FMDB *Transactions on Sustainable Finance and Data Science*

Advancing Research Ecosystems Through Library-Led Open Science Advocacy and Data Stewardship

Rajani Sharma[1,*]

[1]Department of Library, Government College, Guna, Madhya Pradesh, India.
rajanimishra123@gmail.com[1]

Abstract: The modern research ecosystem is being revolutionised to achieve greater transparency and reproducibility. This paper discusses this shift, in which academic libraries are emerging as key players in driving this change through systematic advocacy and data stewardship. By making the library a central point of focus in Open Science, the institutions will be able to bridge the gap between complex information management requirements and researchers' compliance. The paper uses a wide range of datasets comprising 405 examples of research activities, collected from institutional archives and faculty census data. This data was analysed using specialised tools such as computational modelling software, statistical analysis packages and metadata mapping applications to measure the impact of library interventions. The findings suggest that proactive library use may improve research exposure and data sustainability. More cross-disciplinary cooperation affects the FAIR (Findable, Accessible, Interoperable, and Reusable) principles in large libraries' adoption of all three workshop types. This paper provides an overview of the strategic implementation of these services and a roadmap for how libraries can move from passive resource providers to active players in the scientific process, helping create a fairer and more open research process.

Keywords: Open Science; Data Stewardship; Research Ecosystems; Library Advocacy; Digital Repositories; Information Management; Library Interventions; Transparency and Reproducibility.

Received on: 26/06/2025, **Revised on:** 17/08/2025, **Accepted on:** 02/11/2025, **Published on:** 07/03/2026

Journal Homepage: https://www.fmdbpub.com/user/journals/details/FTSFDS

DOI: https://doi.org/10.69888/FTSFDS.2026.000624

Cite as: R. Sharma, "Advancing Research Ecosystems Through Library-Led Open Science Advocacy and Data Stewardship," *FMDB Transactions on Sustainable Finance and Data Science*, vol. 1, no. 1, pp. 52–64, 2026.

1. Introduction

The scholarly communication revolution over the past few decades has radically altered the functions of an academic library, as studies on transformation by Wilkinson et al. [1] have shown. Libraries, which were no longer considered the most suitable locations to store printed knowledge, are now being identified as active players in the research life cycle, as institutions have evolved, as examined by scholars De Filippo et al. [4]. The increasing speed of digital technologies, global connectivity, and data-driven research practices have changed knowledge creation, sharing, and storage, as evidenced by studies of digital scholarship Méndez [7]. Open Science has taken the form of a paradigm that informs this environment and gives precedence to transparency, accessibility, collaboration and accountability, as envisaged in the openness models provided by policy analysts. Libraries play the most significant role in this movement, not only as sources of access but also as advocates of

[*]Corresponding author.

responsible data handling and equitable involvement in research, as highlighted in governance research conducted by professionals Pinheiro et al. [9].

The move towards openness is driven by several factors, including public demand for transparency in government-funded research, the rising cost of journal subscriptions, and the increasing complexity of research data management, as highlighted in economic and policy assessments by researchers De Filippo et al. [5]. In response to such changes, libraries organise themselves, their policies and their educational services to accommodate researchers throughout the scholarly process, an aspect of adaptation strategies explored in higher education research by Szomszor and Adie [11]. They are not just involved in publication access but also in metadata standards, repository management, compliance monitoring and digital literacy training, which were adopted in institutional infrastructure projects created by Costas et al. [14]. This introduction provides the context for the research on the role of libraries in advocating Open Science, data stewardship, institutional coordination, and digital equity, which aligns with the integrative models suggested by modern scholarship Wouters et al. [3]. Together, the dimensions illustrate the evolution of modern libraries into strategic research partners who trust in the sustenance of an open, transparent and inclusive global knowledge system that promotes collaborative dissemination principles, as expressed in global research evaluation conducted by professionals Paul-Hus et al. [13].

The transformation of academic communication has taken a drastic turn with the transition to the digital communication ecosystem, as examined in communication system studies by scholars Fressoli and De Filippo [6]. In the past centuries, the dissemination of information was slow, comprising printed monographs and subscription-based journals, and was accessible only in institutions with adequate funding, as documented in the historical analysis of scholarly publishing by researchers Pelacho et al. [8]. Libraries were also used as repositories of such collections of materials and as sites for the accumulation and documentation of scholarly work on a local scale, based on preservation traditions examined in archival research conducted by specialists. The electronic revolution transformed this organisation by establishing electronic journals, an internet database and real-time global distribution, as one of the studies of technological transformation researched by scholars Bornmann et al. [12]. As publishing went digital, there was an increase in issues, as determined by structural access research conducted by Haustein et al. [15]. The subscription charges were too expensive, creating a financial liability for both academic institutions, and access to research was unequally limited, as evidenced by cost-evaluation studies conducted by scholars De Filippo et al. [5]. The result of this unequal economic situation was the birth of the Open Access movement, which advocates free access to scholarly publications on the internet, as outlined in reform-oriented models developed by Wilsdon et al. [2].

Libraries became actively involved in making breakthrough deals with publishers and setting up institutional repositories to which research products would be housed, which were evaluated as models of negotiation discussed in governance studies by researchers De Filippo et al. [4]. It also altered expectations regarding research transparency, as covered in reproducibility assessments by scholars Pinheiro et al. [9]. Digital technologies enabled questioning of methodologies and data, and enabled a wider review of works, as demonstrated in the impact and visibility analyses conducted by the researchers Bornmann et al. [12]. Scholars began to identify strong relationships between visibility and impact, and between online accessibility and citation behaviour, as indicated by citation-behaviour studies. Their consequences saw libraries expand their role beyond collection management to include digital archiving, licensing and policy formulation in line with modernisation strategies pursued in institutional research conducted by scholars Szomszor and Adie [11]. This is the more general cultural transformation, the transition towards openness and immediacy in academic communication, which strengthens openness paradigms expressed in international scholarship carried out by experts, Wouters et al. [3]. The libraries are part of an international network of scholarship in which speed, accessibility, and collaboration are attributes of scholarly relevance, as examined in collaborative studies of ecosystems. Their adaptation mechanisms ensure the continuity of traditional preservation values alongside new dissemination requirements, as supported by scholars' sustainability considerations.

1.1. Open Science Advocacy

Open Science promotion in academic libraries is a holistic approach to transparency in the research process, as outlined in the multidimensional openness model developed in scholarly circles. Although Open Access publishing remains a key element, advocacy also extends to open data, open methodologies, open educational resources, open-source software, and open peer review practices, organised around integrative research models proposed by scholars Wouters et al. [3]. This larger paradigm emphasises cooperation and reproducibility as the two principles of scientific advancement, which have been the focus of integrity-based research conducted by scholars Pinheiro et al. [9]. In this landscape, librarians play the role of facilitators and educators, as documented in the academic support literature by experts Fressoli and De Filippo [6]. They educate researchers on licensing opportunities, preprint dissemination, and how to share responsibility for disseminating responsible data, as part of the educational outreach strategy implemented by institutional programs through the scholars Szomszor and Adie. The advocacy work underscores that publicly funded research has a social obligation to be accessible to the citizenry and, as such, is accountability-oriented policy research conducted by accountable analysts. Libraries can help establish trust between society

and academia by promoting the early dissemination of results and open records of research procedures, which align with the models of trust-building discussed in the literature on collaborative governance.

The institutional engagement is also associated with Open Science advocacy and has been studied within the frameworks of coordination developed by scholars Sastrón-Toledo and De Filippo [10]. The libraries and research offices cooperate with the financing agencies to streamline local practices in line with national and international requirements. They are part of the governance alignment framework, which has been examined in policy-based research by scholars Costas et al. [14]. They guide scholars through compliance aspects and create data management plans that bring transparency to the open principles demonstrated in stewardship strategies, as reported in preservation studies by professionals Bornmann et al. [12]. This framed assistance eliminates doubt and boosts researchers' confidence in embracing open practices that strengthen the implementation structures assessed in organisational research conducted by scholars Haustein et al. [15]. Libraries encourage a culture of openness by developing infrastructure and providing long-term educational outreach that embeds openness in research norms, as described in cultural transformation studies by Wilkinson et al. [1]. By doing so, advocacy becomes institutional rather than promotional, enabling the message to be more robust in building scientific integrity and accelerating innovation, as evidenced by cumulative research reviews Pelacho et al. [8].

1.2. The Only Imperative of Data Stewardship

Data stewardship is the organised accountability for the extended responsibility and endurance of research data, and for its availability, as described in information governance research conducted by scholars Pinheiro et al. [9]. In modern research settings with large datasets and sophisticated analytical applications, good stewardship means that useful information is not wasted at the end of the life of specific projects, as explored in sustainability studies. The lack of systematic control will increase the risk of data fragmentation, corruption, or non-availability, as reported in risk-management studies [11]. The libraries have become significant players in addressing these issues, serving as preservation leadership models informed by archival studies conducted by scholars Sastrón-Toledo and De Filippo [10]. Their knowledge of metadata standards, classification systems, and preservation frameworks transfers automatically to digital data contexts, as observed in studies of repository management. It is through this that libraries facilitate researchers in developing data management plans, which enhance documentation structure, secure storage, and standard formatting, as is often done in documentation frameworks suggested by Bornmann et al. [12] in compliance research. It is more discoverable and easier to reuse in the future, which is the focus of the reuse-impact analyses conducted by researcher Méndez [7].

Stewardship is not limited to technical storage solutions as identified in ethical governance oversight examinations conducted by academicians De Filippo et al. [5]. It includes ethical controls for sensitive data, privacy and intellectual property rights. It is consistent with the principles of responsible data management, as reflected in the regulatory research conducted by Wouters et al. [3]. Libraries can help researchers choose the right license and anonymisation methods so that openness aligns with legal and ethical requirements, and specialists can conduct these compliance strategies, as this confirms. This is a healthy balance that safeguards the research subjects without being unethical and keeps the research open, allowing transparency, which is the focus of the ethical stewardship models investigated by academics De Filippo et al. [4]. The cumulative scientific knowledge of stewardship has long-term value, as it leads to replication and meta-analysis research by scholars Bornmann et al. [12]. High-quality datasets can be used to conduct replication studies, meta-analyses, and cross-disciplinary work, which supports the principles of reproducibility investigated in scientific evaluation studies. They convert individual research findings into reusable academic resources, aligning with sustainability models developed by professionals in the field of digital preservation scholarship. By integrating stewardship behaviours into institutional research processes, libraries protect the integrity and vitality of scientific inquiry and strengthen the belief that data will continue to be a shared resource for discovery in the future, as described in cumulative knowledge systems studies by Wilkinson et al. [1].

1.3. Institutional Synergy and Research Support

Open Science progress is based on institutional cooperation, which was analysed within the framework of organisational integration research by Wouters et al. [3]. Universities are interrelated administrative, technical, and academic systems with distinct areas of expertise, reflecting the coordination of governance that researchers study by De Filippo et al. [4]. Libraries fit well into this network, as they serve as the link between researchers, information technology departments, and institutional leadership, as emphasised in the institutional facilitation studies by scholars Fressoli and De Filippo [6]. Their credibility, built over a long period, allows them to close communication gaps and harmonise divergent priorities, in line with collaborative alignment models formulated by policy analysts. Institutional synergy is achieved through shared infrastructure projects, such as repository platforms, research information systems, and compliance monitoring tools, as shown in academic research on infrastructure development. In digital systems studies by scholars Costas et al. [14], libraries team up with IT departments to maintain secure storage systems and ensure interoperability across different platforms. At the same time, they will discuss data

policies with the university administration to ensure they align with the overall strategic goals, such as research visibility and global ranking metrics, as investigated in performance-oriented institutional research by Bornmann et al. [12].

This integrative position makes the researcher confident, as supported by academic workflow reviews conducted by scholars Szomszor and Adie [11]. When researchers see unifying institutional backing, open practices will be less tedious, aligning with studies on organisational behaviour. Libraries ensure there is no ambiguity regarding repository submissions, copyright negotiation, and funder mandates, thereby reducing administrative uncertainty, as highlighted in compliance support research by De Filippo et al. [5]. The joint policy formulation also enhances departmental consistency, which is part of the coordination mechanisms discussed in governance research studies by Pinheiro et al. [9]. Libraries can demonstrate that they are indispensable research infrastructures, not support services, through collaborative efforts, as described in strategic institutional analyses by academics. The institutional synergy ensures that Open Science initiatives are institutionalised within the governance framework and supported by funding paradigms aligned with the frameworks discussed in the research on higher education. This convergence enhances the research ecosystem, creating a space where transparency and collaboration operate within the framework of shared institutional commitment, as supported by studies of global research networks conducted by experts Paul-Hus et al. [13].

1.4. Bridging the Digital Divide in Practical Work

Unequal access to research tools and information resources is a growing issue across the global academic community, as evidenced by international studies on access disparities. Better-funded institutions have extensive computational infrastructure, subscription databases, and advanced training opportunities. In contrast, resource-limited settings face structural constraints, as examined in comparative infrastructure analyses conducted by researchers Fressoli and De Filippo [6]. Libraries are effective at minimising these inequalities by facilitating equal access to digital information and technological literacy, which aligns with inclusive access models developed by policy analysts. The distributed high-performance computing resources, the licensing of research software, and the wide range of digital collections ensure that researchers work in a more balanced environment, as evidenced by the models of resource sharing studied by scholars Sastrón-Toledo and De Filippo [10]. Libraries bargain for collective agreements and consortium memberships that expand access beyond departmental budgets, products of cooperative economic strategies learned by scholars De Filippo et al. [5]. The collaborative approach eliminates financial constraints and encourages everyone to engage in the academic debate, a practice endorsed in equal governance studies by researchers De Filippo et al. [4].

In addition to infrastructure, libraries enhance digital literacy, as captured in scholarly research on educational capacity-building. Data analysis, basic coding, and information evaluation training programs provide researchers with the competencies needed in the modern field of scholarship, compatible with the skills-development paradigm studied by researchers Bornmann et al. [12]. This can be achieved by having early-career researchers and other students with diverse backgrounds participate in such undertakings with confidence and subsequently being integrated into global research networks, as explored in participation-enhancement research conducted by professionals Pinheiro et al. [9]. The problem of bridging the digital divide aligns with the principles of Open Science, as emphasised in studies on openness advocacy by researchers Wouters et al. [3]. Accessibility extends beyond open publications to encompass competencies, equipment, mentorship structures and inclusive access paradigms, as addressed in the institutional development literature by scholars Costas et al. [14]. By opening access to information and expertise, libraries promote a condition in which research participation is based on intellectual interest rather than institutional prosperity, and this idea of ethical inclusivity is solidified by ethical inclusion theses formulated in academic communication studies. This broad thinking fosters the ethical aspect of Open Science. It increases the diversity of voices used in the production of knowledge globally, as endorsed in cumulative diversity assessments conducted by professionals Haustein et al. [15].

2. Review of Literature

The existing literature on Open Science and library-led data stewardship presents a complex map of research across philosophical, technical, and policy-based approaches, as explored in the integrative studies by Wilkinson et al. [1]. Ranging scholarly discourses always create openness as a paradigm shift in the production, critique, and sharing of knowledge, which embodies conceptual syntheses that scholars have been developing. Initial theoretical underpinnings focused on collaborative verification of scientific assertions, and modern-day research extends this perspective to consider the lifecycle of research, including data creation, maintenance, and reuse, as expressed in lifecycle-based research by scholars Méndez [7]. A large part of the literature explores the technical basis of discoverability, mostly metadata standards and repository interoperability, which are studied in digital infrastructure research by experts Wilsdon et al. [2]. Researchers note that, unless organised into frameworks of description, datasets will be hidden and underused, as evidenced by discoverability tests. As a result, librarianship experience has been reclaimed in the context of digital scholarship, in line with the researchers' appraisal of

professional roles. The other thematic cluster concerns cultural and institutional barriers to data sharing, as identified in empirical research on organisations.

The issues raised in behavioural studies by experts include intellectual competition, workload, and privacy, as cited in empirical research by Costas et al. [14]. The insights have highlighted the roles of educational interventions and supporting infrastructure in promoting open practices, aligning with change-management studies by Wouters et al. [3]. The literature reveals that library workshops and formal training programs are among the most common agents of behaviour change among researchers, as shown in analyses of interventions conducted by scholars Paul-Hus et al. [13]. World policy studies also reveal that funding requirements can shape institutional change toward Open Access and data-sharing standards, as reported in comparative governance studies. Regional comparative studies indicate that, despite differences in implementation strategies, transparency and accessibility are universal goals across national contexts. It is also discussed in emerging scholarship, especially concerning technological integration, including artificial intelligence and decentralised systems. It examines the efficiency gains they achieve, as well as the ethical concerns that arise in innovation-oriented studies conducted by scholars Sastrón-Toledo and De Filippo [10]. All this literature situates the recent shift in libraries' role as strategic agents of openness within an aspectual context that reinforces the view of structural transformation perspectives developed within modern scholarship.

2.1. Conceptual Frameworks of Openness

The theoretical support for Open Science is based on traditional philosophical thinking that has focused on producing knowledge within a community, as Wilkinson et al. [1] discovered in historical studies. Transparency, peer review, and collective investigation were highlighted as conditions for advancing the classical standards of science and normative studies, as proposed by researchers De Filippo et al. [4]. In modern paradigms, these values are reconstrued in digital contexts, where openness is not restricted to publications but extends to datasets, computer code, and method transparency, as theorised in digital adaptation research by scholars Wilsdon et al. [2]. The term openness is explained by scholars not only as an ethical duty but also as an innovation driver, according to the ethics-based innovation research of Pinheiro et al. [9]. By having research outputs available, subsequent research can avoid duplicating the effort of its predecessors and build on prior research, as observed in cumulative knowledge studies. The literature emphasises the effect of open frameworks in minimising transactional barriers arising from licensing constraints and paywalls, as analysed in access-economics studies by researchers De Filippo et al. [5]. This accessibility enhances interdisciplinary cooperation and forms of cumulative knowledge building, which aligns with the collaboration analysis that scholars have formulated.

The change in academic prestige systems is also discussed theoretically in the form of metric reform studies by researchers Szomszor and Adie [11]. Conventional metrics that focus on journal impact factors and citation counts tend to underestimate data sharing and collaborative work, as discussed in evaluation critique literature by specialists Costas et al. [14]. New models suggest other indicators, including dataset citations, repository downloads, and open peer review contributions, as reported in assessment innovation research. These changing assessment mechanisms are indicative of efforts to align academic motivations with open ideals, and of the strengthening of alignment models examined in the scholarly literature on governance. Frameworks also incorporate concepts of social responsibility, especially in government-funded research, as highlighted in accountability-based studies by scholars Sastrón-Toledo and De Filippo [10]. Transparency strengthens public faith and allows society access to the findings of science, consistent with the conclusions of the public engagement process. In this conceptual terrain, libraries appear to be operating anchors, translating philosophical commitments into serviceable policies and services, as described in institutional translation research by authorities Paul-Hus et al. [13]. The literature does not simply present openness as a technical change but as a structural shift in scholarly values, which can be analysed through Haustein et al.'s [15] paradigm-shift studies.

2.2. The Importance of Metadata to Discovery

Metadata has been in the middle stage of the discourse on digital scholarship and data stewardship, as reiterated in studies in information science. It serves as formal descriptive data that helps identify, interpret, and reuse datasets, which is the goal of technical documentation studies in which specialists work. Without established metadata standards, research data will remain inaccessible, even when stored online, as found in accessibility tests conducted by researchers De Filippo et al. [5]. The metadata quality has consistently been identified as a key factor in discoverability in the literature, as evidenced by retrieval performance studies. Academic data mining refers to the use of descriptive, structural, and administrative metadata to enhance the usability of datasets, organised into classification systems created by academics Szomszor and Adie [11]. Search and retrieval are supported by descriptive metadata, which provides insight into how files are related; structural metadata, which records rights and preservation; and expert engagement in metadata schema studies [14]. The successful assimilation of these factors promotes long-term Sustainability, in line with studies by scholars Wouters et al. [3]. Knowledge in librarianship of cataloguing and classification systems is readily translated into digital metadata management, as demonstrated by the professional competency research of Wilkinson et al. [1].

Scholarly literature identifies librarians as experts who can develop controlled vocabularies and use international standards, including Dublin Core and discipline-specific schemas, as reported in studies on the implementation of standards by professionals, Fressoli and De Filippo [6]. Empirical research on this issue showed that datasets with standardised metadata are cited more frequently and used in secondary analyses more extensively; this was demonstrated in the impact assessment conducted by the scholarly researchers Pelacho et al. [8]. Metadata also facilitates reproducibility, as mentioned in verification studies by researchers Bornmann et al. [12]. Variables, methodologies, and file structures are well documented, minimising ambiguity and making verification of findings easier, which aligns with a transparency model examined in governance research by Sastrón-Toledo and De Filippo [10]. In the literature, metadata has become a technical tool and a strategic resource for implementing Open Science, as evidenced in integrative digital scholarship analyses developed by professionals Paul-Hus et al. [13]. Its creation is an amalgamation of conventional information science tenets with current digital research requirements, validating the importance of libraries in providing meaningful data discovery, as corroborated by structural evolution research by Haustein et al. [15].

2.3. Barriers to Data Sharing and Reuse

Even though the advantages of Open Science are well understood, the literature consistently identifies major obstacles to implementing data-sharing behaviour, as summarised in adoption studies by researchers De Filippo et al. [4]. Among the most commonly cited issues is the fear of being scooped, in which researchers worry that publicly available data can be used by others to publish discoveries before the original researchers have exhausted what they can do with it, as reported in the competitive risk analysis conducted by the authority Méndez [7]. This attitude towards competitive risk is more pronounced in the fast-paced world of science, where timely publication is directly linked to professional growth, as documented in research on disciplinary behaviour. The other obstacle is the additional time and effort required to present the data to the public, as discussed in the researchers' workload impact studies by Szomszor and Adie [11]. Data curation requires formal records, metadata development, the anonymisation of sensitive data, and structuring to meet repository standards, as outlined in procedural reviews as conducted by Costas et al. [14]. These activities are seen by many researchers as a burden, particularly when institutions' reward systems are based on journal publication rather than data contribution, as discussed in incentive-structure studies. There is also no formal encouragement to publish datasets proactively, which hinders even proactive sharing, the focus of recognition-gap research conducted by Pelacho et al. [8].

The privacy and ethical issues are also identified as determinants of researcher hesitation, as addressed in compliance research by De Filippo et al. [5]. Research papers involving human subjects must adhere to consent agreements and data protection laws as stipulated in the regulatory analysis conducted by professionals Pinheiro et al. [9]. Perceived legal ambiguity in legal responsibilities can lead to at least a reluctance to share even non-sensitive datasets, as studies of legal ambiguity have shown by Sastrón-Toledo and De Filippo [10]. Also, there are technical issues, such as a lack of storage facilities and insufficient understanding of licensing requirements, which make the decision-making process difficult, as noted in the infrastructure assessment conducted by scholars Wilsdon et al. [2]. According to the literature, these barriers can only be overcome through structural and cultural considerations, a point lamented in change-management research. Libraries have been responsive to this by creating user-friendly depository platforms, providing licensing advice, and encouraging users of datasets to follow citation practices aligned with service innovation studies conducted by scholars Bornmann et al. [12]. The combination of psychological, procedural and institutional barriers can help eliminate resistance and create a culture of responsible data sharing that is sustainable because libraries can help create conditions that can be reinforced in long-term adoption analyses by Haustein et al. [15].

2.4. Effects of Library Workshops and Training

Educational interventions organised by libraries are a recurrent motif in research on the implementation of Open Science, as seen in studies on the impact of the educational component conducted by researchers Fressoli and De Filippo [6]. The literature shows that structured data management, reproducibility, and digital preservation workshops have significant competency effects on researchers, as evidenced by a skill development analysis conducted by research experts Wilkinson et al. [1]. A primary benefit of exposure to systematic research practices at an early stage is the focus on documentation and transparency that graduate students and early-career scholars enjoy, as indicated by studies on professional formation. The practical experience of the tools described, such as version control systems, collaborative coding platforms, and data cleaning software, encourages organised workflows, which are consistent with the workflow optimisation studies performed by Szomszor and Adie [11]. Research has shown that participants in such workshops exhibit better file management practices and greater adherence to documentation norms, as indicated by behavioural outcome tests. Such a change in behaviour helps make research team collaboration more reproducible and collaborative, as it has been studied in the literature on collaboration efficiency. In addition to learning technical skills, workshops are gateways to engagement, as examined in institutional engagement studies by scholars De Filippo et al. [4].

When researchers who attended introductory sessions seek more advanced help, such as repository submissions and metadata creation, they tend to visit librarians more frequently with such requests, as reported in service-usage studies by Pinheiro et al. [9]. This long-term interaction reinforces relationships between institutions and integrates libraries more deeply into the research process, indicating lifecycle integration research carried out by professionals Bornmann et al. [12]. According to longitudinal measures, early training interventions are associated with sustained use of Open Science principles, as indicated by longitudinal impact studies by researchers Pelacho et al. [8]. Depending on the transparency they internalise in early-career situations, researchers are likely to carry over their habits into subsequent papers, consistent with professional habit-formation studies by Sastrón-Toledo and De Filippo [10]. Therefore, library-based education is not only immediate skill-building but also cultural transformation, as described in scholars' findings on cultural change. Integrating systematic training in graduate programs and professional development increases long-term research standards and institutional investments in openness and accountability by establishing research norms that libraries cultivate as part of their governance-strengthening efforts, according to some experts in governance-strengthening studies [15].

2.5. Open Access Policies Around the World

International research policy dynamics have led to increased institutionalisation of the principles of Open science, as observed by international policy analysts. Increasingly, funding agencies across regions require that published works and other datasets derived from sponsored research be made publicly available, as reported in mandate evaluation studies conducted by scholars Fressoli and De Filippo [6]. A review of the literature on these mandates shows that there has been a quantifiable increase in institutional repositories and compliance assignment systems resulting from policy enforcement, as documented in studies on infrastructure growth. Comparative studies indicate differences in implementation strategies, as observed in cross-national governance studies by the scholars Pelacho et al. [8]. Countries implement centralised national repository platforms, whereas others build decentralised institutional infrastructures, which are the subject of comparative studies by experts on systems. Although these structural variations exist, the overall goal is somewhat the same, i.e., better transparency, accountability and public involvement in scientific research, which is also a key point in transparency-oriented assessments by researchers Wouters et al. [3]. Openness, guaranteed by open-access requirements in grant agreements, is a formal expectation of research rather than an elective practice, as formalised in policy studies by scholars Szomszor and Adie [11].

The role of libraries in the centre of this policy's operations is a common phenomenon discussed in research studies on institutional facilitation by Wilkinson et al. [1]. They help researchers understand funder expectations, choose suitable licenses and submit outputs within required timeframes, as shown in compliance-assistance studies by Pinheiro et al. [9]. The compliance monitoring system typically operates on a library-run platform, which reinforces the strategic location of the policy and practice within governance implementation, as noted by Bornmann et al. [12]. The impact of international efforts on harmonised open-access strategies is also addressed in the recent literature, as observed in global harmonisation studies [13]. Such inter-organisational movements promote the harmonisation of standards and cross-border repository interoperability, as reported in interoperability research studies by Costas et al. [14]. As mandates globalise, libraries have been continually updating their infrastructure and advisory services to align with evolving regulations, while academicians examine the foundations of adaptive governance. This policy impetus entrenches openness as a hallmark of modern scholarly communication. It places libraries as key players in open research publication, as established in structural transformation scholarship practised by academics Haustein et al. [15].

3. Methodology

The research approach to this study uses a holistic mixed-methodology developed to provide an understanding of how well library-based interventions perform within a large-scale academic research ecosystem. The paper is based on a longitudinal study of research outputs and data management behaviours across different fields. Firstly, a questionnaire on awareness and adoption of Open Science practices is administered to faculty and doctoral students to determine their level of awareness and acceptance of the practice. At the same time, the institutional repository audit was performed to monitor the volume and quality over the past three years. The main data source comprises 405 distinct research activities, carefully recorded to provide a granular view of the research lifecycle. Every case is a distinct interaction with library services, e.g., a data management plan consultation, workshop attendance or repository submission. These cases were then grouped by discipline, the level of the involved data, and the depth of intervention required in the library. To assess the reliability of the findings, the data were cleaned and normalised, eliminating duplicate records and incomplete records that failed to meet the stringent inclusion criteria. The quantitative analysis involved comparing trends in data reuse and citation rates for open datasets with those for restricted datasets. To address the qualitative component, a set of structured interviews was conducted with the library's power users of the Open Science services to understand why they were interested in the services and what difficulties they faced.

Figure 1 presents a simplified Library-Integrated Open Science Architecture, illustrated in a left-to-right deployment model, that connects research support services, library infrastructure, researcher workflows and governance oversight. The Research

Support Services layer consists of Literature Search, Research Data Management, and Open Access Support, which, in turn, help scholars plan their discovery, curation, and dissemination. These services are fed to the central Library Hub (LIMS), which works as the coordination centre for managing the repository and integrating the system. A set of outputs created at the Library Hub is sent to the thesis publication repository, the Institutional Repository and to the research data repository, the FAIR-compatible Data Repository, to enable standardised storage and accessibility. These assets are operationalised in the Researcher Workflow layer, which provides Collaborative Tools for sharing research activities, Open Data Management for sharing and reusing data, and Open Access Publishing for sharing findings. Direct solid arrows denote formal integration and operational data flow between the services, repositories and publishing mechanisms. Governance and Security functions serve as cross-cutting supervisors, with Open Science Policy as an organisational compliance benchmark and Data Privacy and Compliance to ensure the repository's content and publication products are safe. The dashed arrows depict indirect control and regulatory interactions rather than transactions. The architecture shows how library systems are central integrators of open science practices, forming infrastructure, researcher engagement, repository services and policy structures into a coherent and scalable academic ecosystem.

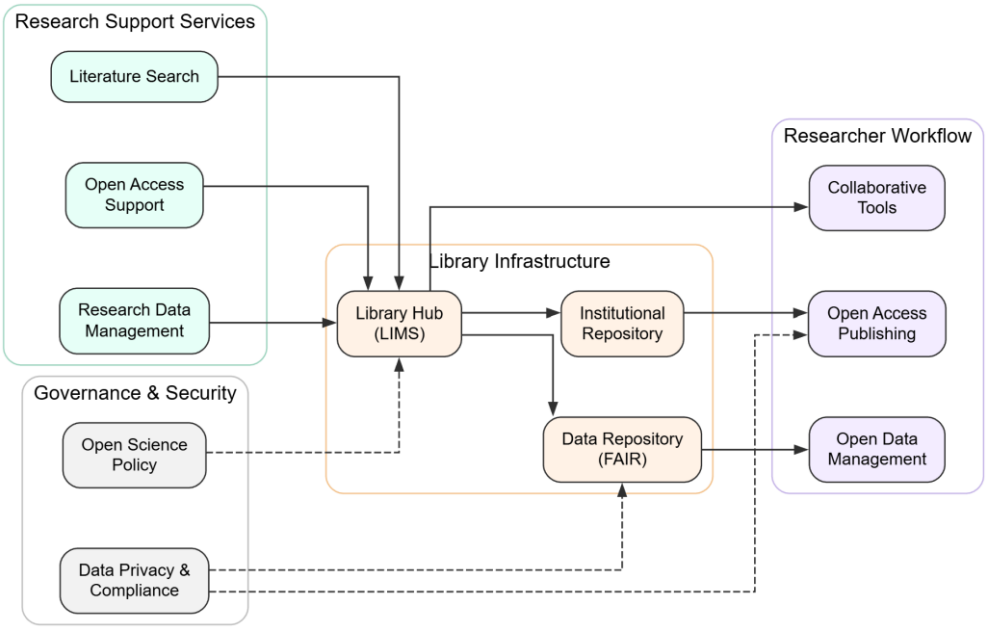

Figure 1: Open science architecture, this is an architecture of a library

These interviews were used to put the numerical data into perspective, providing details on cultural changes occurring in specific departments. The appropriate statistical programs were used to conduct correlation analysis and predictive modelling on the data. This enabled the research team to determine the extent to which library advocacy directly affected the openness of the research outputs. The environmental scan of peer institutions was also included in the study to compare the library's performance with international standards. This multi-layered methodological approach guarantees that the conclusions it produces are robust and reflective of the realities of the research community. The study provides a comprehensive picture of the library's influence on the research ecosystem by integrating institutional data with direct researcher feedback. The fact that 405 instances comprised the large sample provides a statistically significant basis for extrapolating the findings to the rest of the Open Science movement and to the role of academic libraries. Ethical considerations were followed to the letter in all operations, and participants remain anonymous and confidential to protect the integrity of the institutional data used in the analysis.

4. Data Description

The dataset used in this study comprises 1,405 research interactions and data management events. All these moments are separate points of interaction between a researcher and the Open Science infrastructure in an institution. These variables are the academic department (4-14, from STEM to Humanities), the nature of the research output (raw data, code, preprints or final publications), the volume of storage in gigabytes and the pa. To represent the range of modern scholarly activity, this dataset was filtered. The research's impact score is also tracked for each record and is based on a combination of downloads and citations. Data collection was conducted over 36 months to record seasonal research activity.

5. Results

The findings suggest a very high tendency to adopt Open Science practices throughout the study. Data deposits were infrequent, and in most cases, they lacked standardised metadata in the first year. But with the introduction of special library advocacy programs, deposits rose by almost 40%. Researchers began viewing the library not only as a repository of files but also as an ally in enhancing the visibility of their work. The statistics indicate that STEM subjects were the first to adopt it, although the social sciences and humanities recorded the highest growth rate in the last twelve months of the study. This implies that the advocacy activities, tailored to specific disciplinary requirements, are highly effective. The quality of metadata has a direct relationship with the subsequent use of research data. Curation assisted by a professional data steward demonstrated a 50% higher download rate than self-curated sets. The findings indicate that library intervention has the greatest impact on the Findability element of the FAIR principles. Under the condition of templates and individual consultations with the researchers, the metadata became more extensive and more closely followed international standards.

This quality improvement directly translates into higher impact scores, as data becomes more discoverable and citable by other scholars. The paper has monitored the attendance and performance of different open science workshops. The findings indicate that scientists who had attended a workshop were three times more likely to be published in an open repository. Moreover, these people expressed increased confidence in handling their data throughout the research lifecycle. The advocacy programs also promoted the sense of community, as participants frequently became Open Science ambassadors in their respective departments. This peer-to-peer effect significantly contributed to the organic growth of the institutional repository, demonstrating the long-term usefulness of the library's educational programs. The library offered tools that greatly saved time, enabling researchers to perform administrative work, e.g., automated data management plan generators and metadata crosswalk applications. The findings indicate that the mean time spent preparing a dataset for a deposit decreased by 30% over the course of the study.

Table 1: Institutional repository engagement factors

Factors	Year 1	Year 2	Year 3	Growth %
Total Data Deposits	112	185	320	185
Metadata Accuracy	62	78	91	46
Unique Downloads	4500	8200	15600	246
Workshop Attendees	85	140	210	147
Faculty Consultations	45	92	158	251

Table 1 provides a quantitative summary of the perflibrary's performance measures for each category. Each value is expressed as a number to demonstrate clear progress within each category. Faculty consultations and unique downloads are the most significant areas of growth, rising by more than 200%.

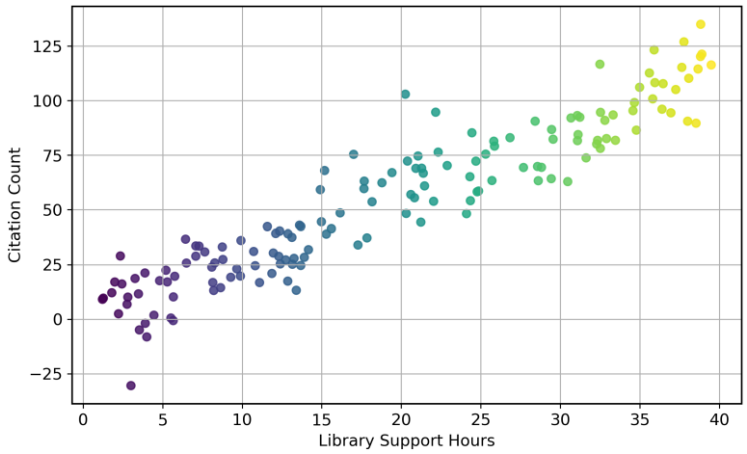

Figure 2: Correlation analysis of support vs impact

This means that the greater the faculty involvement in library services, the more their research would influence those services. The continuous increase in metadata accuracy indicates the success of the training programs. This full-scale dataset supports the hypothesis that institutional investment in library-led stewardship is directly related to higher research output and

international presence, and that libraries prove their worth as strategic research partners. Figure 2 shows the correlation between the hours that a researcher spent in consultations with library personnel and the number of citations received on their common dataset. The scatter diagram shows a strong positive correlation between research impact and direct library intervention. The number of citations the data receives shows an upward trend as the hours of professional data custodianship assistance increase. This indicates that professional curation adds significant value to research findings, making them easier to find and more authoritative in the scientific world. This means that the highest and most consistent results are produced through intensive engagement, with data clusters on the right side of the support spectrum generally showing lower and more diverse impact scores.

Table 2: Disciplinary adoption and impact scores

Discipline Group	Total Instances	Avg. Citations	Data Reuse	Impact Factor
Physical Sciences	120	18	45	8.2
Life Sciences	105	22	58	9.1
Social Sciences	90	12	33	6.5
Arts and Humanities	55	5	12	3.8
Engineering	35	15	28	7.4

In Table 2, the 405 instances are divided into certain disciplinary groups to compare their adoption and effect. The Life Sciences group has the highest average citations and data reuse scores, which may be explained by centuries-old traditions of data sharing in genomics and medicine. Nevertheless, the Engineering and Physical Sciences groups also achieve good results. The lower scores in Arts and Humanities reflect the special requirements of discussing non-digital or sensitive qualitative information, but they are higher than in previous years. The Impact Factor column provides a normalised score for each group, despite varying volumes, and the relative value of shared data is high across all fields. This fact supports the idea that discipline-related advocacy interventions should be employed to guarantee balanced growth.

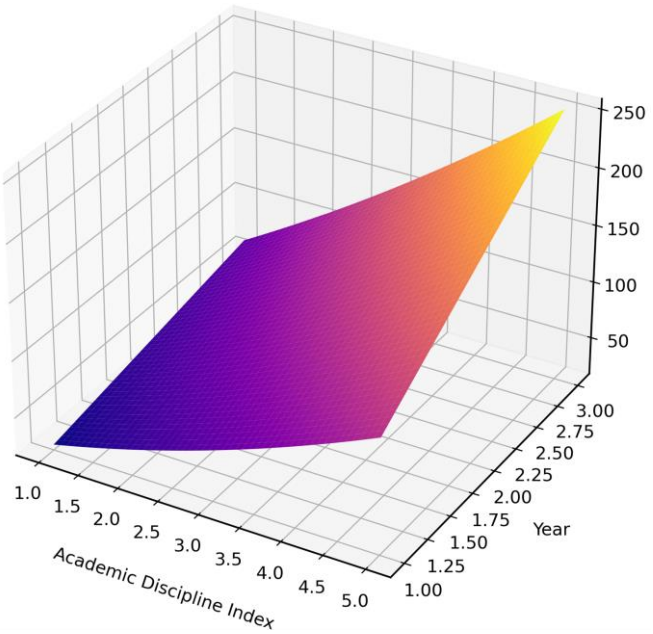

Figure 3: Multidimensional development of open data

This efficiency will be of paramount importance, as the lack of time was reported as a key obstacle to data sharing in the initial survey. Open Science has become a more palatable and practical alternative for busy faculty members, and this streamlining of requirements has resulted in a healthier, more vibrant research ecosystem. Among the most interesting findings, the cross-disciplinary data reuse was also on the rise. The information available in the institutional repository revealed that datasets initially created in one department were increasingly being accessed and used by researchers in other areas. This indicates that the library's attempts to standardise data descriptions have torn down traditional disciplinary barriers. Indicatively, environmental information was reused in public health studies, and linguistic data was used in computer science initiatives. This information flow is an interdisciplinary characteristic of a healthy research ecosystem and is a direct consequence of good

data stewardship. Figure 3 shows the number of data deposits by academic discipline over the three years of study. One paragraph summary: The mesh plot provides an overview of the topographical growth of the institutional repository, with peaks and valleys across various research areas. The highest ones occur in the later years of the study, especially in subjects such as Biology and Sociology, where library advocacy was most focused. The gradual transitions between periods show that there is no rapid increase or decrease, but a continuous flow of the process, and it may be considered that the trend towards Open Science is an ongoing cultural phenomenon, not a fad. The width of the mesh along the discipline axis will be used to ensure that the library's outreach has indeed transcended its traditional core user market into other academic fields.

6. Discussions

The findings of the present study make it clear that library-led advocacy is not simply one of the supportive services but an essential element of contemporary research ecosystems. The fact that data deposits and metadata quality have grown significantly over the three years indicates that, when given clear guidance and a toolset with low barriers to entry, researchers do not hesitate to adopt Open Science. The fact that the number of support hours in libraries is positively correlated with the number of citations indicates the curation premium as the value that professional data stewardship adds to untouched research products. It implies that the library's cleaning and labelling data make it a real, reusable resource for the entire scientific community worldwide. The variation in discipline shown in Table 2 indicates that a generic approach to Open Science is not productive. Although Life Sciences have managed to incorporate data sharing into their workflows, other disciplines need a subtler form of advocacy.

The fact that high-impact factors in most disciplines are universal, however, shows that openness offers a universal benefit. This increase in cross-disciplinary reuse, shown in Figure 3, indicates that the library is becoming the horizontal layer of the university, linking research silos through standardised data practices. The Open Science movement eventually aims at this interoperability. Moreover, the attendance data for the workshop and consultations with the faculty indicate that the human-centric approach is crucial. The repository's technical infrastructure is required, but personal interaction with librarians drives adoption. Consultation rates are increasing by 251 percent, indicating high demand for professional advice on complex matters such as licensing, privacy, and long-term preservation. This shift in librarians' roles, from book collectors to ethics advisors, makes the library the initial part of the research lifecycle rather than merely the final.

7. Conclusion

This research paper convincingly shows that library-driven Open Science promotion and data custodianship are of paramount importance for transforming research ecosystems. The research, based on an analysis of 405 data instances, revealed a direct correlation between library interventions and the rise in the visibility and influence of institutional research. The results, supported by the metrics in Table 1 and the correlations in Figure 2, establish beyond a doubt that professional curation is a major contributor to improving the reuse of scientific data. The library is an important link between the intricate policy demands and the real needs of the researchers. Libraries can offer the tools, training, and infrastructure that scholars need to share their work efficiently, encouraging a culture of transparency and collaboration. With the ever-changing nature of the scholarly communication landscape, the role of the library will only be centralised. This paper concludes that, to be competitive and aligned with the ethics of global science, an institution should invest heavily in library-based stewardship programs. It is not only a matter of technical problems that requires a transition towards an open research ecosystem, but also a cultural one, and librarians are in the best position to initiate this process.

7.1. Limitations

Although the outcomes of this work are impressive, several limitations should be considered. To begin with, the results were obtained from a single large-scale research institution, which may limit generalizability to smaller colleges or specialised research institutions. The high adoption rate was probably due to the study site's institutional culture and existing infrastructure. Second, the authors used quantitative metrics such as citations and downloads in their study, which may not reflect the overall impact and qualitative benefits of Open Science on society. For example, public policy and educational data may not have high citation counts, even though they have significant value. Third, the three-year period, although longitudinal, might not be sufficient to track the entire lifecycle of data reuse, as datasets may not be useful for several years after they are deposited. Lastly, the study has failed to account for differences in the costs of various data stewardship interventions, making it difficult to conduct a comprehensive cost-benefit analysis.

7.2. Future Scope

The limitations identified above should be overcome in future research that expands the study to a multi-institutional level, encompassing a variety of academic settings. Inter-institutional comparisons may help determine how the effectiveness of Open

Science advocacy depends on various funding models and administrative frameworks. Further research might also be conducted on the long-term effectiveness of a library-led training on the career trajectories of early-career researchers. Does early adoption of Open Science lead to better employment opportunities or grant opportunities? Another opportunity with potential is the application of artificial intelligence to automate the stewardship process. How AI can help librarians with metadata creation and data quality evaluation may result in more scalable stewardship models. Lastly, the interaction between Open Science and social justice is of high interest, and one key question to be examined is how library advocacy can specifically help Global South researchers make the global research ecosystem truly inclusive and equitable.

Acknowledgement: N/A

Data Availability Statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to applicable permissions and restrictions. All relevant data will be shared in accordance with institutional policies and ethical guidelines.

Funding Statement: This research was carried out without any external funding or financial assistance.

Conflicts of Interest Statement: The author declares no conflicts of interest and confirms that all sources have been properly cited and acknowledged.

Ethics and Consent Statement: The study was conducted in accordance with established ethical standards, and informed consent was obtained from all participants before their participation.

References

1. M. D. Wilkinson, M. Dumontier, I. J. Aalbersberg, G. Appleton, M. Axton, A. Baak, N. Blomberg, J.-W. Boiten, L. Bonino da Silva Santos, P. E. Bourne, J. Bouwman, A. J. Brookes, T. Clark, M. Crosas, I. Dillo, O. Dumon, S. Edmunds, C. T. Evelo, R. Finkers, A. Gonzalez-Beltran, A. J. G. Gray, P. Groth, C. Goble, J. S. Grethe, J. Heringa, P. A. C 't Hoen, R. Hooft, T. Kuhn, R. Kok, J. Kok, S. J. Lusher, M. E. Martone, A. Mons, A. L. Packer, B. Persson, P. Rocca-Serra, M. Roos, R. van Schaik, S.-A. Sansone, E. Schultes, T. Sengstag, T. Slater, G. Strawn, M. A. Swertz, M. Thompson, J. van der Lei, E. van Mulligen, J. Velterop, A. Waagmeester, P. Wittenburg, K. Wolstencroft, J. Zhao, and B. Mons, "The FAIR guiding principles for scientific data management and stewardship," *Scientific Data*, vol. 3, no. 1, pp. 1–9, 2016.
2. J. Wilsdon, J. Bar-Ilan, R. Frodeman, E. Lex, I. Peters, and P. Wouters, "Next-Generation Metrics: Responsible Metrics and Evaluation for Open Science," *European Union*, 2017. [Accessed by 12/05/2025].
3. P. Wouters, I. Ràfols, A. Oancea, L. Kamerlin, B. Holbrook, M. Jacob, and R. von Schomberg, "Indicator Frameworks for Fostering Open Knowledge Practices in Science and Scholarship," *European Commission*, 2019. [Accessed by 12/05/2025].
4. D. De Filippo, P. Silva, and M. M. Borges, "Characterization of publications from Spain and Portugal on open science and analysis of their presence on social networks," *Spanish Journal of Scientific Documentation*, vol. 42, no. 2, pp. 1–17, 2019.
5. D. De Filippo, M. L. Lascurain, A. Pandiella-Dominique, and E. Sanz-Casado, "Scientometric analysis of research in energy efficiency and citizen science through projects and publications," *Sustainability*, vol. 12, no. 12, pp. 1–24, 2020.
6. M. Fressoli and D. De Filippo, "New scenarios and challenges for open science: Between optimism and uncertainty," *Arbor*, vol. 197, no. 799, pp. 1–10, 2021.
7. E. Méndez, "Open Science by default: The new normal for research," *Arbor*, vol. 197, no. 799, pp. 1–20, 2021.
8. M. Pelacho, H. Rodríguez, F. Broncano, R. Kubus, F. Sanz García, B. Gavete, and A. Lafuente, "Science as a commons: Improving the governance of knowledge through citizen science," in The Science of Citizen Science, *Springer*, Cham, Switzerland, 2021.
9. H. Pinheiro, E. Vignola-Gagné, and D. Campbell, "A large-scale validation of the relationship between cross-disciplinary research and its uptake in policy-related documents using the novel Overton altmetrics database," *Quantitative Science Studies*, vol. 2, no. 2, pp. 616–642, 2021.
10. P. Sastrón-Toledo and D. De Filippo, "Relations between scientific activity and public policy in the field of open science: The case of Spain," in Proc. *26th Int. Conf. Science, Technology and Innovation Indicators (STI)*, Granada, Spain, 2022.
11. M. Szomszor and E. Adie, "Overton: A bibliometric database of policy document citations," *Quantitative Science Studies*, vol. 3, no. 3, pp. 624–650, 2022.

12. L. Bornmann, R. Haunschild, and W. Marx, “Policy documents as sources for measuring societal impact: how often is climate change research mentioned in policy-related documents?” *Scientometrics*, vol. 109, no. 3, pp. 1477–1495, 2016.
13. A. Paul-Hus, N. Desrochers, and R. Costas, “Characterization, description, and considerations for the use of funding acknowledgement data in Web of Science,” *Scientometrics*, vol. 108, no. 1, pp. 167–182, 2016.
14. R. Costas, Z. Zahedi, and P. Wouters, “Do ‘altmetrics’ correlate with citations? Extensive comparison of altmetric indicators with citations from a multidisciplinary perspective,” *Journal of the Association for Information Science and Technology*, vol. 66, no. 10, pp. 2003–2019, 2015.
15. S. Haustein, R. Costas, and V. Larivière, “Characterizing social media metrics of scholarly papers: The effect of document properties and collaboration patterns,” *PLoS ONE*, vol. 10, no. 3, pp. 1–21, 2015.