Thematic Article

Fair Data: History and Present Context

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Abstract

In this paper, we discuss FAIR Data, why it exists, and who it applies to. We further review the principles of FAIR data and how they are managed in research centers. We also discuss the types of problems that researchers encounter, and what an information professional can do to assist them. At present, the vast majority of centers subscribe to the FAIR principles. However, both center and researcher face the arduous task of understanding, managing, and implementing the model. They must know data formats and standards. For a correct description and to facilitate data retrieval and interoperability, they must know about different types of metadata schemas. They must know about digital preservation and specific aspects of knowledge and information management. In addition, there are also ethical issues, intellectual property, and cultural differences. All these controversies translate into extra workload for researchers, who only get a return in the form of citations. It is critical to note that these information professionals can play a key role in the proper management of research data, and can help achieve the objectives described in the principles: making data findable, accessible, interoperable, and reusable.

Keywords: Research data management; FAIR principles; FAIR Data; FAIR implementation challenges; literature review

Introduction

The academic and research world, both public and private, generate large amounts of data throughout the course of their research. The debate on how to share and reuse data has been ongoing, because there were and still are no guidelines or standards for correctly integrating research data into the digital ecosystem.

Likewise, open science is a growing movement that facilitates access to the information generated by research, much of this research is financed with public money, and there is a general awareness that this investment must return to society itself. As a result, society would be able to access scholarly articles more freely. Open access helps to improve research, which is why, like articles, data should also be easy to find, access, and utilize (Collins et al., 2018. p. 19).

Being findable means that the data must be described in a way that machines can retrieve what is being searched for. Once found, the data must be accessed using protocols and standards.

The transmission of information and recognition of its formats are also critical. Machines must know how to communicate and analyze these data troves. Correct integration of data from different sources into the same system is the final piece of the puzzle.

These are the foundation stones for the principles of FAIR Data. FAIR Data's aim is to use the analysis capacity of machines on a large scale, and ensure transparency and social utility.

Research design and Methods

The present study analyzes articles and informative material from relevant sources related to the creation, emergence, and implementation of research data and FAIR Data's guiding principles. The roles of library and information science professionals are examined from the aspects of training, collaboration, and data analysis, also known as data stewardship.

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The criteria for acceptable material were articles published in bibliographic databases (e.g. – Scopus or Web of Science) from the 2010–2022 period. Reports, such as data policies or FAIR policies, were retrieved from Google Scholar and other search engines. We also reviewed European Commission reports concerning FAIR Data. The information collected was filtered, synthesized, and organized to make checking each subtopic's most relevant points a simple task.

Results and Discussion

The following sections provide a historical and current overview of the FAIR principles and their adoption by stakeholders. This is followed by a description of their implementation, and a summary of the possible challenges researchers face with data management. Later, we discuss the role of the information professional as a data steward or librarian, and we go into detail about the services they offer in data management. Finally, we relay the research data management training and collaboration opportunities for researchers.

The Origin of the FAIR Principles

In 2014 in Leiden, Holland, a workshop named 'Jointly Designing a Data Fairport' brought together both academic and private stakeholders from many of the following fields: research infrastructure and policy, publishing, semantic web and life science research. The vision was to come together to support existing communities trying to find solutions to problems in scientific data retrieval and reuse (Data Fairport, 2014).

In the workshop, they wanted to find answers to questions such as: if there were a suitable dataset, where could it be published, and how would it be searched? What search tools could be used, and would it be necessary to apply filters? Is the necessary metadata for filtering integrated into the repositories? What format is the data in? Some of the barriers to data management that make data more difficult to integrate form a vast, decentralized yet diverse ecosystem of data. This data ecosystem only serves to compound the problem of discovery and retrieval for both Man and machine (Wilkinson et al., 2016, p. 2).

This workshop resulted in a set of agreed-upon guiding principles and practices that would make possible the discovery, access, integration and recycling of data, and would facilitate the citation of information produced by current science, which is highly data-centric. Finally, at the end of the meeting, a draft of fundamental principles was drawn up and specified in greater detail (Wilkinson et al., 2016, p. 3).

Later, the draft was improved upon according to these principles. The working group tasked with the work was composed of several members of the FORCE11 community, a cooperation and discussion platform looking for new ways to transform scholarly communication through technology, and to respond to the problems of maintaining a paper-based publishing system in a ditigalized age (Martone, 2015, p. 1).

In 2016, the journal Scientific Data published the 'FAIR Guiding Principles for Scientific Data Management and Stewardship'. The intention behind their publication was to aid those wanting to improve their data reuse.

The FAIR Principles improve machines' abilities to automatically find and use data, as well as support personnel data reclamation (Wilkinson et al., 2016, p. 3–4). The principles are as follows:

Figure 1. The FAIR Guiding Principles

Findable – The data and the metadata are easy to find for both Man and machine:
- **F1**. (Meta)data are assigned a globally unique and fix identifier
- **F2**. Data are described with rich metadata (defined by R1 below)
- **F3**. Metadata clearly and explicitly include the identifier of the data they describe
- **F4**. (Meta)data are registered or indexed in a searchable resource

Accessible – Standard protocols are used:
- **A1.** (Meta)data are retrievable by their identifier
  - **A1.1** The protocol is open, free, and universally implementable
  - **A1.2** The protocol allows for an authentication and authorisation procedure, where necessary
- **A2**. Metadata are accessible, even when the data are no longer available

Interoperable – Easy to combine one data set with already existing data:
- **I1.** (Meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation.
- **I2.** (Meta)data use vocabularies that follow FAIR principles
- **I3.** (Meta)data include qualified references to other (meta)data

Reusable – The data can be used, including descriptions as clear licenses:
- **R1.** (Meta)data are richly described with a plurality of accurate and relevant attributes
  - **R1.1.** (Meta)data are released with a clear and accessible data usage license
  - **R1.2**. (Meta)data are associated with detailed provenance
  - **R1.3**. (Meta)data meet domain-relevant community standards

Implementation of the principles in research centers

In 2016, leaders at the G20 Summit in Hangzhou supported the application of the FAIR principles in scientific research (Leaders of the G20, 2016, p. 12). In 2017 a group of Australian organizations represented as the FAIR Steering Group issued a statement endorsing the principles (The FAIR Steering Group, 2017).

In 2017 too, Germany, the Netherlands and France created "the International Support and Coordination Office" (ISCO) to support "the GO FAIR Initiative". Their aim was to make the research data of scientific and academic institutions available in all fields, as well as being a launchpad for the European Open Science Cloud (EOSC), thus providing a place for data exchange across Europe (GO FAIR, 2017).

Organizations like Research Data Alliance (RDA) and CODATA, Committee on Data of the International Science Council (ISC), are international institutions both working for the implementation of open science in open research data, who also endorsed the FAIR guiding principles. RDA enabled working groups to explore how to apply the FAIR principles and CODATA wrote a decanal program "Data for Planet: Making data work for great cross-domain challenges".

In 2018, the European Union ratified and drove the principles forward with the report "Turning FAIR into Reality", a report and action plan that brings together the study and analysis of what is needed to implement the FAIR principles. Moreover, it provides a set of recommendations and concrete actions for stakeholders (Collins et al., 2018, p. 8). The Association of European Research Libraries (LIBER) was also involved in the adoption of the FAIR principles (LIBER, 2018).

As can be seen, most stakeholders strongly endorsed the FAIR principles, and many publicly funded projects demanded Data Management Plans to ensure the proper handling of research data.

The RDA in 2019 created the working group "FAIR Data Maturity Model", with the purpose of developing a set of evaluation criteria to facilitate and standardize the analysis of data. This working group defined indicators derived from the principles themselves that would help formulate measurable aspects of each principle (Bahim et al., 2020, p. 1). The same group developed a study to analyze current and existing approaches related to self-assessment tools (Bahim et al., 2019).

The FAIRassist.org website also compiles and describes the existing resources for the evaluation of digital objects with reference to the following principles FAIR (FAIRsharing Team & University of Oxford, 2019). The existence of several initiatives and tools for assessment highlights the difficulty in assessing FAIR compliance in data, as appropriate practical solutions are missing or not fully developed. It appears that some of the problems in assessing whether the data meet the FAIR principles are that some of them are vaguely defined (Devaraju & Huber, 2021, p.1–2). In 2020, Jacobsen et al. published a paper intending to harmonize the implementation options of the FAIR principles, which includes a discussion and a non-technical interpretation of the principles, examples of solutions and discussions on the challenges to be considered.

Some studies have been able to perform assessments; for example, a study has been conducted on 80 databases that are representative of the data streams that are critical for low carbon energy transition, where the results obtained reveal the difficulty of translating FAIR guidance principles into domain-specific applications, as current FAIR data practices in the energy domain are yet to be developed, although the community has initiated efforts but still the platforms and tools are not yet ready to be integrated into the workflows of research teams (Schwanitz et al., 2022).

The study "Cultivating FAIR principles for agri-food data" concludes that many agri-food communities still lack the necessary building blocks, such as shared vocabularies, sufficient quality datasets and shared data management practices (Top et al., 2022, p. 11). Therefore, it is too early to tell whether research centers have implemented FAIR principles in data management.

Researchers and challenges with data management

Researchers have different challenges involving research data management (Table 1). Jahnke & Asher (2012) published a report with five significant key findings concerning these challenges:

- Not having formal training in data management practices,
- Some early career researchers think about the long-term preservation of their data.
- Metadata and documentation are of interest only if they help a researcher work.
- Absence of collaboration tools
- Researchers are not aware of the data services that the library may provide.

Table 1. Challenges in Research Data Management

Challenges in Research Data Management (RDM)	Authors
Understanding data is part of the research workflow	(Hermans, 2019; Chigwada et al., 2017)
Need of skills concerning data management plans	(Deroo et al., 2019; Rice, 2019)
Requiring research data management policies	(Morais & Borrell-Damián, 2019)
Lack of institutional guidelines for Open Access	(Shelly & Jackson, 2018)
Understanding the role of the metadata	(Perrier et al., 2017; Ramstad et al., 2020)
Absence of standards on file naming	(Ünal et al., 2019)
Inadequate infrastructures	(Mayernik, 2016)
Lack of standards to codify qualitative data	(Attard et al., 2015)
Absence of experience in RDM among information professionals	(Tenopir et al, 2014; Faniel & Connaway, 2018; Shelly & Jackson, 2018)
Libraries with limited services for RDM	(Chigwada et al., 2017, Yoon and Schultz, 2017; Cox et al., 2019; Huang et al., 2021)

In addition, there are other challenges where researchers are also involved. First, to understand that data is part of the research workflow. To this matter, it should be convenient to have document guidelines to help researchers know what to do with their data. These guidelines should recognize that access to research data needs to be carefully managed to maintain confidentiality and security at the lowest possible cost (Hermans, 2019). Good data management facilitates the verification of research results, and other researchers can base their research on reusing data (Chigwada et al., 2017).

Second, there is a lack of skills and knowledge concerning data management plans. Luckily, there are rubrics (Deroo et al., 2019) that help researchers deal with these plans. It is worth noting that for Europe these rubrics need to be according to H2020 research data requirements. The European Commission's position on this is: "As open as possible, as closed as necessary." In practice, this means to produce a DMP involving the necessary restrictions to data (Lahti et al., 2020). In a study held in India analyzing 47 central universities, it was found that 20 libraries provided more than enough information about how to develop a research data management (RDM) plan for grant applications and data repository drops. Though they had enough information given, they argued that researchers, project investigators, and computer divisions should further collaborate more closely with librarians (Tripathi et al., 2017). This was a wise decision, for with proper data management planning many security breaches and much data loss can be avoided (Rice, 2019).

At the same time, a report from the European University Association (Morais & Borrell-Damián, 2019, p. 30) showed that almost 38% of universities lacked research data management policies, and, furthermore, it was not even on their current agendas. The report was based on a survey of 321 European universities. 21% of universities had such policies, and another 38% were in the process of developing them. In this same report, 43% did not have an institutional guideline for Open Access to research data, but 41% indicated they had a Data Protection Officer. A final 60% said, they did not have any other data support roles.

Perrier et al. (2017) performed a scoping review concerning research data management. Their study focused on the complete research data lifecycle – data creation, processing, analysis, preservation and archiving, publishing, and re-using. They found that a significant part of the researched articles was addressed by providing access to data (31.13%), a phase where researchers are involved. In this phase, distribution, data sharing, control access, establishing copyright and promoting data are included. They also found researchers used a minimum required approach when it was necessary to fill a metadata form on depositing data into a repository, arguing that adding metadata to a dataset is not enough. Data quality, availability, accessibility, and reuse are also crucial regarding sharing policies.

Chigwada et al. (2017) performed a study in Zimbabwe where 25 research institutions participated. They found that researchers for these institutions did not share their data from their repositories. This prevented those researchers from accessing and reusing very precious data. In addition, they also found that research libraries still had limited services as regards research data management. The format of the data (text, spreadsheet, and graphic) was also inadequate. Unfortunately, time was not invested in metadata and documentation. This means that the context of information was lost, and data reuse was made impossible (Ünal et al., 2019). This made the data "un-findable".

Ünal et al. (2019) performed a study analyzing the behavior of researchers in France, Turkey and the UK regarding their research data. They surveyed a sample (N=1098) of researchers. They found that 73% of researchers shared research data among their research teams and 55% with researchers from other institutions.

However, 86% of researchers needed to spend some pre-processing time on data received. Some reasons were that researchers did not use standard file naming or standard metadata for their data.

Another reason involving metadata and documentation in research data is infrastructure. Metadata practices, though independent of the discipline (Mayernik, 2016), would be of great help to infrastructure's very complex system. In marrying metadata and infrastructure, standards from different disciplines must be adopted and fitted together. For example, in Austria, an interdisciplinary data repository was designed and later built. Researchers took part in the repository's design, as they sought to establish a suitable, much-needed subject repository. In designing the data vault, they adopted Eprints, open-source software with the metadata schema IST DataRep, metadata adapted for research data (Petritsch, 2017).

Adding metadata to research data allows data to be shared and later reused. This is one of the reasons why metadata is essential. Metadata provides the context and knowledge to the data. The reuse will reduce research costs and allow combining the data into a more robust data set that can be reused for other purposes (Ramstrand et al., 2020). However, there are some limitations. Researchers who reuse data need a great understanding of the context to interpret the data, theories, tools and other contextual knowledge (Hansson & Dahlgren, 2022). However, there might be some copyright issues to limit the reshare of the metadata. This is the case in the cultural heritage sector like archives and museum collections. Another limitation to researchers sharing data is that competitors take advantage of their research, or data can be misinterpreted (Ramstrand et al., 2020).

Researchers also have to deal with format recognition. Datab may be represented in different forms, such as text, images or videos, which are not always standardized (Boté & Térmens, 2019). Another issue is the anonymization of the qualitative data. This generates a problem not in the accuracy of the data but the reuse of the data because there are no standards to codify the data (Attard et al., 2015). To maximize this effort, it seems necessary to adopt FAIR (findable, accessible, interoperable, and reusable) data management principles (Travieso Rodríguez & Ferreira Araújo, 2019; Wilkinson et al., 2016).

Data privacy can be a barrier to researchers in specific cases, such as clinic data access when the researcher is non-clinical. In Health Science, this situation may happen when non-clinician researchers need to test a hypothesis or study trends with medical data (Tantoso et al., 2019). In addition, consent is required for a single clinical trial, and data cannot be collected for other purposes, which is a waste of economic resources. This can be solved with a much broader consent allowing data to be stored as anonymized in clinical databases for future research efforts (Faden et al., 2013). Quinn (2017) pointed out that research data need to be anonymized when containing personal data. Then, the risk to anonymize the data is that it may destroy the value of the data. He also argued that the secondary use of data and the reuse raised privacy concerns, especially in health. It might be difficult, while not impossible, to reconcile the information consent provided because the new research may be different from the type of research in which the consent was signed.

Finally, funding agencies and other parties claim for research data sharing and researchers still do not have recognition in their careers to keep their data available. Consequently, researchers do not make an effort to liberate them, add the corresponding metadata, and upload them to a repository (Peset et al., 2017).

The role of Information professionals and what can they do to help researchers and challenges with data management

Libraries play an important role in institutions. With the intensive use of technology in different fields and data research production, libraries have started offering services related to research (Yoon & Schultz, 2017; Cox et al., 2019; Huang et al., 2021). Thus, libraries and information professionals can influence their stakeholders and institutions much more than in the past. This influence can be in the form of research data services, stakeholders training, and collaboration as a data stewardship or data librarian.

The role of information professionals can be essential in supporting researchers when managing research data. One of the activities information professionals offer in research centers is research data services that have emerged as critical service. When an information professional is involved in the research data life cycle, their job's title reflects mainly science librarians that serve science. For example, data librarian, data science librarian, or research data management librarian (Bishop et al., 2021). These information professionals cover various disciplines such as social sciences, engineering, physics, and life sciences. Nevertheless, an information professional can help researchers write DMPs or implement it. It seems reasonable that the information professional can help standardize the research data cycle process. Then we stay in this section in two different aspects: training collaborated with researchers, stewardship services.

Training. Self-training and other training

Information professionals who want to deal with research data need the training to be specialized data librarians (Tenopir et al, 2014; Faniel & Connaway, 2018; Shelly & Jackson, 2018). Librarians with no prior training in research data management need to upgrade their skills in digitization, electronic resources management, data standardization skills, and literature gap (Barfi & Sackey, 2021). In addition, it is possible that in some countries, the role of data librarianship does not exist and also needs this training (Barfi & Sackey, 2021; Boté-Vericad & Healy, 2022; Tammaro & Caselli, 2020;).

In institutions where the budget is limited, or there is not enough workforce, they may train researchers team members or different researchers from different teams on how to deal with data management plans and data. This training can be offered through workshops, consultations, relevant courses for faculties or research teams or by creating online resources through collaborations between the library and other units of the research center. In the United States, 142 universities participated into a study concerning research data services staff. They found that the most perceived critical data services were "assistance with data archiving", "assistance with data preservation", or "assistance with data documentation", among others. They also found that the primary skills useful for research data service were "developing and teaching instructional content related to data services", "data management planning", and "data ethics" (Joo & Schmidt, 2020).

There are experiences where librarians and researchers are joined together in research data management training. Librarians and researchers can review data from others' research, and librarians have an opportunity to expand their data services around a specialized community (Strauch, 2019; Muellenbach, 2021). Then, the training concerning research data that information professionals could offer should cover the complete research cycle. This is research planning, project management, data preservation or research dissemination (Barfi & Sackey, 2021; Bishop et al., 2021).

Collaboration with researchers: the embedded librarian and stewardship services

There are different approaches from the information professionals' point of view to help researchers, such as collaborating from the library as a liaison librarian, embedding an information professional into research teams, or data stewardship. One example of this situation was in Malawi, where a study was performed comparing two universities. The three most relevant research activities where librarians help researchers were research areas, data collection and data cleaning. Moreover, the three most critical competencies in managing research data for an information professional were identified as new standards and practices for curation, curating digital objects using curation lifecycle and long-term digital data preservation strategies (Chawinga & Zinn, 2021).

Information professionals can assist researchers' teams with information literacy topics such as disseminating scientific literature and generating knowledge. This is the case of the term "Embedded Librarian", where the information professional is integrated into strategic organizational points, supporting researchers in a research team in retrieving scientific literature (Wu & Mi, 2013). This same term could be renamed "Embedded Information Professional". In Italy, concerning new knowledge generation, there was an experience related to health literacy where five librarians were part of an Editorial Committee to build a new website for the National Institute of Health. Their former skills as a liaison librarian, such as cataloguing, indexing and information literacy, were helpful in the project. They were in charge of selecting content for the website in tasks for librarian curator, line editing, finding the right words online, taking profit from their indexing skills and search engine optimization (SEO), and taking advantage of working with metadata. Finally, they organized courses to combat misinformation in health. Thanks to their traditional role as a librarian, they could get other new skills by taking advantage of the skills they already had (Barbaro et al., 2021).

In South Korea, a study was performed studying the contributions of authors-contribution in scientific papers in many disciplines such as Medicine or Computer Science. They reported that the librarian's role as author-contribution was varied—for instance, search strategy, data curation or reading and approving the final manuscripts. Then, embedded librarians increased over the years, transforming their role as supportive in research projects (Shin, 2021).

Another approach from the information professionals' point of view to help researchers can also be data stewardship. Data stewardship is a very specialized position where the data steward has skills in a concrete discipline and concrete duties. Concerning the data steward title, Tammaro & Caselli (2020) pointed out that data steward has different names depending on the institutional context and the international border. For instance, "data librarian" or "data curator" are some of the characters. Then, the role of the data steward is to support data reuse, storage, and later access of data. This last aspect is important because research data has to be digitally preserved.

In Austrian universities, Gruber et al. (2021) exposed three models of the existing data steward: service point, data steward center and data steward network. The data steward as a service point would offer support, but they do not take any action in the institutes they worked.

In the second role, the data steward center, stewards work together in the same office, and their competencies are distributed. The third role consists of a person who works in a faculty or specializes in a concrete field plus one coordinator. They can offer support to a discipline—for instance, a data steward in librarianship. Indeed, data stewardship (Awada et al., 2022) can ensure that data policies and standards are effectively applied. Orrù (2020) pointed out that data stewards' skills respond to Data Management Plans and support researchers on how data is generated or retrieved, how information is protected or how the data is described and documented.

Conclusions

The emergence of the FAIR principles responds to a need in the research community to provide guidance for sharing and reusing research data. Many stakeholders in the digital ecosystem of research data endorsed the principles.

There are difficulties in being able to evaluate the implementation of the principles on research data, metrics and evaluation methods are still being developed and debated. Researchers, the creators of the data, find it difficult to make the data FAIR, from the application of metadata, to recognizing formats, to the application of standards.

Information professionals can play an important role in the implementation of the principles, offering training in research centers, or collaborating in the research itself and managing the data; in any of the facets the information professional must complete their academic training with specific training on everything surrounding the ecosystem of the FAIR principles.

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