Opening the Heart of Science: A Review of the Changing Roles of Research Libraries

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Abstract: In a world of information overload and data deluge, is opening science a research library's duty? Or is the openness of science deeply changing libraries, ultimately converting them into something else? The purpose of the review is to highlight the challenging issues stemming from the relationship between research and libraries. A broad literature analysis was performed focused on the intersection of three different perspectives: (1) the future of research libraries, (2) the emerging new roles, and (3) the ongoing openness of science. Libraries are still at the heart of science but challenged by several stakeholders within the complexity of present science production and communication. Research support services, research data management, or research information management are emerging roles, among others, sustaining an open path where libraries thrive to be more collaborative while looking forward to establishing new partnerships.

Keywords: research libraries; open science; research support services

1. Introduction

The impact of digital technology on libraries has brought significant changes. However, their core business remained essentially the same: managing the information that can satisfy the information needs, adding competitive value. In 1933, five types of services provided by libraries to researchers were identified: the accumulation of materials, their availability, personalized help to researchers, publication support and research assistance through international cooperation [1] (p. 128).

Many other services were then added, being the main change systemic, or rather eco-systemic. The new services are but a reaction to competition in an increasingly competitive information environment, as it is no longer just the library system that is at stake, but the relationships that different systems establish between them within a given environment [2].

There is an essential relationship between the science that is produced and the sharing and communication of its results [3]. "Science is, in this sense, always open because knowledge is only effective when it is communicated: Much of the remarkable growth of scientific understanding in recent centuries is due to open practices; open communication and deliberation sit at the heart of scientific practice" [4] (p. 13).

Open science, as a new culture in science, is increasingly known in media and society. This movement towards greater openness grew apace with the development of digital networks and, therefore, it can be said that science is now more "open": "Scientists share results almost immediately and with a very wide audience. Strictly speaking, since the first scientific revolution, science has been open. Through the Internet and Web 2.0 science can become 'more Open Science', meaning that researchers share results, ideas, and data much earlier and much more extensively to the public than they do at the moment." [5] (pp. 10, 11). Among the various possible definitions of open science, let us consider the following threefold perspective: "Open science is defined here as open data (available,

intelligible, assessable and useable data) combined with open access to scientific publications and effective communication of their contents" [4] (p. 16).

Recognizing, however, that the library is the heart of the university, the review was organized around three research questions: (1) can we still consider the research library as the heart of institutions dedicated to the construction of science? (2) Is "open science" changing the relationship between libraries and researchers? And (3), to what extent do these libraries contribute to scientific development and to the opening of these institutions to society? If libraries are at the heart of science, their position has undergone profound reconfigurations in a complex process of change that will now be addressed. The new roles, their position in the research lifecycle and their ability to change science itself are some of the aspects that will be analyzed.

2. Literature Search

Intensive research started in September 2016, although the initial exploratory information retrieval began a year earlier and naturally continued after that period, due to the correlation between the different references analyzed. Searches were conducted in the Web of Science databases (for the most relevant literature), Library and Information Sciences & Technology Abstracts (for information science literature), Google Scholar (to perform support searches and to receive daily alerts of new entries), being various sources consulted, available on social networks, such as Facebook, Twitter, Academia.edu, ResearchGate and professional newsletters, among others. The information retrieval here presented is part of an ongoing case study about the relationship between academic/research libraries and researchers in Portugal.

The focus of information retrieval and content analysis is on the intersection of three perspectives: the future of research libraries, the emerging new roles, and the ongoing openness of science. It was included all documents fitting that intersection, with a special attention to those most cited by authors and published after 2010. It was also mentioned some exceptions due to their relevance. A full-text database was built on Google Drive cloud platform and all the references were managed with Zotero (version 5.0.34).

3. What Is (Really) Changing?

One key element in the theoretical framework of the relationship between libraries and scientific research is the definition of "changing environment". The idea that these systems are conditioned and immersed in changes caused by the speed of digital technologies evolution is present today in the scientific discourse on the academic and research libraries. However, "the transformations we are witnessing today are more of a structural nature than essentially oriented by digital technology, that is, the main change is the breakdown of communication linearity, replaced by an interactive network model" [6] (p. 182, in our translation). It is also necessary to understand whether technologies modify the theoretical dimensions that make possible and justify the different forms of action of the libraries or whether the changes are the result of merely superficial variations in the working nature within the science institutions.

According to The Royal Society's 2012 report, this dilemma remains largely unresolved: "A particular dilemma for universities is to determine the role of their science libraries in a digital age. (. . .) The traditional role of the library has been as a repository of data, information and knowledge and a source of expertise in helping scholars access them. That role remains, but in a digital age, the processes and the skills that are required to fulfil the same function are fundamentally different. They should be those for a world in which science literature is online, all the data is online, where the two interoperate, and where scholars and researchers are supported to work efficiently in it." [4] (p. 163)

The change is thus present in the different perspectives from which the research libraries can be observed. It is not, however, a permanent state of change, as if it were an intrinsic and observable characteristic in the phenomenon [7] (p. 1). The key issue is that the environment in which libraries

are embedded is deeply affected by the technology issue [8], with all its sociopolitical implications, and the amount of change does indeed promote what could appear to be a permanent state of change.

Brown describes the impact of digital technologies with the image of a S-curve in which the eighteenth, nineteenth, and twentieth centuries corresponded to an era of relative stability, where skills acquired by professionals were lifelong, careers were linear and institutional architectures seemed to last forever [9]. But in the last 50 years of the twentieth century there has been an acceleration, going through increasingly shorter steps, driven by the exponential growth of computing, which does not allow any stabilization in the short term.

Dempsey draws attention—writing on the problem of collections in higher education and research libraries—to the two long transitions that mark this process: the path from physical to digital, and the evolution of the local design of the collections (and ultimately services) to a global, networked experience that results in numerous organizational and behavioral changes [10]. The question of library collections is essential because it deals with the tensions of the so-called "archive of science" defined as "the set of publications (. . .) which is the most perennial testimony of the affirmation of the intellectual priority of scientific discovery. (. . .) It constitutes the formal communication channel of science (. . .) and should be accessible, and therefore preserved. It is on it that the current proposals for the opening of science are focused." [6] (pp. 183, 184, in our translation)

In this new ecosystem, structured by the practice of networks, two paths lie ahead. The first is a response to the reorganization of researchers' work in the digital environment. Dempsey calls it "the inside-out library". Libraries are increasingly supportive of creation, curation and discoverability of institutional outputs (research data, preprints, academic profiles, digitized special collections, etc.) because the creation of knowledge now takes place in the digital environment [10] (p. 339). The university wants to share these materials with the rest of the world, and the library participates in this endeavor. This is a complementary position to the "outside-in" library, whose traditional roles were focused on the selection and acquisition of materials produced outside the institution that were later acquired [11] (p. 5).

The second path is a response to the network reorganization of the information space, being called the "facilitated collection": increasingly, the library does not build collections for local use, it facilitates instead access to a combination of local, external and collaborative services, available in the network and gathered around user needs [10] (p. 339). Immersion in the digital environment and in the networks' fabric is transforming research libraries and the way we look at them [12]. According to Dempsey, the user ceases to be in the life of the library; it is the library that is now in the life of the user [10]. This shift in focus carries libraries into the research lifecycle, and should this cycle be in an opening process, the library can or will have to participate as well.

The two transitions—physical/digital and local/global—are also reiterated in the recent perspective of the MIT Libraries: "We believe that this transformation—from libraries where knowledge is accessed individually through analog and digital means into ones where creation and access to knowledge are dynamically networked—will affect all aspects of the research library." [13] (p. 4).

Hoffman draws a parallel between the iterative nature of the research process and the exploratory culture that libraries should take up to improve user services. She makes essentially reference to the repeated alignment of this development with the satisfaction of information needs. This apparent routine coexists with a creative dimension which is put into practice by librarians: "In order for our constituents to see research libraries as dynamic spaces where research happens, we must cultivate our own interests and explore new things." In this environment, risk is something positive and failure can't be a defeat but an opportunity: "That's what research is, trying something with an uncertain outcome—whether the results are positive or negative, they deserve to be discussed and utilized. Nothing can be learned without making some mistakes." [14] (p. XV)

In summary, this exploratory culture is essential for libraries remain relevant in their institutions. The profound changes brought by a digital, global and networked environment are deeply challenging research libraries. First, print collections and long-term digitization projects are questioned, particularly

outside social science and the humanities; second, local literature selection and acquisition is overridden by commercial offers and major publishers' decision; third, networks are the workspace of science and where libraries will have inevitably to be.

4. The Future Is Now: RLUK, ARL and LIBER

Looking at the most recent strategic documents of the three main professional institutions in the field of research libraries, it is interesting to note not only the identity dimension, that is, what is understood as a research library in each of them, but also the dynamics of change that these documents reveal.

RLUK (Research Libraries UK), designation adopted since 2008, was established in 1983 under the name CURL (Consortium of Research Libraries). It is a network of 37 research libraries from the UK and Ireland. Its strategic document for the years 2014–2017 is titled "Powering Scholarship". It makes reference to the place or role that research libraries are expected to play within academia: the focus on library development is intended to drive research and innovation across disciplines by acting in the duality of changes in the landscape of information and by permanent valuation of heritage (collections of books, manuscripts and rare archives), a combination of modernity and tradition [15]. The identity presented by RLUK anticipates that libraries can contribute to the knowledge economy on a large scale through innovative projects and services that add value and impact to the process of research and training of researchers.

The five pillars of RLUK's strategy for 2014–2017 suggest such ongoing reconfiguration as well. First, the reformulation of the modern collection of research libraries; followed by the opening of the science communication cycle, including the editing and management of research data. Thirdly, the exhibition and exploitation of library collections, revealing above all what seems to be still hidden from the eyes of researchers and the public. Fourth, another strategic objective is mapping the landscape of changing research, the role of libraries in research and training of researchers, especially assisting library managers to identify the areas where they can add value. Finally, the goal is to set up a creative community by developing leadership and innovation, both by thinking about good practices and encouraging libraries to measure and demonstrate their value to scholarly communities [15] (p. 5).

The ARL (Association of Research Libraries) brings together 125 libraries from the United States of America and Canada. Having been established in 1932, it is one of the most important and oldest library associations. The strategic vision presented in 2014, in view of the year 2033, was the result of a study of the professionals, as well as the analysis of the strategic documents of the various institutions that make up the association. The current change is clearly expressed in this formula: "In 2033, the research library will have shifted from its role as a knowledge service provider within the university to become a collaborative partner within a rich and diverse learning and research ecosystem. [16] (p. 17) This transition from "suppliers" to "collaborators" presents research libraries with more complex challenges, inherent to an era of constant imbalance.

One of these challenges consists in a change of attitude on the part of the information professionals themselves. In the prologue to the update of ARL's strategic document, Brown reports a dialogue that is paradigmatic. A colleague, who had asked Brown about the long-term significance of Google Glass, was laughing about the future of research libraries, having Brown replied that libraries had the opportunity to become the center of learning in the ubiquitous information world, because they complement and structure all the new ways in which we learn from each other [17]. The awareness that librarians can take on this educational mission as trainers and facilitators is a radical step towards breaking the ties with the prejudice that libraries are dispensable vis-à-vis the generalized supply of information provided by the WWW.

Participants in the strategic reconfiguration process promoted by ARL have also recognized three key changes that will occur over the next twenty years: (1) the library has shifted its focus from service provider within a single university to becoming a partner and actively collaborate within a broader higher education ecosystem; (2) libraries will be even more committed to supporting the lifecycle

and range of knowledge discovery, use and preservation activities, as well as curating and sharing in various contexts of the mission of the university and society; (3) the ARL—the organization—will enable libraries to articulate both individually and collectively with one another to promote learning, research and social impact [17] (pp. 19, 20).

LIBER (Ligue des Bibliothèques Européennes de Recherche—Association of European Research Libraries) was established in 1971 and brings together over 420 national libraries, higher education and research libraries. The strategic document for 2018–2022 focuses on the role of libraries in the sustainability of knowledge in the digital age, particularly how libraries will enhance it. The foreseen changes are multiple: open access is the predominant form of publication; the research data are FAIR (Findable, Accessible, Interoperable and Reusable); digital skills support a more open and transparent research lifecycle; research infrastructures are adapted and bring together the various disciplines of knowledge; the cultural heritage of the future is built into the digital information of the present. Against this background, LIBER sets out three strategic directions. Research libraries in 2022 should be: innovative science communication platforms, service and digital competencies centers, and partners in the interoperable, scalable and interdisciplinary research infrastructure [18].

The three strategic documents recognize that the ongoing changes place the research library as an active participant in the transition between tradition and modernity. Their role as creative agents and promoters of innovation is a horizon that could allow libraries to continue to deliver value-added services and products. Likewise, the collaborative dimension is corroborated in the three documents, particularly the role of the research library as a learning center. This educational mission and the sustainability dimension of information flows will be essential bases for science production and dissemination. Libraries' intervention in the research lifecycle is seen by the three associations as the new place that libraries should occupy.

5. The Changing Roles of Research Libraries

Based on the work of Wendy Lougee it is possible to begin the mapping of ideas about the changing roles of research libraries. For this author, in the 1990s, the two key components with which libraries were debated were distributed technologies and open paradigms. To conceptualize this new standing, Lougee proposes the concept of diffuse libraries, in which it is recognized that the universe of information is more distributed and that the library is no longer the center of this universe. At the same time, the conceptions surrounding the idea of "openness" (open access, open source, etc.) also emerge, emphasizing the collaborative and sharing dimension, disruptive elements towards a central position, and ultimately isolated one, occupied by the research library. A new set of functions is thus proposed:

With the incorporation of distributed technologies and more open models, the library has the potential to become more involved at all stages, and in all contexts, of knowledge creation, dissemination, and use. Rather than being defined by its collections or the services that support them, the library can become a diffuse agent within the scholarly community (. . .) we see the library becoming more deeply engaged in the fundamental mission of the academic institution—i.e., the creation and dissemination of knowledge—in ways that represent the library's contributions more broadly and that intertwine the library with the other stakeholders in these activities. The library becomes a collaborator within the academy, yet retains its distinct identity. [19] (p. 4)

The immersion of libraries within the processes of science production and dissemination—surpassing its role as guardian of the archive of science—was thus the result of the emergence of a new culture—distributed, open, diffuse—that would later also be deeply marked by the assumption of the social web and by the new forms of sharing and collaboration that were developed. Lougee recognizes these various forces are visible in a broad set of changes in the focus of libraries: from archiving of scientific publications to participation in the whole process, including the development of an infrastructure supporting all the tasks of science; from collections' holder to the value added by the competences; from access to information provider to the creation of meaning

in informational chaos; from mediation between information needs and collections to facilitation, disintermediation and development of mechanisms that favor the individual work of users; from a local library perspective to the globalization of science [20] (p. 612).

The paradigm shift seen in the roles of research libraries is, for Lougee, the result of a set of anomalies (widespread information supply, computer development, and network power) that call into question a mindset centered in collections, normalization and reactive mode of action. It is not, however, a mere transition to the digital context, since there is a deep reconfiguration of the roles of libraries [20] (p. 613). If the collection no longer occupies the center of the universe of information, a constant adaptation to changes in science is required, particularly the emergence of cyber-science or e-science [21], and digital technologies. Hence, new roles emerge such as the ability to collaborate, to render resources profitable, to simplify complex situations, to understand processes, to empower resources, as well as the ability to adapt the global science infrastructure to local needs [20] (p. 621).

From the literature review on this topic, we can see a profusion of studies (which increases in 2010) in recent years that seek to reflect on the new roles that research libraries are assuming (other reviews can be found in [22–24]). For Anglada [25], the focus of the libraries in the construction of collections was shaken by the changes in science communication [26]. This has led to a reorganization of research support services, from open access, through the development of repositories, to increasing the visibility of researchers.

Webster [27] shows that investment in libraries (percentage of university expenditure) has been declining since the 1980s, putting their traditional mission at risk. On the other hand, the scientific communication system is unsustainable, above all due to the rampant price of resources, which leads libraries to prefer acquisition models that don't guarantee ownership and long-term access. If libraries eventually reflect the problems of universities, only an articulation of collective strategies can overcome the pressure to which the system of science is subject.

Case [28] argues that research libraries should play the role of partners in the creation of knowledge. If the creation of new knowledge was previously dependent on the collection, organization, access and preservation that libraries guarantee, in the digital environment libraries now have the opportunity to integrate even more actively into the process of knowledge creation [22]. Their contribution is not only the replication of the previous roles but also the core values (access, preservation, ethics) that the professional community carries in their work. Pathways are provided that researchers can and should adopt: "By being involved in these choices, librarians can help faculty make the decisions that will increase the odds that valuable scholarship in digital form will not be lost. In fact, our goal should be to help make this scholarship easily found, readily used, and permanently preserved." [28] (p. 145)

In an essential work [29], several authors aim to understand the changes in progress. Mentioning only two examples related to changing roles of research libraries, Smith [30] insists that collection, preservation and access are essential functions perceived and received as an inheritance even though the center of gravity of information has been transferred to the internet. The management of resources will be guaranteed in the future by an entity—which may not be called a library—which must be dedicated to two concrete roles: the local function (community information needs, repository management, etc.) and network function, part of a cyberinfrastructure for local and transnational research. The library is the platform embedded in the infrastructure that researchers turn to so they can be part of the network that supports a global and distributed science.

Luce [31] stresses that the main change in the role of libraries concerns the way in which their traditional functions are extended to respond to a collaborative environment characterized by continuous and synchronous communication as well as the question of automatic description mechanisms and others that adapt to the information speed. It proposes three key roles: (1) support for the early stages of knowledge creation, i.e., greater care with the production phase, along with the dissemination of results. This implies not only active collaboration in the planning of research data management [32], but also adherence to less formal means of science communication; (2) the link

between scientific communities, through the development of collaborative structures at the WWW and the information needs satisfaction in these environments; (3) the research data curation, the development of metadata standardization, and the strategic design of science participation in the semantic web.

All these aspects lead the library to a laboratory image, moving away from the idea of a warehouse or information silo (see [33]). One of the aspects that contributed decisively to the breakdown of this compartmentalization was the open access movement. Harris [34] found that although open access seems to reduce the importance of libraries in the development of institutional collections, librarians' skills remain essential for the repositories management, metadata structures that allow retrieval of information in open access and preservation mechanisms of resources. On a scale that is now more global than local, the value of libraries is measured by the quality of delivery, including the digitizing of unique collections. The future is about collaboration and sharing of resources and the main change will be the transfer of importance from the library to the librarian: «the information professional is the library of the future» [34] (p. 14).

About a decade ago, one of the most prominent leaders in the renewal of higher education and research libraries in Portugal, wrote at a meeting on research libraries in 2020: «In the coming ten years, local research libraries can and must be nodes of a global network of research information providers. This global network will be composed of different types of repositories that will store, preserve, expose and provide access to the research outputs of the communities to which they are attached» [35].

At the heart of the new ways of science manufacture we find data, but researchers only want to use them and do not spend resources on their collection, organization or preservation [36]. The role of libraries as repositories or information providers is transformed, emerging an active function in the process of scientific research [37]. This activation promotes a partnership instance [38] in which the library provides specialized skills and tools and therefore assumes itself as an integral part of the process. The experience of libraries in the field of interoperability is a guarantee of the effectiveness of this new collaboration: "Libraries have the institutional structure and many of the skills needed to maintain large data sets, make different versions available for different purposes, create metadata linkages, add provenance information, address long-term preservation and archiving, and attend to all of the tasks associated with curation and ensure accessibility on demand." [36] (p. 67).

One of the most interesting documents that has been published in recent years proposes that MIT libraries (and these as models for the world) be viewed as open and global platforms, corresponding to a vision that comprises four dimensions: (1) libraries should conceive its community as global, embracing openness, diversity, global social justice and critical thinking; (2) libraries should develop and facilitate the creation of content platforms and tools that encourage the open dissemination of research and facilitate new methods of discovery and use of information; (3) libraries should be leaders in the long-term management of information resources and in the development of collaborative models for the long-term management of science archive; (4) libraries should become a research and development center, looking for new answers to the major challenges around research libraries and science communication [13] (p. 19).

Another key study was held at Cornell University [39] on the library of the future. The design of this proposal is informed by the data collected and analyzed among the researchers, based on the premise that the traditional focus of libraries on information acquisition and research is insufficient due to the complexity of the research process. The library should thus intervene at different points in the research lifecycle: "research is about much more than finding and evaluating knowledge sources, the traditional focus of information-literacy initiatives. Research is about asking questions, about synthesizing ideas, and about creative problem solving." [40] (p. 553).

One of the main aspects is the role of technology in the research process, particularly the possibility that technology offers in terms of customization. The emergence of these idiosyncrasies forces the library to build an offer of services and products that respond to the individual preferences of researchers so that it can become an «academic hub». In the same sense, collaboration

and interdisciplinarity should promote the adoption of tools and applications that allow true interoperability: "The library of the future, as we see it, lies at the juncture of customization and collaboration in support of the overlapping spheres of the research process, academic networking, and self-management." [39] (p. 40).

The main themes that lead to the vision defined by Tancheva et al. are: (1) the research is idiosyncratic and, as such, library services must, rather than organize, give meaning to information (research vs. search); (2) the investigation does not have schedules and is ubiquitous, so the services should also be; (3) notebooks are an essential part of research and are equally idiosyncratic, so services should invest in this area of academic activity; (4) information search and knowledge production systems will certainly fail at a given moment, and the specialized response of library services, personalized, flexible and portable, will be essential then; (5) research is collaborative and, therefore, libraries should support and facilitate collective work [39] (p. 40).

Acknowledging the central place of technology, libraries must respect the idiosyncratic nature of individual research practices and simultaneously link researchers to the international academic community. Therefore, the library of the future should be an academic hub and an app store—intervening in a permanent, fluid, interconnected and idiosyncratic investigative process—that allows for highly customizable research [39] (p. 41) [see also 40]. An excellent example of the development of these ideas has been the field of digital humanities, in which libraries have reinvented their custodial role, enabling the technological transformation of research and the creation of new perspectives and interpretations [41–43].

RIM (Research Information Management) or CRIS (Current Research Information System), in the European nomenclature, are a typology of tools that aim at the aggregation, curation and use of information about research, with a close relationship with the library. RIM «intersects with many aspects of traditional library services in discovery, acquisition, dissemination, and analysis of scholarly activities, and does so through the nexus with institutional data systems, faculty workflows, and institutional partners» [44] (p. 5). It is data about research rather than data generated by research: and "represents institutional curation of the institutional scholarly record" [44] (p. 8).

Libraries, while seeking to align their activities with the strategic plans of the institutions to which they belong, extend their range of services to support institutional objectives in an essentially digital environment, preserving information produced locally and interconnecting it with the network, as Dempsey had also proposed with the concept of the inside-out library [10]. However, in general, institutions don't recognize libraries as partners in the management of information of this type. Bryant et al. propose that this support can be provided in four dimensions, using the capital of experience and knowledge accumulated by libraries over the years, corresponding to four roles of libraries in research information management (RIM): (1) specialized support in the field of scholarly publications and science communication; (2) the ability to discover and exploit the different levels of network accessibility, including open access; (3) end-user training and support; (4) institutional records curation [44] (p. 13).

Given that there is a problem of visibility, which is not exclusive to research libraries but affects other information services, the concept of the intelligent library: " ... an 'intelligent library' is not simply one that has the most up-to-date technology. It is a library that uses technology to respond in a timely and effective way to changes that are taking place in its university." [45] (p. 219) There are three characteristics that libraries must demonstrate: ability to transform the resources that libraries make available; collaboration to improve the way information resources are made available; visibility of the library in a context of internal competition due to the scarce resources available [45] (p. 220).

At the 2017 RLUK conference, one of the topics addressed was the role of libraries in scientific research. These systems should occupy a central place in the ecosystem of science. This requires a cultural shift from the concept of support or collaboration to the concept of partnership: "We need to be creative codevelopers working with the research community if we are to be a research library (...) We should embed library in research questions and processes. [46]" This creativity may

be subversive [45] (p. 220) in the sense that one tries to develop the position out of the traditional sphere of action, but simultaneously serving the interests of the institution where one is inserted. This creativity has been applied in open science, in which libraries have sought to take on leadership roles to positively influence—for breaking and for opening—the whole cycle of scientific inquiry. Despite the loss of the monopoly of information and the ownership of the collections, it is now time to proceed with a re-appropriation of the responsibility for the preservation of the digital objects that are scattered on the servers of commercial publishers. This movement should generate not only open access, but also a shared and open collective collection.

As Lynch stresses: "There's a huge problem with public or OA materials on the web: everybody relies on them, but nobody wants to take responsibility for curating and preserving them." [47] (p. 128) In summary, "this future involves a shift away from libraries purchasing content for their local users, towards libraries curating and sharing with the rest of the world the research outputs produced at their institution." [48] (p. 2).

A study carried out in the United Kingdom with experts and information professionals revealed that these have identified five sets of trends in higher education libraries: (1) scientific research is increasingly being supported by large data sets and digital artifacts involving intelligent, open and networked systems; (2) new pedagogies are being supported by flexible and technology-based learning; (3) libraries are changing the emphasis of their collection-centric strategy for service development; (4) the boundaries between professional groups and services are blurring and their identities changing with greater collaboration and training in new skills; (5) the enormous pressure that higher education and libraries are being subject in order to respond to new situations [11] (p. 16).

Although the alignment of the libraries with the institutions is considered essential by the participants, three styles have been detected that can be found to a greater or lesser degree, depending on the context of each organization: the style of service provider, in line with the requests of the institution; the users partner style and other services within projects or embedded work; finally, the leader style, in which the library assumes a role of innovation, strategy, and vision [11] (p. 36). The authors also considered several paradigms or thought models that help anticipate the future of libraries. From the ones already identified in the literature such as the hybrid library or "library in the life of the user", the service-oriented library or globalized library were added, among others [11] (p. 50).

6. An Open Identity

One of the great challenges is to understand whether the collaborative dynamics between services and researchers don't lead to a process of identity erosion of the libraries themselves [11] (p. 56). The ability to perceive change within the scope of social sciences usually requires the use of tools capable of working large data sets. A recent example is the ongoing international study on the discovery and access to scientific information by early-career researchers, led by David Nicholas (CIBER Research Group). Preliminary results show that the problem of library support for research has to be observed in conjunction with other elements of the science ecosystem (such as publishers), and given the massive supply of information, which has increased with improvement of the WWW services (mainly the Google platforms, but also the social networks of researchers), or with the increasing availability of resources in open access [49].

However, Nicholas states that the observation of this group does not bring good news for the libraries: "The picture is more worrying for libraries, as their scholarly services seem to have lost all visibility. Many early-career researchers have not set foot in their library for years, and consider them mainly as places for undergraduates to work. As with publisher platforms, Google has supplanted their discovery systems. To make matters worse, institutional repositories are not popular, either." [50] (p. 8).

Libraries are facilitators of access to information, mainly through the acquisition of resources—when there is awareness of who acquires the information—but they don't support the

capacity for discovery, which is a relevant fact if we consider that young researchers will be the researchers of the future and the trainers of future researchers.

In any case, the science network includes libraries, which are part of the R & D system. They participate in several projects and are considered in some decisions. Among other things, they are an essential tool for the archive of science management. As Bush noted in his famous report, calling for a firm investment in information services: each new finding depends on the previous ones, and the scientist must master the additions to the "knowledge warehouse". The magnitude of the task of keeping all this knowledge available to the community requires that all possible aids be provided to libraries [51].

Today, libraries support scientific research in a wide range of services: managing publications repositories, providing data required by international rankings or local and national evaluators, supporting research data management, supporting publication processes (books, journals), training of researchers in information skills, support in obtaining scholarships and contracts, among others [52]. These services can be embedded in a model that accompanies the entire research lifecycle, and also serves to promote the offer of libraries vis-à-vis the lack of knowledge of researchers: «it is clear that researchers simply do not know the scope of what librarians can do for them» [53] (p. 313). Another model was proposed in a pyramid with different levels of service, aiming to lead libraries to the development of sustainable and scalable services in order to reach the largest number of researchers [54] (p. 32).

The multiple presence of libraries in the organization of science is also confirmed in the model presented by Björk, who considers them to be relevant stakeholders, particularly in the communication process. This author understands them as crucial in the construction of the archive of science and in the provision of access to publications, although in the diagrams that form its model libraries perform other functions that go beyond this apparently smaller vision [55].

It has therefore been increasingly clear, for information professionals, one must exit the comfort zone of the so-called traditional attitude, turned inwards. Embedded librarians represent a profound conceptual shift as they are intended to take an active stance towards the communities and organizations they serve [56]. It is required today to redefine the professional profiles and training, and professional recognition of these new skills and roles that derive from traditional profile [57].

A new form of identity emerges that promotes a relocation and separation between professionals and institutions, which is cause for some discomfort for librarians such as Plutchak: "I understand the angst that many in the profession feel about making sure the library stays 'relevant'. But frankly, it sets my teeth on edge when I hear someone argue that we need to develop RDM services or institutional repositories to stay 'relevant'! It's an entirely backward way of looking at the issue." [58] (p. 5).

Anderson notes that libraries and librarians who support research today live in a culture of silent war between a local perspective (as soldiers fighting for the mission of their institution and the needs of their community) and a global perspective (as revolutionaries who want to improve the world of science communication). The conflict arises from the dispute of resources that are scarce and originates from the multidimensional complex generated from the change of the analogical information to the digital era. However, this war may have a relatively simple solution, since funding, being mainly local, will require more soldiers and less revolutionaries [59].

7. Conclusions

Libraries are still at the heart of science, but are challenged by several stakeholders within the complexity of present science production and communication. The literature shows that research libraries are trying to find a place that is not necessarily new, but which is now in an environment with new features. Libraries are and have been responsible for a very important part of the archive of science. This role makes them essential elements for the transition from the "old" processes of science production and dissemination to an environment deeply marked by digital technologies, globalization and the importance of networks. Research support services, research data management, or research

information management are emerging roles, among others, sustaining an open path where libraries thrive to be more collaborative looking forward to establishing new partnerships.

The literature also reveals that research libraries contribute to scientific development and to the opening of science institutions to society, although some of the researchers and research leaders don't acknowledge it. Libraries need to remain visible and claim a central position, not based on an information «monopoly», but on an advanced expertise, strong values and willingness to help the research endeavor as they have always done. Their educational mission and their role as a learning center is essential to ensure new partnerships, which is quite clear in the embedded librarianship experiences reported on the literature. This shift in focus—providers to active promoters—transports libraries to the research lifecycle, and if this cycle is in an opening process, libraries can or will have to participate.

Networks, globalization, partnership, cultural shift, enhanced skills, discoverability are keywords in research libraries vocabulary and passwords to cooperate in the opening of science, to fulfil society's strong expectations towards public and private investment.

References

1. Wilson, L.R. The Service of Libraries in Promoting Scholarship and Research. *Libr. Q. Inf. Community Policy* **1933**, *3*, 127–145. [CrossRef]
2. Vandegrift, M. Designing Digital Scholarship Ecologies. *LIS Scholarsh. Arch. Prepr.* **2018**. [CrossRef]
3. Garvey, W.D. *Communication: The Essence of Science: Facilitating Information Exchange among Librarians, Scientists, Engineers and Students*; Pergamon Press: Oxford, UK, 1979; ISBN 0-08-022254-4.
4. The Royal Society. *Science as an Open Enterprise*; The Royal Society Science Policy Centre Report; The Royal Society: London, UK, 2012; ISBN 978-0-85403-962-3.
5. Bartling, S.; Friesike, S. (Eds.) *Opening Science: The Evolving Guide on How the Internet is Changing Research, Collaboration and Scholarly Publishing*; Springer: Cham, Switzerland, 2014; ISBN 978-3-319-00026-8.
6. Borges, M.M. Reflexos da Tecnologia Digital no Processo de Comunicação da Ciência. In *Una Mirada a la Ciencia de la Información Desde los Nuevos Contextos Paradigmáticos de la Posmodernidad*; Oficina Universitária: Marília, Brazil, 2017; pp. 179–196, ISBN 978-85-7983-904-7.
7. Dewey, B.I. *Transforming Research Libraries for the Global Knowledge Society*; Chandos: Oxford, UK, 2010; ISBN 978-1-84334-594-7.
8. Earnshaw, R.; Vince, J. (Eds.) *Digital Convergence—Libraries of the Future Rae Earnshaw and John Vince*; Springer: London, UK, 2008; ISBN 978-1-84628-903-3.
9. Brown, J.S. Changing How We Think About and Lead Change. In *Library Workforce for 21st Century Research Libraries*; Association of Research Libraries: Washington, DC, USA, 2012.
10. Dempsey, L. Library Collections in the Life of the User: Two Directions. *Liber Q.* **2017**, *26*, 338–359. [CrossRef]
11. Pinfield, S.; Cox, A.M.; Rutter, S. *Mapping the Future of Academic Libraries: A Report for SCONUL*; Society of College, National & University Libraries: London, UK, 2017.
12. Dempsey, L. *The Network Reshapes the Library: Lorcan Dempsey on Libraries, Services, and Networks*; ALA: Chicago, IL, USA, 2014; ISBN 978-0-8389-1997-2.
13. Institute-wide Task Force on the Future of Libraries. *Preliminary Report*; Massachusetts Institute of Technology: Boston, MA, USA, 2016.
14. Hoffman, S. *Dynamic Research Support for Academic Libraries*; Facet: London, UK, 2016; ISBN 978-1-78330-049-5.
15. Research Libraries UK. *Powering Scholarship: RLUK Strategy 2014-17*; Research Libraries UK: London, UK, 2014.
16. Association of Research Libraries. *Report of the Association of Research Libraries Strategic Thinking and Design Initiative*; Association of Research Libraries: Washington, DC, USA, 2014.

17.   Association of Research Libraries. *Strategic Thinking and Design Initiative: Extended and Updated Report*; Association of Research Libraries: Washington, DC, USA, 2016.

18.   LIBER. *Research Libraries Powering Sustainable Knowledge in the Digital Age: LIBER Europe Strategy 2018–2022*; LIBER: The Hague, The Netherlands, 2017.

19.   Lougee, W.P. *Diffuse Libraries: Emergent Roles for the Research Library in the Digital Age*; Council on Library and Information Resources: Washington, DC, USA, 2002; ISBN 1-887334-93-9.

20.   Lougee, W.P. The diffuse library revisited: Aligning the library as strategic asset. *Libr. Hi Tech* **2009**, *27*, 610–623. [CrossRef]

21.   Marcum, D.B.; George, G. (Eds.) *The Data Deluge: Can Libraries Cope with e-Science?* Libraries Unlimited: Santa Barbara, CA, USA, 2010; ISBN 978-1-59158-887-0.

22.   Lincoln, Y.S. Research Libraries in the Twenty-First Century. In *Higher Education: Handbook of Theory and Research*; Springer: Dordrecht, The Netherlands, 2010; Volume 25, pp. 425–448. ISBN 978-90-481-8598-6.

23.   Koltay, T. Are you ready? Tasks and roles for academic libraries in supporting Research 2.0. *New Libr. World* **2016**, *117*, 94–104. [CrossRef]

24.   Cox, J. Communicating New Library Roles to Enable Digital Scholarship: A Review Article. *New Rev. Acad. Librariansh.* **2016**, *22*, 132–147. [CrossRef]

25.   Anglada, L. ¿Son las bibliotecas sostenibles en un mundo de información libre, digital y en red? *Prof. Inf.* **2014**, *23*, 603–611.

26.   Borgman, C.L. *Scholarship in the Digital Age: Information, Infrastructure, and the Internet*; The MIT Press: Cambridge, MA, USA, 2007; ISBN 978-0-262-02619-2.

27.   Webster, D. Strategic Challenges Facing Research Libraries. In *Report and Proceedings of a Seminar on Managing University Libraries, Held on 26–27 August 2002 at the OECD Headquarters in Paris*; OECD: Paris, France, 2002.

28.   Case, M.M. Partners in Knowledge Creation: An Expanded Role for Research Libraries in the Digital Future. *J. Libr. Adm.* **2008**, *48*, 141–156. [CrossRef]

29.   *No Brief Candle: Reconceiving Research Libraries for the 21st Century*; Council on Library and Information Resources: Washington, DC, USA, 2008; ISBN 978-1-932326-30-7.

30.   Smith, A. The Research Library in the 21st Century: Collecting, Preserving, and Making Accessible Resources for Scholarship. In *No Brief Candle: Reconceiving Research Libraries for the 21st Century*; Council on Library and Information Resources: Washington, DC, USA; 2008; pp. 13–20. ISBN 978-1-932326-30-7.

31.   Luce, R.E. A New Value Equation Challenge: The Emergence of eResearch and Roles for Research Libraries. In *No Brief Candle: Reconceiving Research Libraries for the 21st Century*; Council on Library and Information Resources: Washington, DC, USA, 2008; pp. 42–50. ISBN 978-1-932326-30-7.

32.   Heidorn, P.B. The Emerging Role of Libraries in Data Curation and E-science. *J. Libr. Adm.* **2011**, *51*, 662–672. [CrossRef]

33.   Gold, A. Cyberinfrastructure, Data, and Libraries, Part 2: Libraries and the Data Challenge: Roles and Actions for Libraries. *D-Lib Mag.* **2007**, *13*. [CrossRef]

34.   Harris, S. *Moving Towards an Open Access Future: The Role of Academic Libraries*; Sage: Thousand Oaks, CA, USA, 2012.

35.   Rodrigues, E. GRL2020 Position Paper. In *Paving the Way for a Collaborative Global Research Environment: Outcomes of GRL2020 Europe*; GRL2020: Pisa, Italy, 2008.

36.   Griffin, S. New Roles for Libraries in Supporting Data-Intensive Research and Advancing Scholarly Communication. *IJHAC* **2013**, *7*, 59–71. [CrossRef]

37.   2nd Global Research Library 2020. *Paving the Way for a Collaborative Global Research Environment: Outcomes of GRL2020 Europe*; GRL2020: Pisa, Italy, 2008.

38.   Corrall, S. Designing Libraries for Research Collaboration in the Network World: An Exploratory Study. *Liber Q.* **2014**, *24*, 17–48. [CrossRef]

39.   Tancheva, K.; Gessner, G.C.; Tang, N.; Eldermire, E.; Furnas, H.; Branchini, D.; Steinhart, G. *A Day in the Life of a (Serious) Researcher: Envisioning the Future of the Research Library*; ITHAKA and Cornell University Library: New York, NY, USA, 2016.

40.   Gessner, G.C.; Eldermire, E.; Tang, N.; Tancheva, K. The Research Lifecycle and the Future of Research Libraries: A Library of Apps. In *At the Helm: Leading Transformation: The Proceedings of the ACRL 2017 Conference*; ACRL: Chicago, IL, USA, 2017; pp. 533–543.

41. Hartsell-Gundy, A.; Braunstein, L.; Golomb, L. (Eds.) *Digital Humanities in the Library: Challenges and Opportunities for Subject Specialists*; The Association of College & Research Libraries: Chicago, IL, USA, 2015; ISBN 978-0-8389-8768-1.

42. White, J.W.; Gilbert, H. (Eds.) *Laying the Foundation: Digital Humanities in Academic Libraries*; Charleston Insights in Library, Archival, and Information Sciences; Purdue University Press: West Lafayette, IN, USA, 2016; ISBN 978-1-55753-739-3.

43. Kamposiori, C. *The Role of Research Libraries in the Creation, Archiving, Curation, and Preservation of Tools for the Digital Humanities*; RLUK Report; RLUK: London, UK, 2017.

44. Bryant, R.; Clements, A.; Feltes, C.; Groenewegen, D.; Huggard, S.; Mercer, H.; Missingham, R.; Oxnam, M.; Rauh, A.; Wright, J. *Research Information Management: Defining RIM and the Library's Role*; OCLC: Dublin, OH, USA, 2017; ISBN 978-1-55653-031-9.

45. Johnson, I.M. The intelligent university library: Developing a more comprehensive option for the researcher. *Inf. Dev.* **2017**, *33*, 219–223. [CrossRef]

46. Kingsley, D. "Become Part of the Research Process"—Observations from RLUK2017. Available online: https://unlockingresearch-blog.lib.cam.ac.uk/?p=1384 (accessed on 7 March 2018).

47. Lynch, C. Updating the Agenda for Academic Libraries and Scholarly Communications. *Coll. Res. Libr.* **2017**, *78*, 126–130. [CrossRef]

48. Confederation of Open Access Repositories. *Next Generation Repositories: Behaviours and Technical Recommendations of the COAR Next Generation Repositories Working Group*; COAR: Göttingen, Germany, 2017.

49. Nicholas, D.; Boukacem-Zeghmouri, C.; Rodríguez-Bravo, B.; Xu, J.; Watkinson, A.; Abrizah, A.; Herman, E.; Świgoń, M. Where and how early career researchers find scholarly information. *Learn. Publ.* **2017**, 1–11. [CrossRef]

50. Nicholas, D. Publish or perish thwarts young researchers' urge to innovate. *Res. Eur.* **2016**, *440*, 7–8.

51. Bush, V. *Science: The Endless Frontier*; National Science Foundation: Washington, DC, USA, 1945.

52. Research Information Network. *The Value of Libraries for Research and Researchers: A RIN and RLUK Report*; RIN: London, UK, 2011.

53. Vaughan, K.T.L.; Hayes, B.E.; Lerner, R.C.; McElfresh, K.R.; Pavlech, L.; Romito, D.; Reeves, L.H.; Morris, E.N. Development of the research lifecycle model for library services. *J. Med. Libr. Assoc.* **2013**, *101*, 310–314. [CrossRef] [PubMed]

54. Vinopal, J.; McCormick, M. Supporting Digital Scholarship in Research Libraries: Scalability and Sustainability. *J. Libr. Adm.* **2013**, *53*, 27–42. [CrossRef]

55. Björk, B.-C. A model of scientific communication as a global distributed information system. *Inf. Res.* **2007**, *12*, 307.

56. Carlson, J.; Kneale, R. Embedded librarianship in the research context: Navigating new waters. *Coll. Res. Libr. News* **2011**, *72*, 167–170. [CrossRef]

57. Brewerton, A. Re-Skilling for Research: Investigating the Needs of Researchers and How Library Staff Can Best Support Them. *New Rev. Acad. Librariansh.* **2012**, *18*, 96–110. [CrossRef]

58. Plutchak, T.S. A Librarian out of the Library. *J. eSci. Librariansh.* **2016**, *5*, 1–5. [CrossRef]

59. Anderson, R. A quiet culture war in research libraries—and what it means for librarians, researchers and publishers. *Insights* **2015**, *28*, 21–27. [CrossRef]