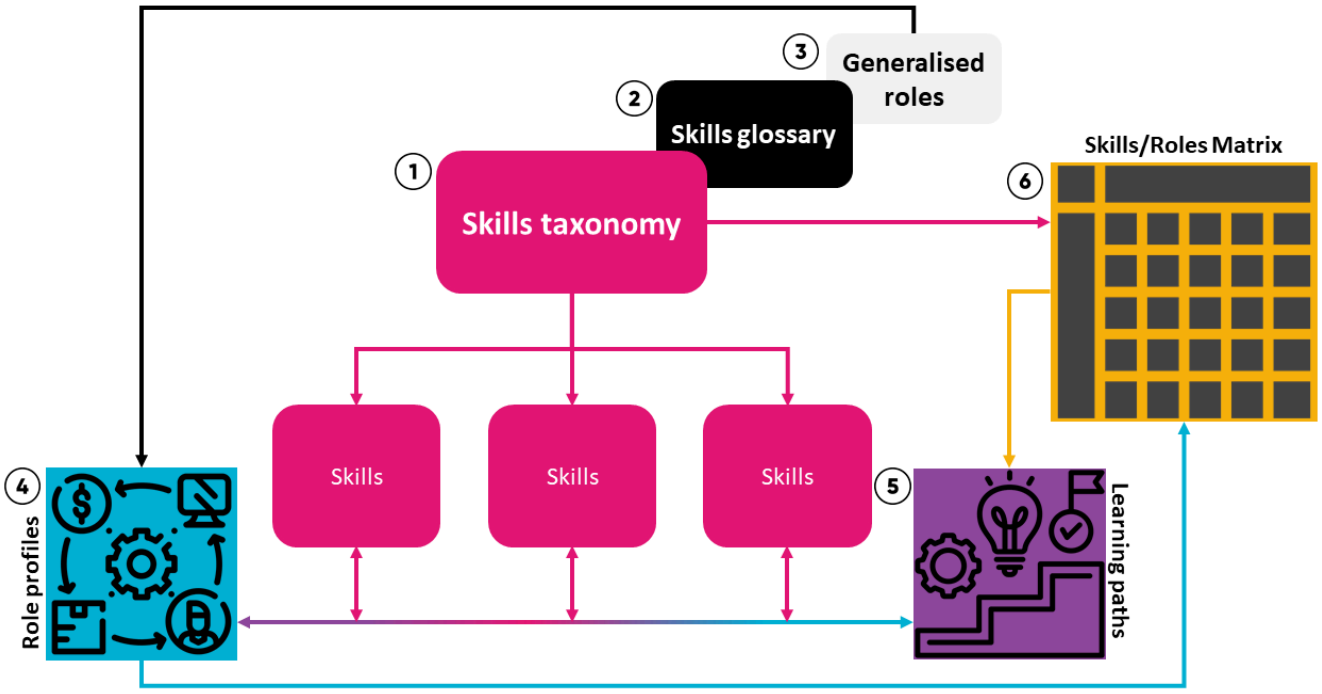


Figure 7: Skills Framework components and their relationship to each other

6. NEXT STEPS

A skills framework reflects the current state of skills with a hint to the future skills needs of its stakeholders. It can never be static, requiring continuous refinement and expansion to incorporate new and evolving digital research skills to keep the framework relevant.

To maintain this dynamism, the ARDC Skilled Workforce Development team will:

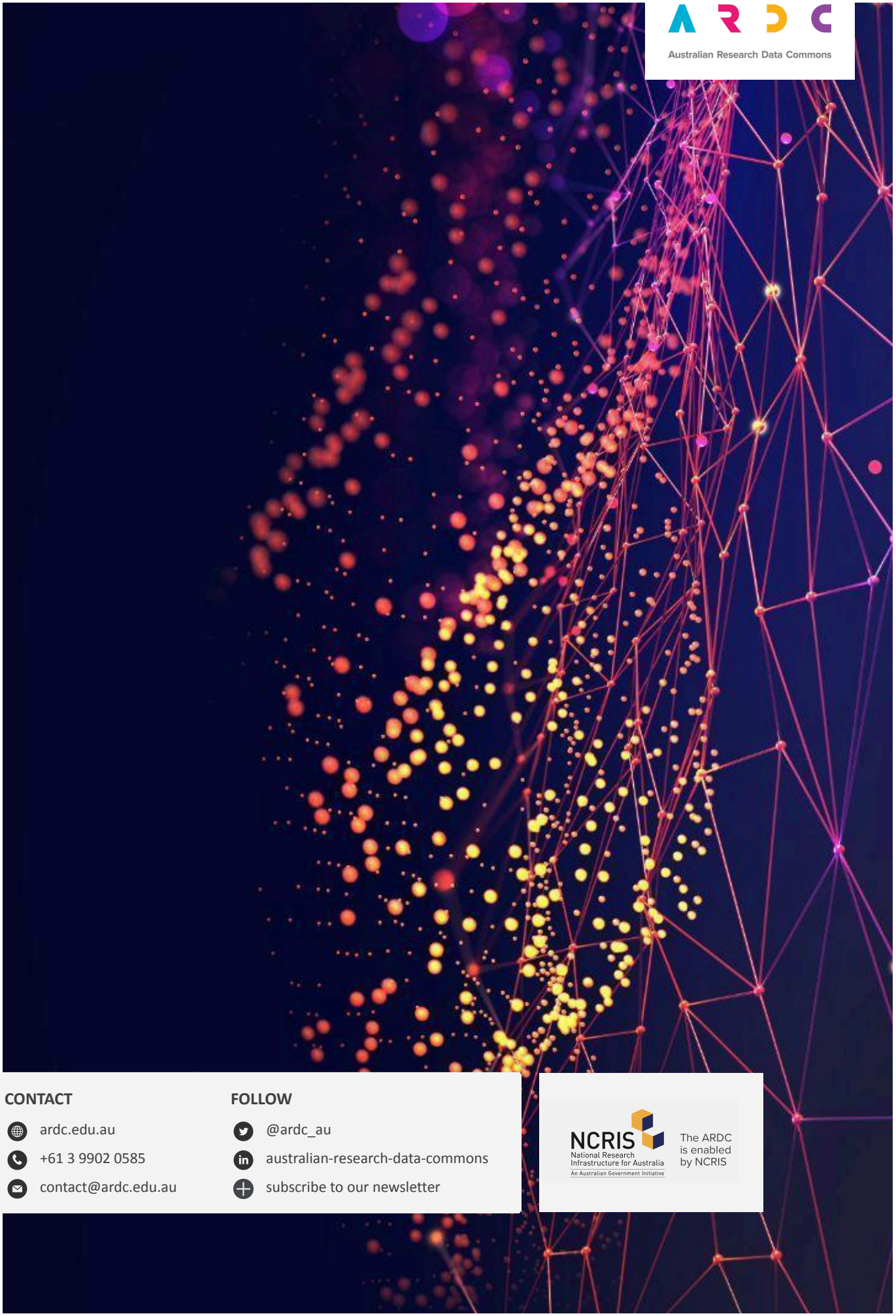
- Canvas feedback from and collaborate with universities, research institutions, industry partners, and policymakers to ensure the framework meets the needs of its stakeholders
    - Build a catalogue of role profiles and learning paths
        - Share these resources with the research sector
        - Encourage contributions from others in the sector
    - Monitor new implementations and adoptions of the framework and assess the impacts of these implementations.

Join us in shaping the future of the Digital Research Capabilities and Skills Framework.

We invite universities, research organisations, training providers, industry partners, and policymakers to contribute to the evolution of the Skills Framework. Your real-world implementation use cases are invaluable in refining and expanding this framework to meet the ever-changing needs of research communities.

How to get involved:

- Tell us about your use cases and/or share detailed examples of how your organisation has implemented the Skills Framework.
- Collaborate with the ARDC to refine and expand the Skills Framework.
- Participate in workshops, webinars and forums to discuss best practices and future directions of digital research skills relevant to the research sector.



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CONTACT

ardc.edu.au

+61 3 9902 0585

contact@ardc.edu.au

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