

# **Course: Data and Information Literacy**

## **Lecture: 11 Open Data and Open Science**

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### **11.1 Introduction**

Open Data and Open Science are integral components of the broader open-access movement, promoting transparency, accessibility, and collaboration in research and data sharing. These concepts advocate for making data, research findings, and scientific processes freely accessible to the public, researchers, and other stakeholders without restrictive licenses. By the end of this topic, learners should be able to:

1. Define and differentiate between Open Data and Open Science and explain their key principles.
2. Discuss the benefits, challenges, and ethical considerations associated with Open Data and Open Science.
3. Analyze how Open Data and Open Science contribute to data literacy and knowledge-sharing in academic and research environments.
4. Evaluate various Open Data platforms and repositories and understand their applications in different fields.

Open Data refers to data that is made freely available for use, reuse, and redistribution, typically in structured formats and without limitations. Open Science expands on this by encompassing the entire scientific research process, including the sharing of methodologies, software, peer-reviewed publications, and other resources that facilitate collaborative scientific discovery.

### **Key Concepts in Open Data**

- **Accessibility:** Open Data emphasizes that data should be accessible to everyone, ideally through public platforms or repositories. This accessibility allows for data to be used in ways that support new insights and innovation.
- **Usability and Interoperability:** Open Data is generally provided in standardized, machine-readable formats, ensuring that it can be integrated into various systems and applications. This interoperability is crucial for data analysis and knowledge-building.

- **Licensing and Legal Aspects:** Open Data is often released under licenses, such as Creative Commons or Open Data Commons licenses, that clarify how data can be used, shared, and modified. These licenses protect creators' rights while allowing public access.
- **Transparency and Reproducibility:** By making data open, researchers provide the means for others to verify and replicate their findings, increasing the credibility and reliability of scientific results.

### 11.1.1 Core Principles of Open Science

Open Science builds on the principles of Open Data, but it encompasses the full spectrum of scientific research, aiming to make the entire research process transparent and accessible. Key principles include:

1. **Open Access to Publications:** Open Science supports unrestricted access to scientific publications, allowing researchers worldwide to benefit from and build upon published findings without subscription barriers.
2. **Open Research Data:** As with Open Data, Open Science promotes sharing research data to foster collaboration, transparency, and reproducibility.
3. **Open Peer Review:** Open Science advocates for transparent peer review processes, where reviewer identities and feedback are accessible, promoting accountability.
4. **Open Methodology:** Open Science encourages sharing the research methodology and workflows, allowing other researchers to understand, reproduce, or even improve upon these methods.
5. **Open Educational Resources (OER):** Open Science promotes educational resources that are freely available, facilitating the sharing of scientific knowledge beyond academic or institutional barriers.

### Benefits of Open Data and Open Science

- **Enhanced Collaboration:** By sharing data and scientific findings openly, researchers can collaborate across institutions, disciplines, and borders, leading to multidisciplinary insights and faster progress.

- **Increased Innovation:** Open Data provides the foundation for innovative applications, allowing governments, private sectors, and communities to use data in ways that address societal challenges and create economic value.
- **Public Trust and Transparency:** Open Data and Open Science foster trust by making research processes and results transparent to the public, which is particularly crucial for publicly funded research.
- **Educational Opportunities:** Open resources allow educators and students to access cutting-edge research and data, enhancing educational experiences and supporting data literacy initiatives.
- **Reproducibility and Quality Control:** Open Data allows researchers to validate and reproduce studies, addressing issues of reliability in scientific research.

### 11.1.2 Platforms and Tools for Open Data and Open Science

There are several platforms and tools that support Open Data and Open Science, providing researchers with resources to share data, collaborate, and disseminate findings. Some notable examples include:

- **Open Data Portals:** Examples include data.gov and the World Bank's Open Data, offering freely accessible datasets across diverse fields such as government, economics, and environmental data.
- **Open Access Journals:** Journals like *PLOS ONE* and *eLife* support open-access publishing, making scientific articles freely available to the public.
- **Repositories:** Platforms like Zenodo, Figshare, and Dryad allow researchers to upload datasets, publications, and other research outputs, ensuring long-term storage and public access.
- **Collaboration Tools:** GitHub and Open Science Framework (OSF) provide collaborative environments where researchers can share code, data, and project documentation, supporting transparency and open collaboration.

### 11.1.3 Role in Data and Information Literacy

Open Data and Open Science are crucial for data literacy, empowering individuals to critically engage with, analyze, and interpret data. They encourage transparency in research methods, which

is essential for understanding scientific integrity and reliability. By promoting openness, these practices enable individuals to develop informed opinions based on evidence and verify information independently.

Open Data and Open Science represent transformative movements within research and academia, promoting accessibility, transparency, and collaboration. While there are challenges to overcome, these movements align with ethical imperatives to democratize knowledge and foster public trust in scientific processes.

## **11.2 Principles and Frameworks of Open Data and Open Science**

Open Data and Open Science rest on foundational principles that promote accessibility, transparency, and collaboration across the scientific and research communities. By establishing a structured framework, these principles support data-sharing practices that make research processes and outputs accessible to a wide audience. We delve into the core principles and widely adopted frameworks guiding Open Data and Open Science, highlighting the ethical, technical, and regulatory standards that ensure data is shared responsibly and remains useful across fields.

### **Key Principles of Open Data and Open Science**

#### **1. Transparency**

Transparency in Open Data and Open Science refers to making the research process, methods, data, and results openly available to the public and scientific community. Transparent practices allow other researchers and stakeholders to scrutinize, replicate, and build upon original work, increasing the credibility and reliability of scientific findings. Transparency also enables the public to understand and verify the processes that lead to scientific conclusions, fostering trust in research outputs.

#### **2. Accessibility**

Accessibility is a cornerstone of Open Data and Open Science, ensuring that data, publications, and methodologies are available to everyone without paywalls or restricted access. Accessibility is facilitated through open-access publishing, data-sharing platforms, and public repositories that provide free access to research materials. The principle of

accessibility also emphasizes the need for data to be available in formats that are machine-readable and compatible with various software, ensuring ease of use and further analysis.

### 3. **Interoperability**

Interoperability refers to the capacity of data to work seamlessly across different platforms, systems, or disciplines. This principle ensures that data is stored in standardized, machine-readable formats that enable integration with various applications, tools, and datasets. Interoperability is crucial for large-scale data analyses that often require combining data from multiple sources. It is achieved through consistent use of metadata standards, controlled vocabularies, and adherence to widely recognized data formats.

## 11.2.1 Frameworks Guiding Open Data and Open Science

Several frameworks have been established to support the principles of Open Data and Open Science, setting standards for data accessibility, sharing, and ethical use. These frameworks provide structured guidelines to help researchers and institutions maintain consistent and responsible open practices.

### 1. **FAIR Principles (Findable, Accessible, Interoperable, Reusable)**

The FAIR Principles provide a widely adopted framework for managing and sharing data in Open Data and Open Science initiatives. Developed by the European Commission in 2016, the FAIR guidelines ensure that data is:

- **Findable:** Data should be easy to locate for both humans and machines, which requires detailed metadata and unique identifiers for each dataset.
- **Accessible:** Data should be retrievable via standard protocols, whether freely or through authentication, and remain accessible long-term.
- **Interoperable:** Data should be compatible with other datasets and systems through the use of standardized formats and controlled vocabularies.
- **Reusable:** Data should have detailed metadata that allows it to be reused in various contexts, supported by clear licenses that specify conditions for reuse.

The FAIR principles enhance the overall usability of data, making it suitable for integration across multiple disciplines and ensuring it remains a valuable resource for future research.

## 2. **Open Research Data Framework**

The Open Research Data Framework provides guidelines specifically tailored for the ethical sharing and management of research data. This framework encourages transparency and collaboration in scientific research by promoting open-access data and metadata.

## 3. **Open Science Framework (OSF)**

The Open Science Framework (OSF) is an open-source platform developed by the Center for Open Science (COS) that facilitates collaboration, transparency, and reproducibility in research. The OSF supports researchers by providing a centralized platform to store data, share results, and document workflows. Key components include:

- **Collaborative Tools:** OSF provides researchers with tools for collaborative project management, version control, and real-time updates, which are essential for multi-disciplinary projects.
- **Data and Workflow Sharing:** OSF allows researchers to openly share datasets, protocols, and methods, enhancing reproducibility and collaborative discovery.
- **Transparency in Research:** OSF supports pre-registration of studies, where researchers outline their methodology and hypotheses before conducting experiments, increasing transparency and mitigating publication bias.

## 4. **DataCite and Persistent Identifiers**

DataCite is an international organization that promotes the use of Digital Object Identifiers (DOIs) for datasets and research outputs, ensuring they remain accessible and citable over time. Persistent identifiers (PIDs) are unique, long-lasting references to datasets that support data integrity and findability. This framework is integral to Open Data practices, as it ensures that data can be consistently referenced and accessed, even if it is moved across repositories or platforms.

The principles and frameworks guiding Open Data and Open Science establish a structured approach for researchers to share and collaborate responsibly. By adhering to these standards, researchers enhance the accessibility, reusability, and ethical integrity of data, fostering a more transparent and collaborative scientific environment. These frameworks provide essential

guidelines for making data a public good, ensuring that it serves as a valuable, reliable, and sustainable resource for future discoveries.

## **11.3 Technological Infrastructure and Platforms for Open Data and Open Science**

The technological infrastructure supporting Open Data and Open Science is central to making research data accessible, reusable, and interoperable. Infrastructure includes digital tools, platforms, repositories, and technical standards that enable researchers to share, store, and collaborate on data and research outputs. Here, we explore the key components of technological infrastructure, such as data repositories, open-access journals, collaborative platforms, data-sharing standards, and data management tools. It also highlights specific platforms widely used in Open Science and describes their functions and benefits for facilitating open research practices.

### **11.3.1 Components of Technological Infrastructure for Open Data and Open Science**

#### **1. Data Repositories and Digital Archives**

Data repositories and digital archives serve as primary storage and access points for research data, making it available to other researchers, policymakers, and the public. These repositories ensure the long-term preservation of data and often provide metadata and search capabilities for easy retrieval. Examples of commonly used repositories include:

- **Zenodo:** A general-purpose open-access repository developed by CERN and OpenAIRE that supports research data, software, and publications across disciplines.
- **Dryad:** A curated repository for datasets underlying scientific publications, specifically designed to ensure data is accessible, discoverable, and reusable.
- **Institutional Repositories:** Many universities and research institutions maintain their own repositories for storing and sharing faculty and student research, which support Open Data initiatives and make locally produced research accessible to the global community.

#### **2. Open-Access Journals and Publishing Platforms**

Open-access journals and publishing platforms are crucial for disseminating research

findings without paywalls, ensuring that published research is accessible to everyone. These platforms offer open peer review, preprints, and other forms of transparent publishing that contribute to Open Science. Examples include:

- **Public Library of Science (PLOS):** A nonprofit publisher of open-access journals across disciplines, promoting immediate access to research.
- **arXiv and bioRxiv:** Preprint repositories for fields such as physics, mathematics, and life sciences, allowing researchers to share early versions of their manuscripts before peer review.

### 3. Collaborative Platforms and Tools for Open Science

Collaborative platforms enable researchers from different institutions and disciplines to work together seamlessly. These platforms provide tools for sharing data, co-editing documents, managing workflows, and version control, fostering transparency and collective research efforts. Common collaborative platforms include:

- **GitHub:** A web-based platform for version control and collaborative software development, which is widely used by researchers to share code, datasets, and documentation openly.
- **Open Science Framework (OSF):** Developed by the Center for Open Science, OSF is an open-source platform for managing, sharing, and collaborating on research projects. It supports reproducibility by allowing researchers to register studies, store data, share workflows, and pre-register hypotheses and methods.
- **Google Collaboratory (Colab):** A free, cloud-based platform that allows researchers to write and execute Python code in an interactive environment, making it easy to share computational experiments and collaborate on data analysis.

### 4. Data Management and Curation Tools

Effective data management and curation tools ensure that research data is organized, documented, and stored for easy access and future use. These tools assist with cleaning, annotating, and structuring data, allowing for easier sharing and interoperability.

Examples include:

- **DataCite:** An organization that provides persistent identifiers (DOIs) for research data, ensuring data can be easily located, cited, and accessed long-term.

- **CKAN (Comprehensive Knowledge Archive Network)**: An open-source data management system designed to make data open, accessible, and discoverable. CKAN is commonly used by governments and organizations to store and manage large datasets.
- **DMPTool and DMPonline**: These tools help researchers create data management plans (DMPs), which outline how data will be managed, stored, and shared throughout a project. They ensure that researchers adhere to best practices in data curation and compliance with funding agencies' requirements.

## 5. Metadata Standards and Interoperability Protocols

Metadata standards and interoperability protocols are essential for ensuring data can be integrated across various platforms and domains. Metadata standards provide consistent descriptions of datasets, making it easier for others to understand and reuse the data.

Examples of common standards include:

- **Dublin Core**: A metadata standard that provides a basic set of elements to describe digital content, including title, creator, subject, and date.
- **Data Documentation Initiative (DDI)**: A standard for describing social, behavioral, and economic science data, which supports the entire data lifecycle from creation to preservation.
- **Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH)**: A protocol that enables repositories to share metadata, facilitating search and retrieval across multiple repositories.
- **Schema.org**: A collaborative effort to standardize metadata across the web, which provides schemas for a wide variety of resources, including datasets, enhancing discoverability in web searches.

## 6. APIs (Application Programming Interfaces) for Data Access and Integration

APIs allow researchers to access and integrate data across platforms and systems programmatically. Through APIs, data can be retrieved and analyzed directly, supporting automated workflows and enabling interoperability between diverse data sources. Some widely used APIs in Open Data and Open Science include:

- **World Bank API:** Provides access to a vast collection of economic and social data from around the world, supporting analysis in fields like economics, public policy, and development.
- **Twitter API:** Allows researchers to access Twitter data for social science, communications, and sentiment analysis research.
- **ORCID API:** Connects to the ORCID system, providing researchers with access to a standardized identity system that links them to their research outputs across multiple platforms.

## **Examples of Widely Used Platforms in Open Data and Open Science**

### **1. Open Research Data Commons (ORDC)**

ORDC is a cloud-based platform that supports data sharing, analysis, and collaboration for researchers. It provides extensive data storage and analysis tools, making it suitable for research involving large datasets. ORDC enables collaboration through data-sharing options and tools for managing data access, curation, and analysis in a secure environment.

### **2. JSTOR Data for Research**

JSTOR Data for Research provides access to a large repository of scholarly publications and metadata for text and data mining. It allows researchers to conduct analyses on historical and contemporary texts, supporting research in fields like literature, social sciences, and digital humanities.

### **3. Harvard Dataverse**

The Harvard Dataverse is an open-access data repository where researchers can upload and share their datasets. It allows for data citation, provides DOIs, and includes built-in tools for data analysis and visualization. The Dataverse platform is widely adopted by academic institutions and research organizations as it supports data curation and collaborative projects.

The technological infrastructure and platforms for Open Data and Open Science provide the necessary tools and systems that make data sharing, collaboration, and open research possible. By utilizing repositories, open-access journals, collaborative platforms, data management tools,

and adherence to metadata standards and APIs, researchers can make their work accessible, reusable, and interoperable. These platforms and tools contribute significantly to advancing Open Science, fostering global collaboration, and supporting a transparent and reproducible scientific ecosystem.

## **11.4 Benefits and Impacts of Open Data and Open Science on Research and Society**

Open Data and Open Science initiatives have brought transformative benefits to both research communities and society at large by making research outputs, data, and processes more accessible, transparent, and reusable. This shift enhances the quality, efficiency, and impact of research, fostering collaborative efforts across borders, improving decision-making, and driving innovation in various sectors. By removing barriers to data and scientific knowledge, Open Data and Open Science help bridge the gap between research and real-world applications, with direct social, economic, and environmental impacts.

### **Key Benefits for Research**

#### **1. Enhanced Transparency and Reproducibility**

Open Data and Open Science promote transparency by making the underlying data, methodologies, and results accessible to other researchers, enabling them to replicate or scrutinize studies. This openness strengthens the credibility of scientific research, as it allows for verification and comparison of findings, reducing the risk of misconduct or data manipulation. Reproducibility is fundamental for scientific progress, as researchers can build upon verified data and methods, leading to more reliable and cumulative knowledge.

#### **2. Increased Collaboration and Interdisciplinary Research**

Open access to data and research resources encourages collaboration across institutions, countries, and disciplines. By removing barriers to data sharing, researchers can work together more effectively, sharing insights and resources that would otherwise be restricted. This fosters interdisciplinary research, which is particularly valuable in addressing complex global challenges such as climate change, health crises, and

sustainable development. Open platforms and repositories facilitate communication and co-development of projects, leveraging diverse expertise for innovative solutions.

### 3. **Accelerated Innovation and Discovery**

Open Data allows researchers to access large datasets that can reveal patterns and insights through methods like machine learning and data mining. This accessibility accelerates the pace of discovery, especially in fields such as genomics, epidemiology, and environmental science, where vast amounts of data are essential. By reducing the time and resources needed to gather new data, researchers can focus on analysis and innovation, generating faster and potentially groundbreaking results.

## 11.4.1 Societal Benefits and Broader Impacts

### 1. **Informed Decision-Making and Policy Development**

Open Data empowers governments, policymakers, and public institutions with access to reliable and up-to-date data for evidence-based decision-making. Whether addressing health, education, or environmental issues, policymakers can make better decisions when informed by data. Open Science also makes it easier for citizens to hold public officials accountable, as the public can access and evaluate data and reports that affect their communities.

### 2. **Enhanced Public Engagement and Science Literacy**

By making scientific data and findings accessible to the public, Open Science fosters a more informed and scientifically literate society. Open access to research encourages citizens to engage with scientific topics, understand ongoing research, and develop critical thinking skills. Public access to scientific knowledge also demystifies the research process, building trust in science and increasing the likelihood of societal support for science and innovation initiatives.

### 3. **Economic Growth and New Business Opportunities**

Open Data can stimulate economic activity by providing valuable datasets to industries, startups, and entrepreneurs who can leverage this data to create new products, services, and business models. For example, open geospatial data has enabled advancements in fields such as navigation, urban planning, and logistics. Access to research data in health

and agriculture has also spurred innovation, leading to improved healthcare technologies, sustainable agricultural practices, and more efficient supply chains.

#### 4. **Addressing Global Challenges**

Open Data and Open Science play a critical role in addressing urgent global challenges, such as climate change, global health pandemics, and poverty reduction. When researchers openly share data and collaborate across borders, they can respond more effectively to global crises. For example, during the COVID-19 pandemic, rapid data sharing across countries enabled scientists to track the virus, develop treatments, and create vaccines in record time. Open Science accelerates collective action by providing a foundation for global research cooperation.

The adoption of Open Data and Open Science practices offers transformative benefits to research and society by enhancing collaboration, accelerating discovery, improving public trust in science, and fostering innovation. By making scientific knowledge more accessible and actionable, these practices help bridge the gap between research and societal needs, driving positive economic, social, and environmental outcomes. As Open Science continues to evolve, addressing the associated challenges will be crucial to maximizing its impact and ensuring equitable access for all researchers and communities.

### **11.5 Challenges, Risks, and Ethical Considerations in Open Data and Open Science**

The movement towards Open Data and Open Science presents numerous benefits but also brings a range of challenges, risks, and ethical considerations that need to be carefully addressed. These challenges span technical, cultural, regulatory, and ethical domains, impacting researchers, institutions, and society at large. A thoughtful approach to these issues is essential to foster an open and inclusive research environment while ensuring data integrity, privacy, and responsible use.

### 11.5.1 Challenges in Open Data and Open Science

1. **Data Privacy and Confidentiality** Open Data initiatives often involve sharing information that may include sensitive or personally identifiable data. In fields such as healthcare, social sciences, and education, privacy concerns are particularly pronounced, as data may contain details that could reveal individual identities or sensitive personal information. Researchers must implement robust anonymization techniques to protect participant confidentiality, and in some cases, even anonymized data can be re-identified when combined with other datasets. Balancing transparency with privacy protection requires ongoing attention to data security measures and compliance with privacy regulations like the General Data Protection Regulation (GDPR).
2. **Intellectual Property and Attribution** Open Data and Open Science can blur the lines of intellectual property (IP) rights, raising questions about data ownership and the attribution of research contributions. Researchers may hesitate to share data due to concerns about losing control over their work or not receiving proper credit. Institutions, too, may be concerned about sharing proprietary data that could lead to loss of competitive advantage. Addressing these concerns involves implementing clear licensing models, such as Creative Commons or Open Data Commons, and establishing standards for citing datasets and giving appropriate recognition to data contributors.
3. **Data Interoperability and Standardization** With the vast amount of data generated in various formats and by different disciplines, achieving data interoperability is a major challenge. Researchers face difficulties in integrating datasets across fields due to differences in data structures, units of measurement, and metadata standards. Standardizing data formats and adopting common metadata schemas are essential for making data more compatible and usable across disciplines. However, developing universal standards is complex and requires significant collaboration across research communities and institutions.

### 11.5.2 Risks Associated with Open Data and Open Science

- **Misuse of Data and Misinterpretation** One of the inherent risks of making data open is that it may be misinterpreted or used for unintended purposes. Open datasets can be

accessed by anyone, including individuals with limited knowledge of the data's context, leading to potential misinterpretation. Misuse of data is particularly concerning in sensitive areas such as health, where misinterpretations could influence public opinion or lead to unfounded conclusions. Providing detailed documentation and clear explanations of the data's context, limitations, and intended use can help mitigate these risks.

- **Commercial Exploitation and Loss of Control** Open Data can lead to commercial entities accessing and utilizing publicly funded research data for profit without contributing back to the scientific community. This can be problematic, particularly when corporations gain competitive advantage or financial benefits from data that was intended for public benefit. To address this, some Open Data frameworks implement "fair use" policies or "copyleft" licenses that allow open access but require attribution and restrict purely commercial use without contributing back to the community.
- **Increased Administrative and Compliance Burdens** Meeting the requirements for Open Data sharing often entails a significant administrative burden, as researchers must document and curate datasets for public use, ensure compliance with legal and ethical standards, and maintain data over time. This can be particularly demanding for small research teams or individual researchers who may lack the time or resources for extensive data management. Support from institutions and funding agencies to reduce these burdens can help alleviate the strain on researchers.

### 11.5.3 Ethical Considerations in Open Data and Open Science

- a) **Informed Consent and Participant Autonomy** Ethical research practices require obtaining informed consent from participants, ensuring they understand how their data will be used and shared. In Open Science, this principle becomes more complex, as data may be used by unforeseen parties in ways participants did not anticipate. Researchers must clearly communicate the potential uses of data to participants and seek informed consent specifically for open access. This may include allowing participants to opt-out of certain types of data sharing or placing restrictions on data that is particularly sensitive.
- b) **Equity and Inclusivity** Open Science and Open Data aim to democratize access to knowledge, but disparities in access to technology, resources, and expertise can create inequities. Researchers from wealthier institutions or countries may benefit

disproportionately, while others, particularly in low-resource settings, may be unable to fully engage with or contribute to open data initiatives. To address this, policies and funding initiatives should support open science practices in under-resourced regions, ensuring that Open Science promotes inclusivity rather than exacerbating inequalities.

- c) **Transparency and Accountability** Open Science promotes transparency by allowing researchers to share data and methodologies openly, but it also requires accountability in how data is collected, managed, and shared. Ethical issues may arise if data is manipulated or selectively reported to present biased findings. Researchers and institutions must adhere to strict ethical guidelines and provide clear documentation of research processes to ensure that Open Data and Open Science practices uphold the integrity of the scientific process and foster trust in research outputs.

Challenges, risks, and ethical considerations are integral to the development and practice of Open Data and Open Science. Addressing issues like data privacy, intellectual property, data quality, and infrastructure is crucial for creating an open research environment that is sustainable, ethical, and inclusive. By considering the ethical implications and actively managing risks, researchers and institutions can foster a culture of responsible Open Science that maximizes societal benefits while protecting individuals and communities. As Open Science and Open Data practices evolve, continued dialogue, policy development, and support for ethical research practices will be essential to overcoming these challenges and realizing the full potential of open research.

## **Self-Assessment Questions**

1. How does Open Data contribute to transparency and reproducibility in scientific research?
2. What are the main ethical considerations when sharing sensitive data under Open Science principles?
3. How can institutions address data interoperability challenges to foster effective data sharing in Open Science?

4. What role does technological infrastructure play in the successful implementation of Open Data initiatives?
5. How can Open Data practices be balanced with privacy concerns, especially in fields involving personal or confidential information?

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