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Article

Data Curation Activities in Research Data Repositories: Best Practices

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I N F O

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A B S T R A C T

Although, the massive amount of research data is being generated through modern-day research activities, lack of awareness regarding the documentation, metadata rendering, versioning, file format selection, data cleaning, secure storage options, data deposit templates and making research data easily accessible through research data repositories has resulted in invaluable research data becoming lost or rejected. Proper management and sharing of research data increase the access, impact and efficiency of research activities. Therefore, as a requirement of the government funding agencies' guidelines academic and research institutions have started to establish research data repository platforms. However, to build effective research data repositories with appropriate data curation activities are needed before uploading and publishing data. The current study has been undertaken with the primary objective of presenting the best data curation activities in research data repositories. The study further gives an overview of the software tools and applications available for various data curation activities viz. data cleaning, metadata creation, editing images/ videos, storing data, identifying and validating data files, applications for data curation and data indexing for searches among other core activities. The author further identifies the roles of interdisciplinary librarians and data generators and data providers to perform the best data curation activities in research data repositories. The methodology of the study was guided by content analysis of literature on data curation activities and the role of interdisciplinary librarians in data repositories. Additionally, data about the software and application tools available for data curation was collected through web surveys. The outcome of this study will greatly benefit the key stakeholders in adopting the best practices for data curation practices in research data repositories for enabling research data sharing and reuse. It will help in the development of required skills and competencies to full-fil the role of interdisciplinary librarians in data curation activities.

Keywords: Data Curation, Data Cleaning, Research Data Repositories, Data Librarian, Data Generator

Introduction

Research Data Curation is a process to consider data needs for current and prospective use, focusing on consultation and solutions for improved access, data protection, citation and documentation. Data curation is the "active and on-going management of data through its lifecycle of interest and usefulness to scholarship, science and education" through activities that "enable data discovery and retrieval, maintain quality, add value and provide for re-use over time (Library, 2021)". The best data curation activities are required for enabling research data sharing and reuse through research data repositories. The University of California, library states the process of research data curation includes metadata and documentation, file and folder organization, storage and preservation, version control, the carpentries, data dictionaries, etc. (University of California, 2021). The frequently used terms in research data curation are archive, preservation, back-up, file formats, file sharing, creative commons, agreement, license, metadata, data repositories, non-proprietary file format, persistent identifiers, standards etc. Majorly eight data curation steps are receiving, appraising and selecting, processing, ingesting and storing, describing (with appropriate metadata), facilitating access, preserving and reusing research data.

Librarians are increasingly expected to play a role in data curation, where they can assist researchers with data curation by maintaining and adding value to research data for current and future use. A librarian can take measures to ensure the data is documented, maintained and access through the proper channel. Now a day's librarians are also called as data curators, digital curators, data analysts, data manager, metadata creator etc. according to the role and responsibilities of librarians within data curation practices. Since data curation is an area of inter-disciplinary research and practice, librarians need to develop the knowledge on research lifecycle, data policy, data curation, subject knowledge on managing data etc poses new challenges for librarians. And the process of future data curation is crucial, ICT in organizations and libraries with their preservation skills and repository experience need to work together. Thus, globally library professional associations have developed the education and training frameworks of skills and competencies required for librarians to extend their services in data curation. Librarians can play vital role in the current data curation system with creating policy, data deposit templates, preserving data, administrating infrastructure, the establishment of collaboration network among the data generator to understanding data curation needs and the importance of data management and sharing.

Data Curation

Data curation is the technical function that ensures research datasets are stored and managed in ways that promote ongoing integrity and accessibility. The data curation activity of managing data throughout its lifecycle, appropriately maintaining integrity and authenticity, ensuring that it is properly appraised, selected, securely stored and made accessible, while remaining usable in subsequent technology environments. Understanding of data, as well as research results, data acquisition and manipulation processes must also curated. The research data curation can be performed by the individuals, departments or groups, institutions, communities, disciplines, publishers, national services and third party services (Rusbridge, 2007). Data curation is the significant role that data librarians, data curators, research communities play in appraising the value of data for long-term preservation. The term appraisal refers to the method of identifying digital content's permanent value for long-term preservation. Therefore appraisal in data curation has been closely linked to data repository or data archival policies on research data management (Ogier, Nicholls and Spee, 2017).

Research Data Repository

Data repository (also referred to as a research data repository) is a searchable interfacing entity that can store, manage, maintain and curate Data/ Digital Objects. It manages the location where research data is registered, permanently stored, made accessible and retrievable and curated (Johnston, 2017). Research data repositories are an opportunity for librarians to leverage their expertise in curation, outreach and preservation while strengthening their long-standing relationships with academic departments in order to implement robust repositories that satisfy the needs of their communities (Gerwig, 2017). Treloar and Wilkinson, (2008) argue that research data repositories should be support for easy access to data and other information reliable and consistent forms. Gradually data repositories are increasingly replacing institutional repositories of universities (Gowen, Meier, 2020), because institutional repositories platforms (Eprints, Dspace, Digital Commons, OJS,) also supports data discovery, provenance, access controls, access, identity management, auditing of use, accountability and impact (Alsaad, O'Hara, Carr, 2019; Macgregor, 2020).

The re3data.org-Registry of Research Data Repositories which indexes the research data repositories and offer the services to the researchers, funding organizations, libraries and publishers etc launched 28th May, 2013. It indexes over 2300 + research data repositories from around world and presents data in typologies categories like institutional, disciplinary, multidisciplinary project-specific repositories (Pampel, H., et al., 2013). These repositories are being sponsored by the Governments, funding agencies, academic institutions, professional societies and scholarly publishers (Goben & Sandusky, 2020). FAIRsharing registry is also

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a collection of public research data repositories which provides the standards, databases, policies collection/ recommendations (Suhr, et al., 2020).

The key factors of research data repositories to encourage research data deposit and sharing, make the repository more visually appealing, carry out tailored and continuous advocacy, demonstrate statistics, international interest, get good visibility in Google's search engine results, strong community support for the repository, use of terminology and the language of 'repository-speak', make the deposit process as easy and streamlined as possible, saving time with data entry and avoiding duplication of effort. Support and good practice in managing research data and own IPR and clearing third-party copyright (Gramstadt, 2012). JISC has been encouraged in the creation of several repositories like EThOS (http://www.ethos.ac.uk/), JorumOpen (http://www.jorum.ac.uk/), Depot (http://depot.edina.ac.uk/) etc. in the UK provides the usage services, preservation services andshared infrastructure services (Jacobs, Thomas, & McGregor, 2008).

Literature Review

Data Curation is not a new term, being well used established in art and museum practices (Rusbridge, 2007). However, it is relatively new in relation to research data and was first used in Russian literature (Kosinov, et al., 2019). Research data curation goes beyond data management, as it comprises additional services to preserve and add value within the research lifecycle of the research project and beyond, i.e. by enabling reuse (Partlo, Symons and Carlson, 2015). It adds value and increases the quality of data (Ali, 2019) and as it is active and on-going data management activity throughout the research lifecycle, it enables the data "authentication, archiving, management, preservation, retrieval and representation" (GEO, 2015). The Data Curation Centre (DCC) guide on how to develop RDM services describes the role and responsibilities of individual stakeholders who can deliver RDM service (Jones, Pryor, Whyte, 2013). DCC takes to broad view on data curation and is concerned mainly with sustainability and exit strategy, data resources, access, re-use, preserving and archiving and time scales (Rusbridge, 2007). Curating research data is a part of scholarly record and is recognized by research funders, government agencies and research institutes (Bryant, Lavoie, Malpas, 2017). Digital curation is defined as "maintaining and adding value to a trusted body of digital information for future and current use, specifically, the active management and appraisal of data over the entire lifecycle" (Ogier, Nicholls, Spee, 2017).

A research report by Rusbridge (2007) has identified the top data curation activities as documentation, secure storage, metadata, data visualization, versioning, file format transforms, quality assurance, software registry, contextualize, code review, persistent identifier and file audit for research data. Bielefeld University library has formulated minimal data quality framework "Data Irreproducibility Analyzer (DIRA)" for checking data quality (Schirrwagen, et al., 2019). UiT University library provides the data curation services including data collection, description and organizing, analysis, archiving, haring, re-collection (Ali, 2019).

Nowadays' data processing in the data curation may range from the simple calculations made in a spreadsheet editor, to distributed processes that data using dedicated software and hardware tools (Miksa, Rauber, 2015). The data processing process would be comprehensive guidance, few process are build workflow of curation/ re-usability, keep data which has ability to process, make ownership and allowable uses and make it citable (Rusbridge, 2007). The level of staffing and skills for curating data are the key to research data curation and it made easier for fellow researcher and future collaborators to understanding and more likely to be trusted (Johnston et al., 2017).

A librarian should be required the more skills on subject knowledge, IT knowledge, legal knowledge, ethics, research life cycle awareness including data curation skills, data description and documentation skills (Schmidt, Shearer, 2016). The board skills that a librarian required for RDM implementation are: providing access to data, advocacy and support for managing data and managing data collections additionally librarians role also related to the open access and institutional repositories, collection development, advisory services (copyright, policies, etc.), information literacy, digital curation, digital preservation, digital collections.

Objectives

The objectives of this research study are governed in presenting the best data curation activities in research data repositories for enabling effective research data sharing and reuse. The broad objectives study as follows:

- To identify the best practices of the data curation process in research data repositories
- To examine the interdisciplinary role of librarians, skills and competencies required for providing data curation services
- To highlight the responsibilities of data generators and data providers
- To give an overview of the software and applications tools available for various data curation activities

Methodology

The researchers adopted the qualitative research methodology for the study. It was guided by content analysis of literature published. Scopus citation and bibliographical database and Google Scholar scholarly search engine were

used to find the literature on data curations activities in research data repositories, interdisciplinary librarians' role, skills and competencies required to perform the research data curation activities. Literature we also analyzed on the primary role and responsibilities of data generator/ provider in data curation process to ensure the data access made available through proper channel. A web-survey was undertaken to identify and collect software and application tools available for data curation activities including data repository, data cleaning, metadata schemas, data identifier schemas, controlled vocabularies, creating and editing metadata, editing images or videos, storing data, identifying and validating, data files, transferring data, indexing data for searches, tracking and measuring data, internet web applications etc.

Findings and Discussion

Data Curation Process

The effective implication of data curation process, fundamentally required the professional skills, educations, domain knowledge and IT skills for the data librarian, researcher and other stakeholder (Goben, Raszewski, 2015; Wiljes, Cimiano, 2019). The information professionals, data stewards, data libraries, data curator, IT departments, metadata experts and IR manager are aspiring the skills on data storing, managing, archiving and research data sharing, metadata creation and metadata analysis. The general aspects of the data set when received from researcher are how many files? Total size of the data set, file formats and software need to open the files stage of data (e.g., raw, processed, etc.), is there documentation available, who owns the copyrights for this data? What related metadata standards are commonly used in the data or the field? Data sharing concerns, who are the coauthors of the data? Who funded this research, are there agency requirements for sharing? What are the institutional obligations for data release? Is there potentially patentable information, what licenses, if any would the data be released under? Are there sharing concerns, such as protecting the identity of human subjects? What are the goals for dissemination (e.g., world wide access, researcher only access)? Are there existing repositories in the field that you find and download data from? Long-term value, are there existing publications that make use of or cite the data? Will the data change or be added to over time? How often? Are there alternative file formats recommended for deposit? (e.g., the data curator may recommend a format for preservation purposes.), is the data easy or difficult to reproduce and why? What is the reuse potential of this data? When, if ever, should the data be withdrawn or destroyed? etc. To answering these questions, the potential set of data curation activities are needed. The Figure 1 and Table 1, presents the major data curation process, major activities, interdisciplinary librarians and their required skill set responsibilities of data generator around the data curation.

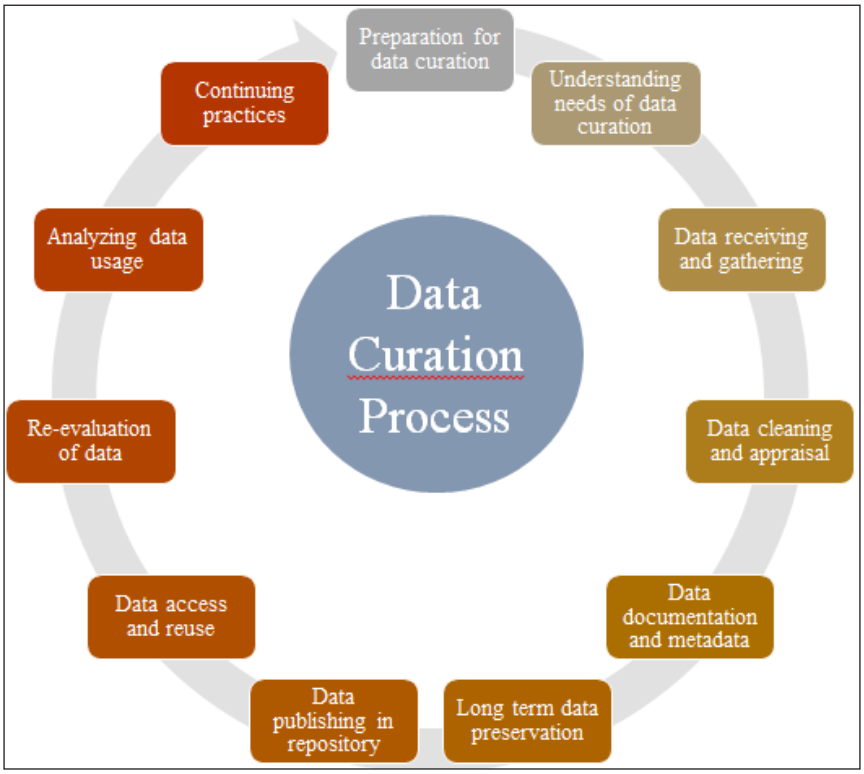

Figure 1.Data Curation Process

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Table 1.Data Curation Process Best Practices, Interdisciplinary Librarian's Role, Skill Set and Responsibilities of Data Generator and Researcher

Data curation process	Major activities	Interdis-ciplinary librarians	Skill Set	Possible responsibilities of data generator
Preparation for data curation	Creating local policies and rules Data curation workflow wizard Building infrastructure and facilities Skills and knowledge for data curations, Assign curation responsibilities to appropriate data curator, Build plan data curation structure in data repository	Head - Data Librarian	Understanding data curation lifecycle, Strategic understanding and influencing skills, Understanding the best practices of data curation, Knowledge of data curation activities, Soft skills, time management	Collaboration with data curator, librarian, metadata specialist, data repository manager and other stakeholder, Part of creating internal data curation policies and rules, workflow, Volunteering for data curation activities
Understanding needs of data curation	Understanding researcher needs, Interviewing data generator, Consulting researcher and data provider, Conceptualize data with data provider, Provide outreach for data repository and data curation		Knowledge on researcher's needs and available datasets, Negotiation and communication skills, Coordination skills across institutions, Ability to communicate and collaborate, Ability to work with data curation team	Conceptualize data with data curators Selection of data to be curated and published, Identification of data generate sources
Data receiving and gathering	Data receiving policy for researcher, Deport rights and license agreement, Facilities for data deposit, Data deposit template, Data gathering with minimum available metadata and documentation, Acknowledgement of data recieving	Data Curator	Knowledge on data deposit template creation, Negotiation skills, Coordination skills across institutions, Familiar with research data, Academic research methods, Ability to handle data complexity and diversity, Skills in computer science	Adhere data deposit policy Deposit data files in required template with data sources, Provide the minimum metadata of data Provide data access rights, Providing Creative Commons license
Data cleaning and appraisal	Understanding of data-stage of data (e.g. raw and processed etc.), size, types, format etc. Data validation and verification Data cleaning from statistical perspective Data classification, Identifying qualitative & quantitative errors, Error repairing, migration, Consider key risk factors	Data Scientist / Data Analysist	Data quality literacy skills, Ability of data cleaning and error detection, Familiarity with research data cleaning tools and application, Familiarity with data analysis and statistical tools, Ability to understand and measure data quality Knowledge on Geospatial data and software, Knowledge about data manipulation technologies	Convert the file formats to non-propriety formats, Data classification by stage of data, size format, types, Minimize the errors, Extend operational support for error repairing, Extend support in data analysis

Data documentation and metadata	Data preparation for preservation formatting, file organization, packaging, Metadata creation, description Structure and descriptive metadata, Disciplinary metadata standards / schema Metadata tools and resources, Identifier schemas, controlled vocabularies, Use of application tools available for data curation	Metadata Specialist / Subject specialist	Familiarity with metadata elements, standards, schemas and tools Skills metadata creations Knowledge of data preparation methods, organization, Knowledge on disciplinary metadata standards particularly research data, Knowledge on subject area Skills on creation of metadata standards according data sets, Familiarity with identifier schemas, controlled vocabularies	Familiar with metadata structure, standards and schema Metadata creation for data, Unique and proper file naming system, File arrangement in hierarchy system, Work with metadata specialists to create appropriate metadata
Long term data preservation	Needs of long-term preservation Selecting dataset for long-term preservation, Rights and permissions, Data storage and security Long-term preservation value, Plan and standardization	Data Manager	Skills on license agreement and copyright Data long-term management skills, Knowledge on policies for preserving data	Valid datasets for long-term preservation, Provide rights and permission for archive Secured authentication for confidential data preservation
Data publishing in repository	Find trusted data repositories, Building open data repository Assists of required data security features, Transfer the processed data files to the repository, Data sharing policies Key components of data publishing	Repository Manager	Technical skills, Software required for the repository, Development and managing data repositories, Knowledge on Server and digital library architecture, Managing data repository daily basis, Team work sills, Maintain and update repository software	Suggest and find discipline data repositories, Allow data sharing and publishing, Ensuring deposited data published in repository, Work with data curator and repository manager to upload dataset into repository
Data access and reuse	Searchable and discoverable facilities, Annotating data for relevant entities, Optimizing data to search engine, Keeping data up to date into mirror repository, Data embargo, authenticate access Monitor data reuse, data citations, Consider post-ingest review techniques, Provide customer support User access guide and		Data promotion skills, Data attention platforms, Search engine optimization, Data repository index in scholarly search engines, Enabling automatic process for indexing, Optimizing data repository content	Make sure published data accessible to users, Embargoed access, Provide request base confidential data access, Monitoring data citation received, Promotion of data access, Searching/ browsing / downloading, Share recommended citations and contribute citations data

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Re-evaluation of data	Evaluate or view research data, Withdrawal of data from repository, Ensuring future usability, Enabling data citations, Regular data up-to-date	Data Curator	Evaluating value of dataSkills to identify out dated data	Evaluate the data published in data repository Ensure long-term data quality
Analyzing data usage	Monitor the usage, downloads, view, citations, Managing descriptive statistics of data usage, Data usage tracking, Data external users, researcher, funder, agencies	Data Manager	Usage analysis and review skills, Enabling data usage tools skills, Enabling Almetrics Improve access experience, Skills in metrics	Disseminate of data sets, Social networking /sharing/tagging, Data citing
Continuing practices	Educating researchers, Providing workshops for data analysis tools, Outreach program for data curators and institute community Adopting best practices of data curations Learning future technologies	Head - Data Librarian	Data literacy skills, Event organizational skills, Tutorial and training module development skill, Networking skills, Subject-experts	Taking place of workshops and training program, Identify the best practices in data curation

Research Data Librarians: Interdisciplinary Roles and Competencies

Research data curation process is typically defined as a set of activities that required to involved multi skilled information professionals, therefore it described the data curation planning, data acquisitions, data cleaning, analysis, data publishing and long-term preservation etc. Therefore, interdisciplinary skilled information professional required to impalement best practices in the data curation activities. As mentioned in Table 1, the major information professional are like data librarian, curation librarian, digital collections curator, digital content strategist, data management consultant, data curation librarian, digital projects designer, repository specialist, technical analyst, repository coordinator, data curation specialist, repository coordinator, metadata specialist, system administrator, software developer.

The worthy skillset and competencies are required for such interdisciplinary librarians to develop the best practices in data curation activities in the research data repository. The major skills including Understanding of data curation lifecycle, Familiarity with research data (e.g., Ability to handle data complexity and diversity), Collection management skill, Metadata knowledge particularly for research data Technical details of repository software, server and its architecture Understanding disciplinary metadata, workflow and knowledge on academic research helps them to build or plan data curation structure in their data repository, consult with data providers and connect them to metadata specialists or repository managers, facilitate communication across different entities, outreach and educate campus community, work with data providers to help add metadata and upload data into data repository, helps data provider to create appropriate metadata for their dataset and provide the support researcher and help in management of data repositories.

Responsibilities of Data Generator

Data generators and also called data providers are primary stakeholders of the research data curation practices in institutes. The major data generator of the institute includes faculty members, postdoc researchers, researchers, graduate students, undergraduate students and other afflicted researchers who have been involved in creating research data from a sampled data sources in both qualitative and quantitative studies. Therefore data generator has huge role to play in the research establishment of best practices in the research data curation. Data generator have to collaboratively work with data librarian, data curator, data scientist, metadata specialist, data manager and repository manger to make sure research data published through research data repositories and enabling data sharing reuse.

Gradually, researchers have been managing and organizing the data created to easily retrieving when it is required. But, for publishing research in a repository the researcher has to work with the data curation team to properly preserve

research data. Being a data owner, the researcher has to help metadata specialist to define the metadata elements of the data generated by them. The various types of the data created like data (e.g., raw data), text documents (e.g., word, pdf, latex, txt), spreadsheets (e.g., excel), slides (e.g., PowerPoint), audios, audio-visuals, images, laboratory notes, statistical data, databases (e.g., access, MySQL) would require different metadata elements to be used to define the data. As mentioned above in Table 1, along with the metadata creations, the data generator has a key role to play with Head-Data Librarian for creating internal data curation policies and rules, workflow, conducting outreach activities and identifying the best practices in data curation. The data generator has to further deposit the research data in a template made by the data curator, transfer data access rights, convert file formats to nonproprietary formats, data classification, error minimizing, data analysis support, browsing/ downloading, etc. The data generator also helps in promoting the research data published through a research data repository while they share research data through social networking sites, scholarly search engines, data repository directories, to increase the data citations and widely disseminate the research data across the world. The data generator can also evaluate the data published in data repository to ensure the long-term data quality and up-to-date data available for user access. The data generator hold the rights to share the confidential data to users, therefore users have to make formal request to the data generator through a data repository to avail the confidential data. Table 1 gives and overview of the key roles of the data generator in each stage of the data curation.

Software and Application Tools for Data Curation

Data curation process is set of technical and non-technical activities, it requires various software application tools to implement data curation process in the research data repository. There are many open source and property software application tools available in the each stage of data curation process. Table 2, presents the major list of application software available for data curation in a research data repository. A data librarian can use the best practice template to prepare draft of the data curation process, and online survey/ interview tools can be used to understanding needs of data curation. A data deposit template helps in gathering research data from the data generators with required additional details. However, members of a data curation team should have skills to use the below software application tools for data curation activities.

Table 2.Software and Application Tools for Data Curation in Research Data Repository

Types	Software and Application Tools
Data Repository Software	Bepress Digital Commons, DSpace, Hydra, Dataverse, HUBzero, Aubrey, SobekCM, EPrints, CKAN,
Metadata Schemas	Dublin Core (DC), Qualified DC, DataCite Metadata, MODS, METS, PREMIS, MIX, EAD, Darwin Core, Ecological Metadata Language (EML), Visual Resources Association (VRA Core), DDI, CIF (Crystallographic Information Framework), ABCD (Access to Biological Collection Data), AgMES (Agricultural Metadata Element Set), AVM (Astronomy Visualization Metadata), PREMIS
Metadata Schemas used in Supplementary Space	Darwin Core, EML, DDI, TEI, FGDC, ISO 19115 Geographical Metadata (ISO 19115),
Identifier Schemas	DataCite, DOI, Handle, ARK, HTTP URI, Permanent local URL,
Controlled Vocabularies	DC Contolled Vocabularies, Library of Congress Subject Headings (LCSH), Medical Subject Headings (MeSH), Faceted Application of Subject Terminology (FAST),Only with Hydra: DC RDF Ontology, FOAF, RDF Schema, Astronomy Thesaurus, NASA Thesaurus, Art & Architecture Thesaurus
Creating and Editing Metadata	Microsoft Word, Microsoft Excel, Text Editor (WordPad, Notepad++), Oxygen XML Editor, Morpho (Ecology Metadata Editor), Nesstar
Editing Images or Videos	SnagIt Photoshop for images, Handbreak for audiovisual, image
Cleaning Data	Open Refine, Data Cleaner.
Storing Data	Dropbox, Google Drive
Identifying and Validating Data Files	DROID, PRONOM, Git for version control, FITS for ®le characterization
Transferring Data	BagIt

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Indexing Data for Searches	Apache Solar
Tracking and Measuring Data	Altmetric
Internet web applications	EZID service, Google refine

Conclusion

Data curation activity of managing and promoting the use of research data from its point of creation ensures its usage for contemporary purpose, helps in for the discovery and re-use of data. The best practices of data curation process is like a cycle begins from preparation, understanding the needs and arrangement of infrastructure prerequisite, data receiving, cleaning, documentation, metadata creation, preservation, data publishing, data access, evaluate the usage and data citations. Disciplinary metadata creation is a major activity of the data librarians along with data repository development which helps in publishing data for future reuse. Librarian's has to develop the interdisciplinary and IT oriented skills and competencies along with academic research knowledge to perform best data curation practices. The interdisciplinary skills help them to curate data, metadata creations, description and documentations. IT oriented competencies serve to develop the user friendly data repositories and data cleaning. Academic research knowledge helps librarians to understand the research activities and need of the data curation assistance by data generators. Appropriate use of software and application tools facilitate in the development and practice of data curation. The training and continuing education of data curation skills in is not limited only to library and information professionals, its scope has been expanded to professionals form the computer science domain too. This study benefits the key data curation stakeholders in understanding the best practices for data curation by identifying the key stages of data curation, core data curation activities, software and application tools available, the role and responsibilities of each stakeholder including data librarians and researchers

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