Chemistry–A European Journal
Perspective
doi.org/10.1002/chem.202202720

Chemistry Europe
European Chemical Societies Publishing

www.chemeurj.org

How Research Data Management Plans Can Help in Harmonizing Open Science and Approaches in the Digital Economy

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Abstract: Within this perspective article, we intend to summarise definitions and terms that are often used in the context of open science and data-driven R&D and we discuss upcoming European regulations concerning data, data sharing and handling. With this background in hand, we take a closer look at the potential connections and permeable interfaces of open science and digital economy, in which data and resulting immaterial goods can become vital pieces as tradeable items. We believe that both science and the digital economy can profit from a seamless transition and foresee that the scientific outcomes of publicly funded research can be better exploited. To close the gap between open science and the digital economy, and to serve for a balancing of the interests of data producers, data consumers, and an economy around services and the public, we introduce the concept of generic research data management plans (RDMs), which have in part been developed through a community effort and which have been evaluated by academic and industry members of the NFDI4Cat consortium. We are of the opinion that in data-driven research, RDMs do need to become a vital element in publicly funded projects.

1. Open Science

In the age of digitalisation of research, open science (i.e., open research) is gaining ever more attention, appreciation and momentum.[1–4] The term "open science" describes the practice of sharing research data and methods as openly as possible in a research process.[5,6] This opening up of research can be achieved through a bundling of strategies and processes to make all components of science accessible, comprehensible and reproducible. To reach this goal, while supporting good scientific practice, open science combines six subprinciples, covering open access, open data, open source, open peer review, open methodology and open educational resources.[7,8]

1.1. Open data

While many research communities have already adopted the provisioning of publications as open access, the provisioning of research data as open data[9,10] is still not a very common practice.[11] The idea of open data is that data can be freely used, modified and shared by users for variable purposes beyond the original ones. The subprinciple might not be applicable to data that include sensitive information or that can be associated to intellectual property rights and is therefore at a given point in time not public.[11]

1.2. FAIR data

While open data is an important concept, the sheer openness of data does not guarantee its usefulness to the community. The term FAIR data was coined, which includes four principles ensuring the usefulness of data to humans and machines. Those principles are **F**indability, **A**ccessibility, **I**nteroperability and **R**eusability (Figure 1).[12]

- Findability: "Metadata and data should be easy to find for both humans and computers. Machine-readable metadata

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Supporting information for this article is available on the WWW under https://doi.org/10.1002/chem.202202720

Figure 1. Overview of the FAIR principles.

are essential for automatic discovery of datasets and services."

- Accessibility: "Once the user finds the required data, she/he/they need to know how they can be accessed, possibly including authentication and authorisation."
- Interoperability: "The 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."
- Reusability: "The final goal of FAIR is to optimise the reuse of data. To achieve this, metadata and data should be well-described so that they can be replicated and/or combined in different settings."

1.3. Linked data

Linked (open) data is a collection of interrelated data sets. Within this data network, the data and their relationships are provided in standard formats.[13] The standardised format enables humans and machines to explore the data network and find related data.[14] Similar to FAIR data, linked data are not equivalent to open data. Data can be linked within a data network while not being openly available for everyone. The concept of linked open data unites both approaches.[15]

2. European Regulations

With the digital technologies transforming society, a (re-)shaping economy and the evolution of new business models, data have become a topic of public interest. In this context data are now seen as an important tradeable item, that drive business and innovation.[16] In accordance with data as tradeable items, services around data harvesting, analysis, interpretation and resale of aggregated data and information have emerged and need to be fostered further. The recent European commission, under Ursula von der Leyen's presidency, aims to establish common rules and practices for the EU to ensure an efficient and fair exchange of data in the context of an EU-based data and digital economy.[17]

Over the years[18] and under several presidencies, the European commission has prepared and released a number of regulatory acts, namely the General Data Protection Regulation,[19] the Regulation on the free flow of impersonal data,[20] the Cybersecurity Act[21] and the Open Data Directive[22] with the overall aim to regulate the European data environment and economy around data and to establish safety standards (Figure 2).

The General Data Protection Regulation (GDPR) was introduced in 2016 and concerns the right of the protection of personal data by establishing rules for the processing of personal data and the restricted movement of such sensitive data. "Personal data" refers to any information related to a natural person that can lead to its identification.[19] Data not covered by the GDPR are covered by the Regulation on the free flow of impersonal data. This regulation deals with the processing of impersonal electronic data coming from the use of services. More specific, when a dataset comprises both personal and impersonal data the regulation applies to the impersonal part of such dataset. If the data (personal and impersonal) within the dataset are inextricably linked, they will fall under the GDPR regulation.[20] Additionally, the European Union Agency for Cybersecurity (through the Cybersecurity Act) received a permanent mandate and a strengthened role as an organisation. The main goal of these regulations and agencies is to guarantee a high level of security, cyber resilience, and trust amongst public and private users within the EU. To achieve these goals, certification schemes to ensure harmonised standards in the field of information and communication

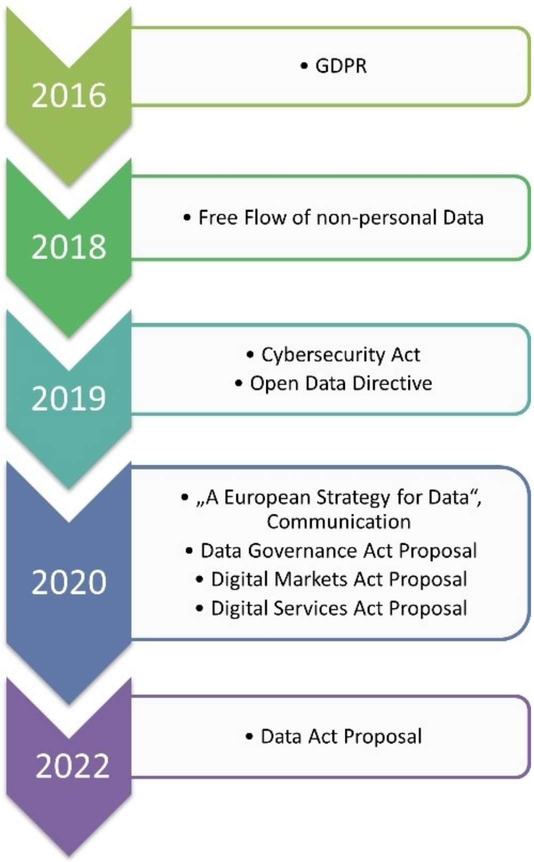

Figure 2. Timeline of European data regulations.[19–27]

technology are to be established.[21] The development of such certifications schemes and standards is currently underway.[28]

As the use and flow of personal and impersonal data were structured based on the regulations mentioned before, the Open Data Directive aims to overcome the barriers for the re-use of public sector information, setting as one of its objectives to increase the availability of new types of public and publicly funded data. They also include research data output arising from activities in publicly funded projects. Member states are asked to support the availability of research data by adopting "*open access policies*", following on the one hand the principle of "*open by default*" and compatible with the FAIR principles. Further, on the other hand the principle of "*as open as possible, as closed as necessary*" shall be adopted, where concerns about intellectual property rights, personal data protection, confidentiality, security, and legitimate commercial interests arise.[22] The latter principle is from our point of view an extremely important one, allowing for transitions from open science into a digital economy (and back), particularly in the context of publicly funded project schemes.

With this legal background, in February 2020 the European commission, more specifically the commissioner's group "A Europe Fit for the Digital Age" led by Margarethe Vestager,[29] took a great step forward and presented the "European Strategy for Data",[30] which outlines a strategy for policy measures and investments to enable the data economy in the foreseeable future. In the light of this strategy, data are given a protagonist role in the decision-making process for private and public sectors, as data (as digital items) can be replicated and be used by several entities simultaneously. The strategy's vision is hereby to release such potential by ensuring better access to data and their responsible use. To achieve this, the intention is to create a single market for data, in which EU laws can be enforced effectively, and where the data-driven products and services as well as data content comply with relevant norms.[23]

Shortly after presenting this strategy, a proposal for a Regulation on European Data Governance (Data Governance Act, DGA) was disclosed.[24] The DGA has already undergone a critical review[31] and has been passed, after the first reading process within the EU parliament, the final hurdles in May 2022 as an EU regulation.[32,33] The DGA is addressing several scenarios, more specifically, making public sector data available for use, sharing data among businesses, help individuals exercise their rights under the GDPR with the help of data-sharing intermediaries and allow data use for purposes of general interest (e.g., scientific research or improvement of public services), so called "*Data Altruism*".[24,34] The DGA also gives general guidance for rules and obligations in a future data economy, in which lawful access to data is highlighted (Figure 3). Hereby, a data holder, according to Art. 2 of the DGA is defined as every natural (data subject) or legal person, who has the right to grant access or to share certain personal or impersonal data in his/her control. The DGA defines additionally two legal entities, namely the data sharing provider and the data altruism organisation, whose role it is to help to manage the lawful access to data and the necessities of data holders.

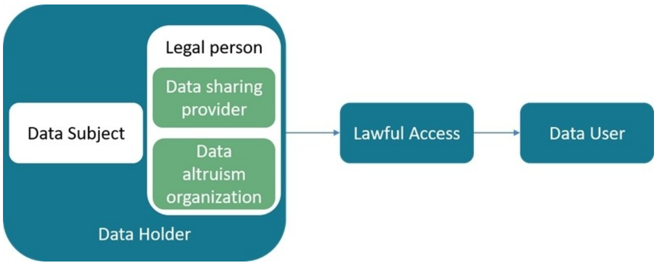

Figure 3. Data economy structure described by the DGA.

These instances shall become neutral intermediaries in a future digital market.

To incentivise individuals to share data, the commission saw the necessity of increasing the trust in such intermediaries (data sharing providers), who will have a key role in the data economy. This goal is intended to be achieved by establishing clear duties, requirements and boundary conditions for the data sharing service provider and entities interacting with the provider (Art. 9, 10 and 11. DGA proposal). By establishing such framework conditions, the intention is to give defined ownership of data to the data subjects and to strengthen their position. Data subjects can decide under which conditions and for which goal or purpose their data can be used. To ensure that the will of the data subject is executed and not violated, a prohibition for data-sharing services to use data for other purposes than sharing can be included. Relevant for data sharing, specifically in the academic community, will be the data altruism organisations, which will manage the consent or permission to process personal or impersonal data without seeking a reward, for purposes of general interest, such as scientific research purposes, or improving public services. Such organisations will meet transparency requirements to ensure their altruistic goals (Art. 18, DGA Proposal).[24]

To ensure fair and open digital markets, the European commission released a proposal for a regulation on contestable and fair markets in the digital sector (Digital Markets Act, DMA) in 2020 and has been accepted by the EU parliament and council in September and October 2022, respectively.[25,35] This act regulates the activities of large platforms, as they act as gateways or gatekeepers between business users and end users and enjoy an entrenched and durable position. The large platforms that meet the conditions defined in the DMA will be defined as gatekeepers, and those that do not meet such conditions can be defined as gatekeepers after a market investigation (Art. 3, DMA Proposal). Companies classified as gatekeepers should comply to a set of prohibitions and obligations (Chapter 3, DMA Proposal), which seek to keep an equal opportunity market regardless the size of the undertaking.[36]

Together with the DMA, the European Commission released a proposal for the Regulation on a Single Market for Digital Services (Digital Services Act, DSA) with the goal to ensure a safe and accountable online environment. In accord with these settings, the DSA will set measures to counter illegal practices, set new obligations on traceability of business users and set effective safeguards for users between others.[26,37]

Recently, in February 2022, the European Commission further released a proposal for a regulation on harmonised rules on fair access to and use of data (Data Act). This proposal sets rules on making data generated by connected products or related services being sold, rented, or leased in the digital market. Simply said, it regulates the use, re-use and availability of data; making it available to the data generator, while giving power over such data to the data generator (data subject).[27,38]

To allow for a smooth transition of traditional science disciplines into the digital age, the German National Research Data Infrastructure (Nationale Forschungsdateninfrastruktur e.V., NFDI) was founded as an initiative as part of the "Digital-strategie" of the Ministry of Education and Research.[39] The vision is to establish and develop a digital eco-system for all science domains through a series of measures realised by the consortia forming the NFDI. The network of consortia takes care of the required measures to establish sustainable standards, procedures, and services for the digital transformation of science and research.[40] The different NFDI consortia take over the responsibility for the respective science domains but are also responsible to create linkages in between the science domains and the consortia. NFDI4Cat is part of these consortia within the NFDI and has as specific differentiator installed an industrial advisory board, to help in designing the transformation of the field of catalysis and its related sciences into what has been coined as "*Digital Catalysis*".[41]

Although several the EU regulation acts are currently in the reading and have still to undergo discussion on EU parliament level, others have been finalised, a new legal environment will clarify current open questions in the scene and will help in shaping the legal basis that allows all parties to participate in open science and the upcoming digital economy. One main aim must of course be to foster a flourishing data/digital economy in connection with open science. The use of the FAIR principles should be self-evident for publicly funded projects and national and international initiatives, such as the NFDI consortia, can aid the digital transition on the science side. Beside the NFDI consortia, research institutions and universities must be held accountable to teach their staff and students how to comply with the FAIR principles. Also, industrial companies must create a working environment that emphasises a FAIR data handling. From our perspective, the unaddressed question of how to create and connect a permeable interface between open science and digital economy remains and must be addressed urgently. As mentioned above, the creation of awareness in the open science and digital economy communities plays a vital part, but beyond this, the conscious decision of the data producers/owners on the fate of their data and related immaterial goods is a mandatory precondition. In the following, we will make an argument for allowing a seamless permeation of open science and digital economy. In traditional interactions between academia and industry in the fields of chemistry, catalysis, materials sciences, and chemical engineering this permeance is not new but has been exercised since a long time—for the benefit of the stakeholders, creating also immense value for society.

3. Thoughts about Connecting and Permeating Open Science and the Digital Economy

Two paradigms are currently influencing research and development in the fields of engineering, materials sciences, and chemistry. The first one is the paradigm of open science in conjunction with the FAIR treatment of research data. The second one concerns the development of a digital economy around data, data analysis and connected digital services in the above-mentioned science and technology domains. In this context, data are regarded as property and tradeable good, which form the basis of any economy.[42] Specifically, the digital economy, evolving around data, tradable immaterial goods, and services in the field of natural sciences, engineering and technology, is a relatively young field. In the following we therefore try to outline exemplarily items and interactions that can be most obviously considered as parts of a digital economy around data arising in natural sciences. Further information can be found in the Supporting Information.

- Data trading (buying, selling or exchange of data, simple case: bilateral, between two institutions; complex case: multilateral, between more than two institutions)
- Data generation on demand (data producers produce data–experimental/simulation–on demand for customers) and subsequent data trading
- Digital trading services (sales processing–closure–token–transfer)
- Data analysis services (digital)
- Meta-analysis services (digital)
- Service to product support: (e.g., data analyser offers service to clients for data analysis and provides suggestion for better physical product to customer–alternative consulting)
- Product placement services: showroom for data, trade items associated to immaterial rights (inventions, patent applications, granted patents, know-how, etc.), and services
- Evaluation of data sets (rating of data sets)
- Contextualisation and validation services of data sets (digital/physical)
- Consulting for data augmented solutions (consulting on best practice approach/querying for curated data sets)
- Pricing and valuation/regulation services

As mentioned above, at present open science and digital economy, are mostly seen, discussed, and treated as separate domains and fields. No strong efforts have been made so far to conceptually interconnecting them or to seek for opportunities for the creation of permeability. The current perspective creates a dividing line that, from our perspective, can be discussed as unnatural separation. From our point of view this perspective hinders unleashing the full potential, that can be achieved by the connection/permeation of both fields through participation of all stakeholders on both sides (academia/industry). Particularly the participation of small and medium size entities, start-

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doi.org/10.1002/chem.202202720

ups, or consultants and especially academia in a digital economy around data and immaterial goods stemming from research, associated digital services and products will largely depend on the development and acceptance of (new) business models around the trade and economisation of data and services related to data. The general ambition to connect open science and digital economy is in line with current and upcoming European regulations and legislations. In the light of "Data Altruism" it must be acknowledged that data, together with associated immaterial goods and services around data, should be considered as important items that will form the basis of new business models in the context of an economic valorisation.

Not only will science and technology in general largely profit from the developments of a digital economy connected to open science, but also completely new value chains around data and services can be created and explored (Figure 4).

In this context, the topic of information transparency in particular will have a dramatic impact on research and development. Information transparency through open science improves the view and allows to identify gaps in available and accessible data sets for a given science and technology application or technology field through the analysis of data available in open archives. Based on such gaps it can be expected that resulting technological opportunities ("uncharted territory") will be much better visible and will help in the data-driven prospection of technological opportunities and opportunity fields.

The connection of open science and digital economy is not only expected to be beneficial for science and technology in general, but also possess distinct advantages for academia and industry (Table 1). Obviously, based on future data value chains that come with the open science/digital economy movement, some of these advantages account also for platform and service providers. Especially, to mention in this context is the opportunity for academic institution to create completely new training sets concerning FAIR data handling, research data management tools, and the benefits of research data management for individual researchers.

Crucial factors to promote the successful connection of open science and digital economy are the implementation of data standards and the use of platform services as enablers, both of which NFDI consortia in Germany are playing a key role in. For the NFDI4Cat community in particular, the interconnection/permeation of open science and digital economy will be a driving force for technology and science fields, such as catalysis and chemical engineering as enablers for laying the basis of the next generation catalysts and processes of the sustainable production of chemicals and energy carriers. However, these key developments addressing urgent societal needs require a synergistic effort of the chemical, energy related and engineering industry sectors, in accordance with academia and stakeholders from the digital science domains, to push and unite the development efforts in the area.

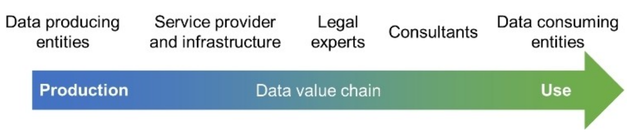

Figure 4. Data value chain that opens with the connection of open science and digital economy.

Table 1. Advantages of open science and digital economy for academia and industry.

Academia	Industry
• New modes of interaction/business • Increase in transparency • Better approach to open innovation • Enhanced outreach and visibility • Time reduction in research and development cycles • Creation of common data standards (ontology/meta data)	
• Market access/participation for academia • Economisation of unexploited data resources • Better access to data and data products and services • Education: new aspects in teaching and training (for students, scientific and nonscientific staff)	• New and better services • Cost reduction in research and development cycles • Better approach to customer security and product quality

Apart from ongoing efforts and funding frameworks, it is recommended to funding agencies to explore the potentials of programs allowing to explore the field of the connection, respectively creation of permeance between open science and digital economy. It is expected that this interface has a dramatic potential to foster new partnerships, economic and business approaches and may be the crystallisation point of new data-centric eco-systems promoting both: science and economy. To investigate new interactions, business models and the adjustment to new roles within new partnerships it is proposed to allow project efforts that use modern and agile development tools like design thinking or gamification approaches to most efficiently and effectively explore currently uncharted territory.[43,44]

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4. Balancing the Needs of Data Producers and the Public by Employing Research Data Management Plans

The increasing demand of digital data sharing among scientists, has promoted a discussion about research data management plans (RDMPs). RDMPs may be an emerging tool for researchers to communicate specific intentions for storing, using, maintaining, and making data assessable to all stakeholders involved, also including funding bodies.[45] The advantages of RDMPs for the scientific community and for funding agencies become more and more obvious, not only for individual researchers. This is also demonstrated by the newly published "Specification of Requirements Relating to the Handling of Research Data in Funding Proposals" from the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation).[46] Smale and co-workers categorised the benefits of RDMs according to:[47]

- Professional benefits with respect to the researcher's productivity and visibility
- Economic benefits regarding the enhanced academic and non-academic impact of research per unit of investment
- Institutional benefits for institutional planning and compliance[47]

Through the implementation of RDMPs for publicly funded research projects as mandatory element, control and responsibility over the data should be granted to the data producer on the one hand, whereas one the other side the data are provided to the public according to the FAIR[48] principles.[49] We are of the firm opinion, that by following the FAIR principles, the benefits of RDMPs go beyond the categories describes before, since RDMPs can also act as tool to balance and unify the interests of the data producer and the public. Also, RDMPs have the potential to establish the before mentioned missing connection between open science and a digital economy.

Despite the fact that in some research disciplines an active data sharing culture and therewith associated comprehensive research data management has already been established, other scientific communities are still hesitant and the main driving force for the adoption of RDMPs in these communities often comes from funding agencies, such as the DFG. We attribute this lack of interest to two main factors: 1) the shortage of training concerning which RDM tools are available and how to use them and 2) the missing understanding of the benefits of research data management for the individual researcher. Another factor to consider are cost issues associated with IT infrastructure, electronic lab notebooks and software. Especially in academia, where the costs for data management and the costs of research funding are often not borne by the same institution, cost issues can attribute to a lack in RDM practise. To overcome these resistances and to aid the digital transformation, it is a main task of the NFDI consortia to educate and to provide easy access to RDM tools. However, not only the NFDI consortia but also local institutions should help to pave the way towards a successful research data management culture and a FAIR handling of research data.

As part of the NFDI4Cat consortium, we established a RDMP, especially coined with regards to the needs of catalysis-related sciences—but also applicable in a broader context. Since NFDI4Cat is at present the only NFDI consortium with industry participation, points, such as intellectual property and confidentiality, are of especial importance for the community of catalysis related sciences. The established RDMP is based on the classification of the research data ("cool-off" model, critical vs. uncritical data) that is generated during the project (Figure 5) and also acknowledges that not all data can be open (see above).[45] However, the guiding principle with respect to data sharing and deposition is, in accordance with the EU commission, "as open as possible, as closed as necessary".[23] With this guiding principle we would like to guarantee that the data producer is, despite a very liberal data sharing strategy, still

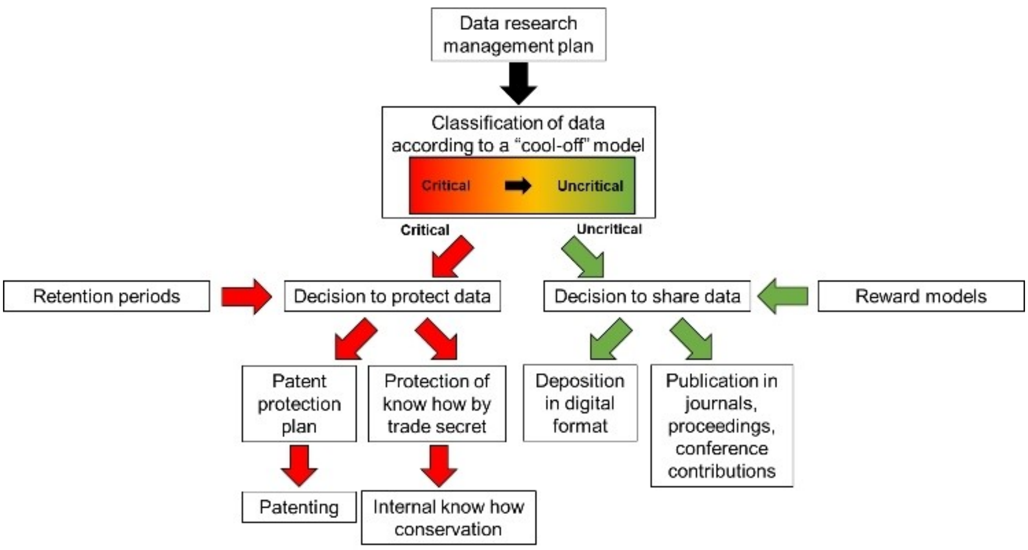

Figure 5. Research data management plan developed by the NFDI4Cat. Graphic adapted and modified from ref. [50].

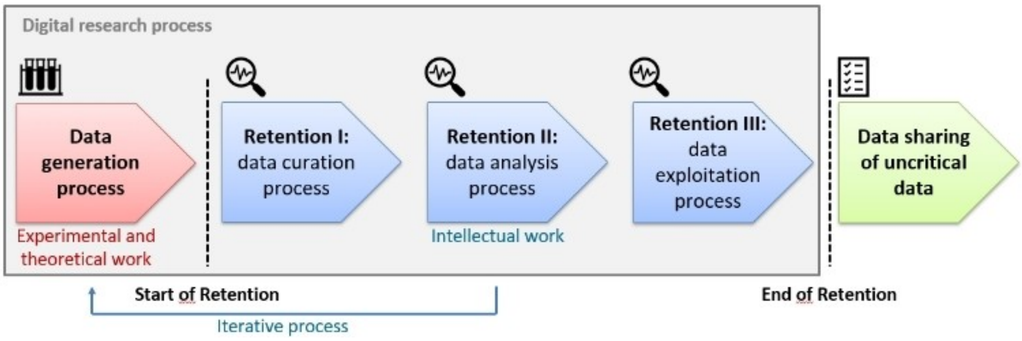

Figure 6. Retention periods within the RDMP to convert critical into uncritical data.

able to participate in a digital economy, where value can be generated from data generation and analysis.

In case the data producer classifies its data as critical, we integrated retention periods as additional tool within our RDMP. Through that we would like to give the data producer time to curate, analyse and exploit data intellectually in a so-called digital research process (Figure 6). Hereby it must be considered that this process is iterative and consequently new data might have to be generated and will have to be classified. The aim of the implementation of retention periods into our RDMP is to reclassify the data generated and to convert critical data into uncritical data that can then be published.

In case the data producer classifies data as uncritical from the beginning of the research project or after a sufficient retention period, we established "tailor-made" reward models within our RDMP for industry and academy to promote a liberal data sharing approach through social (e.g., possibilities to build new collaborations, recognition for data deposition) and metric rewards (e.g., allocation of a digital object identifier, implementation of citation levels). When discussing reward strategies, we also considered the fact, that reward strategies for a liberal data sharing culture can act as inherent quality-control measurements for deposited data sets. In this context, the San Francisco Declaration on Research Assessment, which recognises the need to improve the ways in which research outputs are evaluated, can be considered.[51]

To evaluate the feasibility of our RDMP within our community further, a focussed survey with 66 participants from university, research institutes, industry, and others (publisher, librarian) was carried out (Figure 7). All detailed information about the survey can also be found in the Supporting Information. Despite the small number of participants, we can present not only an academic understanding of our RDM, but we are also capable of including industry-related interests and compare both sides.

Almost all participants in the focus group survey agreed that the conception of a RDMP is crucial before the beginning of a research project. We found that this was independent from the fact whether the researchers think that they produce data that can be classified as critical or uncritical along with the RDMP. The question concerning how the participants would classify their research output in terms of confidentiality (1: uncritical, 10: critical) was answered with an overall score of 6. The same accounts for the question to what extent data of the researchers require protective measures regarding IP and confidentiality (overall score 6, 1: no protective measures, 10: must be completely protected). Hereby, clearly participants of the survey with an industrial affiliation answered that their work undoubtedly may produce critical data and that their data will need protective measures. This becomes also obvious from the question: "How much of your work has to be protected by patents?". The overall score of 3 (1–0%, 10–100%) indicated that most research data must not be protected through intellectual property rights; however, industrial participants rated with a score of 7.9. These differences clearly indicate the need for tailored RDMPs when it comes to interfaces between academia and industry. Obviously, interests must be balanced well, especially in collaborative projects.

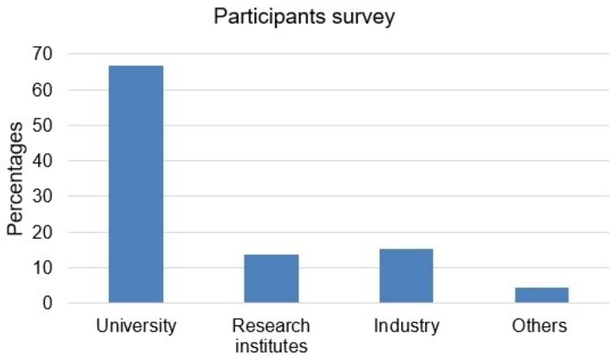

Figure 7. Overview of the participants of the NFDI4Cat RDMP survey.

To evaluate the additional tools developed, such as the retention periods and reward strategies of our RDMP further, we have asked the participants whether they think the implementation of a retention period is a sensible complement. The overall answer score was 5 (1: does not make sense for me, 10: is very sensible). Again, participants working in industry rated higher than university related researchers (7 vs. 5), showing that IP, patenting, and the internal conservation of know-how is a much more prominent topic in industry, especially also with respect to being part in a competitive environment like a digital economy in the nascent state.

To evaluate the retention time concept further, we have asked what extent of the retention period researchers would see as adequate (3 months–1 year) with the results being depicted in Figure 8. Almost 50% of the participants think that one year is a sufficient time for the intellectual work on experimental and theoretical research data. Participants, who answered with other options usually indicated the need for longer retention periods of up to 18 months. In general, industry related participants voted for longer retention times than researchers from university and research institutes. This might also be due to the fact, that industrial research usually comprises securing of immaterial goods with respect to the strategic direction of a company, an effort which is time and resource consuming.

With this NFDI4Cat-based survey, we have also tried to estimate the success of a reward model within a RDMP. Therefore, we have started asking the question of how willing researchers are in general to deposit, meaning share, their data. Participants answered with a score of 8 (1: not at all, 10: completely). As we are aiming to promote liberal data sharing practices further within the community of catalysis-related sciences through a (social and metric) reward strategy, we have asked how important rewards are for researchers. The participants answered with an overall score of 6 out of 10 (1: not important, 10: very important). Interestingly, participants from research institutes ranked the importance of reward models much higher than industry- and university-related participants (7.9 vs. 6.2 vs. 5.8). It is concluded that this measure is potentially seen as helpful for these institutions in their regular review processes. As we are also considering reward strategies as an inherent quality control measure for the deposition of data, we asked whether the researchers think this might be a plausible argument. However, the researchers indicated with an overall rate of 5 out of 10 (1: not at all, 10: completely) that this concept might not be completely feasible for them. However, the social reward system might need time to become accepted within the community, where currently metric rewards, such as journals impact factors and publication scores, are considered as gold standards.

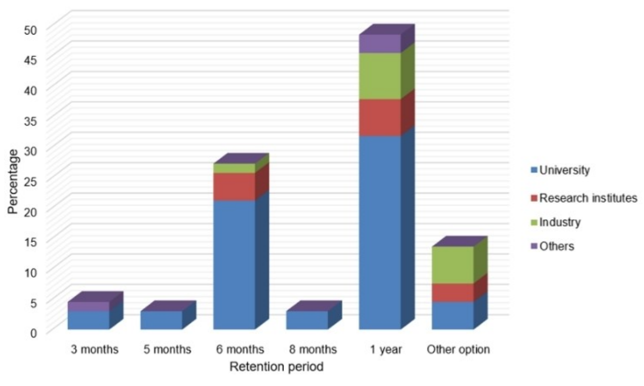

Figure 8. Answer to the question: "What extent of the retention period would you see as adequate?" 3 months–1 year.

Besides the evaluation of our RDMP within the NFDI community, we were interested in the fit of the developed RDMP model along with the European regulations established so far (Figure 9). Obviously, one of the key questions in this regard is the classification of data into critical or uncritical data and the consequent decision to protect or share data. A decision to protect immaterial goods generated based on the data, by patent law[52] or by defining it as trade secret,[53] will give the data producer reasonable degree of control/ownership. On the other hand, the decision to share will in the EU be based on the legal framework concerning data sharing mentioned before. In this context, the DGA and the therewith associated data altruism organisations come into play. As mentioned before, these entities are supposed to act as provider of data repositories for objectives of general interest and should meet a list of requirements to qualify as such. Once the defined requirements are met, and after due process they can be listed in a national register and will enjoy recognition across the EU.[24]

5. Proposed Measures, Conclusions, and Outlook

In front of a background of clarified definitions in the context of open science, and by having given an overview on the European regulations concerning digital economy, we believe that we have made a clear case for data and services around data becoming an appealing good, trade item and field of interaction in the future.

In this context, the connection of open science and the digital economy creates immense opportunities for propelling science towards exploring applications addressing current and future societal needs. Hereby, permeable interfaces must be created, and it is foreseen that symbiotic relationships can be created, in which all stakeholders will benefit from participating and the true value of open science in the common public interest can be harvested. Agreements on fundamental topics, such as data standards for specific science domains, user-friendly interfaces, a suitable environment for the safe and fair trade of data and services, as well as a series of to be developed digital business approaches will unleash the potential of connecting open science with the digital economy. A crucial factor will be also to promote and to foster the permeance of open science and the digital economy on a funding program level so as to allow participation from partners of all sides in the paradigmatic change process. We propose the use of modern

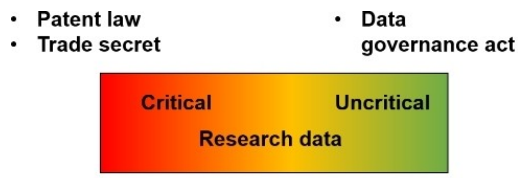

Figure 9. NFDI4Cat RDMP within the European legal framework.

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and agile tools for the evolution of the desired permeance and to allow for the development of new interaction models, roles, products and services within publicly funded programs and projects. The final goal of such programs must be to allow fair access to digital markets for academia and industry on a level playing field, which in turn will provide the economisation of unexploited data resources and better access to data and data-related products and services.

The establishment of new data value chains paired with data transparency will open up new opportunities by allowing digital science workflows for the discovery of new technologies aimed at the closure of technological gaps, which in turn will create new impulses for science. We hope that in light of the demand for new and alternative technological approaches in the field of sustainability and specifically also in the light of fostering technological sovereignty within the EU, the permeance between open science and the digital economy will have game-changing potential.

Finally, we have introduced generic research data management plans as simple models for transparency and sensibilisation that have been evaluated by academic and industry members of the NFDI4Cat consortium. These generic RDMPs will help to balance the demands and needs of industrial partners, data producers, funding agencies, public, etc. by having tailored retention periods and different reward strategies.

How current European regulations set the scene for the environment of a future data economy and how data sharing in open science evolves will shape the relationship between academia and industry in the context of an evolving digital economy.

Acknowledgements

We would like to thank all members of the NFDI4Cat and the DECHEMA for input concerning our research data management plan. Also, we would also like to thank BASF SE and hte GmbH for constant support. Open Access funding enabled and organized by Projekt DEAL.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability Statement

The data that support the findings of this study are available in the supplementary material of this article.

Keywords: Data Governance Act · digital economy · European regulations · NFDI4Cat · open science · research data management plans

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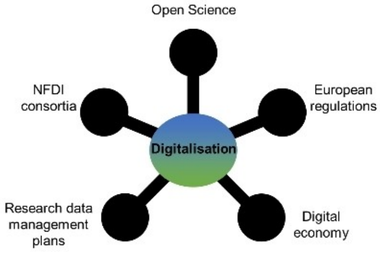
Manuscript received: August 31, 2022
Version of record online: [redacted], [redacted]

PERSPECTIVE

The integration of open science into a digital economy, while considering legal European regulations, is a balancing act. Here research data management plans play a key role and has the potential to combine the interests of researchers as data producers and the public as data users in publicly funded projects.



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How Research Data Management Plans Can Help in Harmonizing Open Science and Approaches in the Digital Economy