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Article

A Model for Institutional Infrastructure to Support Digital Scholarship

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Abstract: There is a driving imperative for new knowledge, approaches and technologies to empower scholarship, especially in emerging areas of inquiry. Sources of information now extend beyond the written word to include a wide range of born-digital objects. This paper examines the changing landscape in which digital scholars find, collaborate, create and process information and, as a result, scholarship is being transformed. It discusses the key elements required to build an institutional infrastructure, which will not only support new practices but also integrate scholarly literature into emerging and evolving models that generate true digital scholarship. The paper outlines some of the major impediments in implementing such a model, as well as suggestions on how to overcome these barriers.

Keywords: digital scholarship; built infrastructure; digital artifacts; scholarship

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1. Introduction

As society tackles increasingly complex issues, specialists across a number of disciplines have been examining the role of research and innovation in underpinning solutions to these issues [1–6]. New knowledge, approaches and technologies are discussed as core to proposed strategies. Concurrently the very nature of scholarly communication is changing partly in response to these same drivers. As a result, new research practices are evolving.

In this paper the authors examine this rapidly evolving and transformative landscape in which scholars work. They discuss the emerging concept of *digital scholarship*. The authors conclude with a discussion of the key components required to build an institutional infrastructure to support new practices and new models of scholarship, as well as some of the barriers, which need to be overcome to achieve this goal.

2. Background

The role of new technologies in causing a change or paradigm shift in the practices of research, learning and teaching, and scholarly communication has been, and is continuing to be, widely discussed in the literature. For example, Christensen's [7] theory of *disruptive innovation*, which is based on the changing application of technology in the marketplace, has been expanded to apply more broadly to technologies that have introduced radically different behaviors into society generally. In learning and teaching specifically, there is considerable discussion about the *flipped classroom* [8].

In scholarly publishing, there is a focus not just on new digital reading devices but also on the changing nature of publishing itself. The Internet has enabled new models of scholarly communication in which authors are directly linked with other scholars and readers, and in which distribution models can no longer rely on a wholesale model based on physical content. In an industry, which, by its nature, is content-focused, digital content has disrupted the former relationships and roles among writers, publishers and readers [9]. New publishing and pricing models are being explored for journals, scholarly monographs, textbooks, and digital materials, as the various stakeholders try to establish sustainable business models [10,11]. Along with the impact of open access [12–15], an important trend—from a publishing perspective—has been the emergence of different models for providing access to the data, which underpins published research [16–19].

The rapid development and dissemination of digital technologies have helped to enable interdisciplinary research, not just in "big science" but also in the fast growing field of digital humanities. Electronic networks are making it much easier for investigators from different fields to communicate and collaborate. These rapid changes are pointing toward a very different model of research practice and have led major international, national and funding bodies to examine their respective impact. Both the American Association for the Advancement of Science [5] and the Arts and Humanities Research Council (AHRC) [20] in the UK, for example, have highlighted the importance of interdisciplinary, collaborative approaches. In Europe, the EU RIF2030 Project [6] has been established to explore new and emerging ways of doing research in universities, research organizations, companies and society as a whole.

3. The Changing Nature of Scholarship

Against this backdrop of evolving models in research practice and scholarly communication, especially in regard to publishing, it is not surprising that the concept of *scholarship* has also been undergoing profound change. It is intrinsically linked to these concepts.

Historically scholarship tended to be regarded as work undertaken in a tertiary institution, based on research, which led to publication as a book, book chapter or an article in a peer-reviewed journal. A narrower definition has limited this activity to "original" research conducted in the sciences [21].

Drawing upon the work of others, Boyer [22] subsequently expanded the concept, based on four areas, to show that scholarship is broader than just traditional notions of research: the scholarship of discovery, the scholarship of integration, the scholarship of application, and the scholarship of teaching. His work has been important in helping university departments assess the outputs of their staff.

More recently, Beattie [23] and Diamond [21] have advocated expanding the definition of scholarship to reflect practice in the twenty-first century. In the humanities, particularly English studies, for example, there has been a tendency to attempt to categorize digital outputs as equivalent to print publications instead of considering them in terms of "design and delivery, recentness and relevance, and authorship and accessibility" [24]. Activities, which are undertaken in so-called "nontraditional" areas, need to be recognized as well. The performing arts sector is a primary example. In addition, scholarship, as Diamond [21] suggests, is defined at any given time, depending upon factors such as discipline, individual interests and institutional priorities. As the authors will show later, these are important considerations when building an infrastructure to support an institution's scholarship.

Concepts such as *digital scholarship* and *transformative scholarship* have emerged to describe new ways in which scholars engage with innovative research practices. Digital scholarship is defined by Rumsey [25] as "the use of digital evidence and method, digital authoring, digital publishing, digital curation and preservation, and digital use and reuse of scholarship". Ayres [26] asserts that most frequently it is used to describe "discipline-based scholarship produced with digital tools and presented in digital form". For Pearce *et al.* [27], digital scholarship is more than just the use of information and communication technologies to inform research, collaboration and teaching: "… it is embracing the open values, ideology and potential of technologies born of peer-to-peer networking and wiki ways of working in order to benefit both the academy and society. Digital scholarship can only have meaning if it marks a radical break in scholarship practices brought about through the possibilities enabled in new technologies. This break would encompass a more open form of scholarship."

Transformative scholarship, for its part, tends to focus on the transition from traditional, print-based forms to an integration of digital practices into the intellectual creation process. At the University of Southern California, the Center for Transformative Scholarship's mission is to "facilitate, explore, test, and advance the potentials of new media and networked scholarship for scholarly research, analysis, and publication" [28]. The Center provides a supportive institutional framework for those in the University community who wish to take advantage of developing born-digital scholarly projects. For purposes of this discussion, the authors have included transformative scholarship under the broader term of *digital scholarship* since both concepts are anchored in digital practice.

Fundamental to this overall discussion are also the changing concept of knowledge and the nature of its relationship to scholarship. As with scholarship, "knowledge is perpetually in motion. Today, what we call 'knowledge' is constantly being questioned, challenged, rethought, and rewritten" [29]. According to Wilbanks [30], whereas traditionally knowledge has been thought of as "a paper, a product, property", it can now be thought of as "a network, an infrastructure". Unlike its manifestation in an object, such as a book, which is limited by physical boundaries, knowledge as a network invites both the creator and the reader to link content in ways previously not imagined. As a result, notwithstanding the tendency within institutions to continue time-honored traditional approaches, the increasing dialogue about new possibilities in both the creation and dissemination of scholarship is helping to drive the development of innovation. In this period of transition, there is recognition of the

importance of pushing boundaries and reconceptualizing the form, as well as the very substance, of scholarship.

Digital scholarship potentially has a key role in expanding these boundaries; its outputs will hopefully create new insights. Ayres [26] asserts that "digital scholarship is the missing part of the cycle of productivity that we have long believed our investments in information technology would bring to institutions of higher education." Therefore tertiary educational institutions have an obligation not only to provide the necessary supporting infrastructure to bring this potential to fruition but also to validate digital scholarship as a valued model of scholarship.

In the following section the authors outline the key elements that an institution needs to consider in building the type of infrastructure which can support new models of digital scholarship.

4. Institutional Infrastructure

The *New Oxford American Dictionary* [31] defines *infrastructure* as "the basic physical and organizational structures and facilities needed for the operation of a society or enterprise". Information infrastructure specifically has been discussed in the literature for more than a decade. Two common themes are: (a) the importance of the non-technological aspects – the human components, comprising of standards, social norms, practices with technology that collectively facilitate scholarly work from a distance [32] and (b) the need for interoperability between local and multiple divergent systems [33].

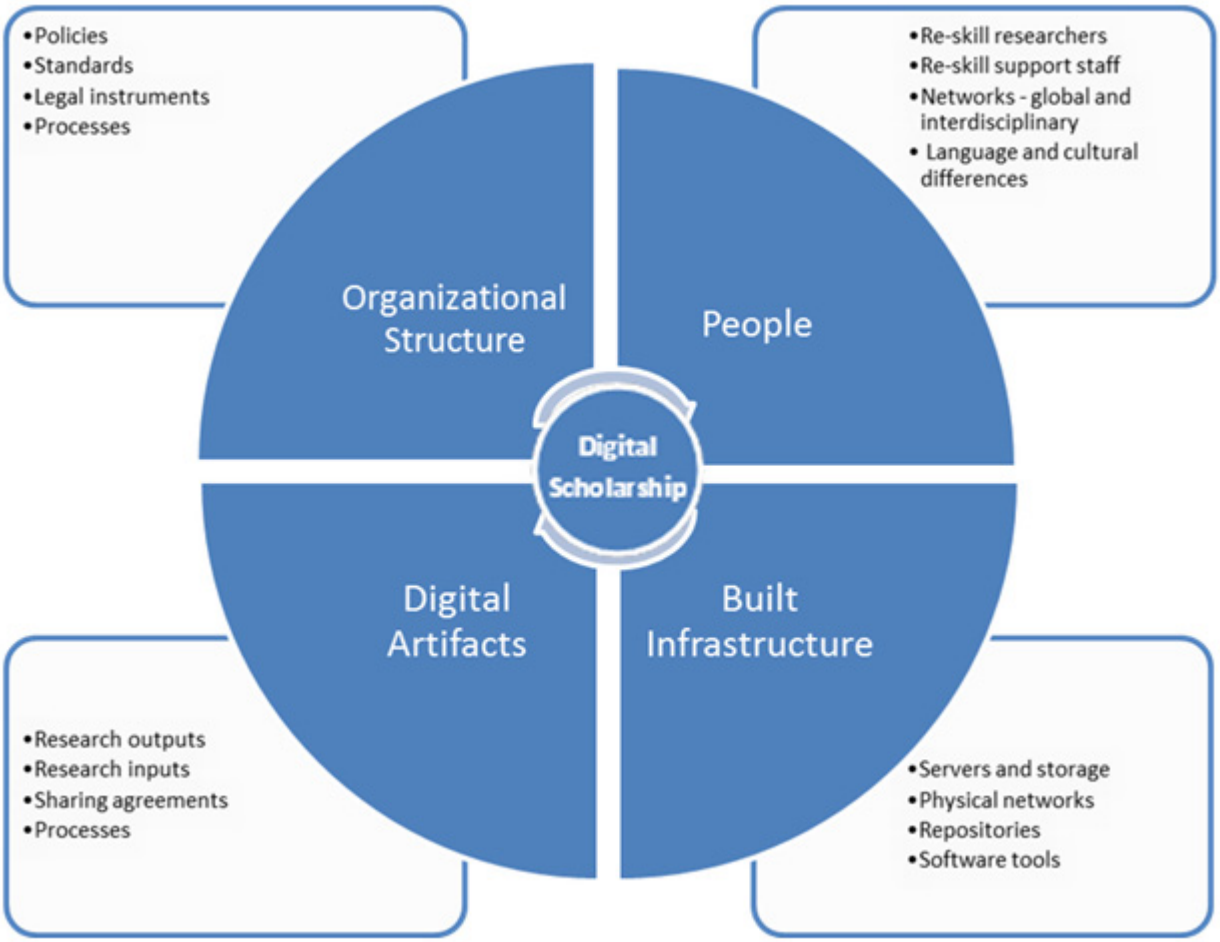
In discussing information infrastructures, Borgman [34] asserts that traditionally initiatives have tended to be oriented toward the purely technical aspects of infrastructure, *i.e.*, infrastructure *of* information, whereas the focus should be on infrastructure *for* information, which encompasses information practices within their specific social context and discipline.

In the specific domain of digital scholarship, innovation values content/artifacts, people and technology as fundamental components. Since knowledge is not created in isolation and is inherently evolving, the corresponding infrastructure needs to integrate these components, which are also continually evolving. This applies both within the institution and on a global level.

The challenge for institutions is to build infrastructure for this new environment, especially for those engaged in digital scholarship. Historically *infrastructure* in this context favors a traditional concept of scholarship in terms of big science. An example is the provisioning of mass storage for "big data". Institutional administrators traditionally have viewed infrastructure as something built for and within their own enterprise. However digital scholarship is about sharing information, collaboration and knowledge creation beyond the enterprise. The institutional infrastructure does not operate in a vacuum; it needs to be regarded as a "node" in the much broader knowledge ecology and regarded as more than just physical infrastructure. Therefore institutional administrators will need to re-conceptualize infrastructure to meet new requirements.

Core components would include organizational structure, built infrastructure, digital artifacts and people (See Figure 1).

Figure 1. Institutional Infrastructure Model.



4.1. Organizational Structure

Organizational structures are those governance structures, policies, standards, legal instruments and processes, which are required to facilitate scholarship. This could include policy changes, regulations, new standards and licensing frameworks, and operational processes required to make research data more easily discoverable and shareable. It includes the roles of organizational units and the financial responsibilities that are required to facilitate the development of the infrastructure.

4.1.1. Current Approaches and Constraints

While the enthusiasm and innovation exemplified by individual digital scholars are readily evident, the same perspective may not necessarily be shared at the institutional level. Weller [10], for example, talks about the significant challenges for scholars when "faced with norms and values which oppose, hinder or fail to recognize these forms of scholarship". He goes on to discuss the general lack of understanding of, and experience with, this type of scholarship by senior university management; this in turn can lead to what Weller terms as "resistance" in recognizing it as a valuable activity.

Ayres [26] makes the point that digital scholarship will not get traction until it ceases to be viewed as a “series of isolated experiments”. While it is true that substantial projects have been underwritten by funding agencies, there is a sense of unrealized potential. Projects may not have been viewed

initially as scholarship because the focus has been more on the underlying technology rather than on creating new disciplinary knowledge.

The challenge, from an organizational perspective, is one of being tied to long-held, policy-based definitions as to what constitutes "research", especially for purposes of funding and/or other high-level activities. For example, in Australia two national research assessment exercises use the reasonably broad Organisation for Economic Co-operation and Development (OECD)'s definition [35] but tend to focus on "publications" as the assessed metric. In addition the national and international ranking of universities in the so-called "league tables", e.g., QS World University Rankings [36], relies on easily quantifiable metrics such as research citations. New forms of digital scholarship, on the other hand, challenge the conventional methods for measuring research impact. Unlike a text-based journal article, they do not currently easily lend themselves to citation analysis.

Much of the potential for digital scholarship is based upon its adoption of open values, e.g., open access, open scholarship, open data. At an institutional level, this "openness" requires a corresponding high-level commitment, if not policy or mandate. While some institutions are notable for their progress, the rate of implementation has been generally slow [37].

As members of their respective institutional community, scholars are frequently subject to regulatory and legal requirements affecting their organization. Some of these may not reflect current digital innovations. In Australia, for example, the *Copyright Act 1968* is being reviewed because it is generally considered that the exceptions and statutory licenses in the *Act* are neither adequate nor appropriate in the digital environment.

4.1.2. Strategies for Overcoming Barriers

In implementing an enterprise-wide strategy, the institution needs to understand both the current and future research needs of its diverse research community. The challenge is to overcome the natural tendency within organizations to have a siloed approach. Therefore, in universities both IT and the library need to partner with key academic groups to understand the current and future research information needs of a diverse university research community. From this understanding will be derived relevant operational processes and policies. Addressing organizational processes is critical to such outcomes as facilitating information flow and the retention of valuable assets. From a governance perspective, some universities have implemented, for example, an advisory group, chaired by the Vice President, Academic Research, (or corresponding role) to ensure input from across all the disciplines.

Proposals to build infrastructure to support new models of scholarship must necessarily be aligned with the strategic goals of the institution. It is, therefore, useful to develop discussion papers for senior executives that articulate an institutional vision within the context of the broader, external environment –including opportunities– and propose a corresponding digital strategy. Each institution's vision will of course be influenced by a range of drivers, which will vary across the sector [21,38]. There is a need to ensure "senior university awareness of, and engagement in, national (and international) research information infrastructure opportunities … if the most effective investment decisions are to be taken" [39]. This can only happen if the institution itself is clear about its digital strategy.

Once the vision and strategy have been articulated, the next step would be to establish the gaps between the current state and the desired state so as to know where to focus effort. A combination of

self-assessment and benchmarking against good practice could be used to inform this fact-finding, even if good practice is still being defined for some areas. For example, providing hard data on how much–and what –research data is stored –and where–within a university and if it is at risk. Analysis done at this stage may lead to revised processes, governance models and policies not only within the organization quadrant but also across the other three quadrants.

As a result of the strategies outlined above, common problems will be identified, from which there will be an opportunity to partner with key stakeholders to address them. The library is ideally positioned to take a lead role in drawing together the various stakeholders to develop institutional strategies to respond to new drivers [40]. MacColl [41] observes, "The library should be knowledgeable about knowledge, and should be the main authority on the campus about the ways knowledge is generated and transmitted through all of the disciplines it contains". It is well positioned to work with diverse groups.

At Griffith University (Australia) the Division of Information Services (includes the library) has capitalized on the development of a researcher profile system to work with key stakeholders on research data management guidelines for the University and to initiate the development of data archives and related systems. In addition to further developing relationships with the researchers involved, this initiative has resulted in an improved communication network within the Division itself as well as within the University as a whole, especially with the Office for Research and with major research centers [42].

Finally institutions should support opportunities to participate in national and international initiatives, which are tackling the high-level challenges discussed in this paper. The Research Data Alliance [43], for example, is developing enablers—social and technical—to facilitate the sharing of open data.

4.2. Built Infrastructure

The traditional approach to meeting IT infrastructure demand is to build it within the institution. Developing solutions for scholarly communities internal and external to the institution requires a mixture of local and cloud infrastructure and internal and external services. For example, institutional-based communication and collaboration technologies such as video conferencing are used in combination with consumer-based solutions, such as Skype, to facilitate scholarship. Institutions need to develop blended infrastructure solutions to support scholarship beyond the enterprise gateway, which operates in hidden sub-surface ecosystems [33]. From the scholar's perspective, ideally the underlying technologies should operate seamlessly.

4.2.1. Current Approaches and Constraints

Infrastructure planning approaches have tended towards developing built infrastructure within the institution. However, this has changed in recent times to leverage the cost savings and efficiencies of using cloud infrastructure, whether as Infrastructure as a Service (IaaS), Software as a Service (SaaS) or Platform as a Service (PaaS). This has seen the use of externally hosted solutions for email and other corporate systems. However, this approach still tends to develop single purpose solutions and does not take into account that there are now many services available to scholars outside of the

institution, especially for collaboration and storage. On the one hand, the institution may provide an enterprise solution for video conferencing or working storage, while on the other hand most scholars may be using instead common tools, such as Skype or Dropbox. For those institutions attempting to address this problem a variety of technical issues present themselves with regard to integration and lack of industry standards.

Another constraint is the institutional and system view of identity management. Generally institutions have identity management systems, which are restricted to current employees or user accounts created through some internal process. This is problematic to scholars seeking secure mechanisms to share data and information with a community, which has members across many institutions. In some institutions there is no coordinated central planning around these core services.

Central support for specialized scholarly applications is generally limited. The increasing use of information and communications technology (ICT) to respond to demands of scholarship—including online learning, managing and analyzing big data, and support for large communities of researchers—has been driven from the discipline level, frequently through the use of grant funding. Institutional support for many of these bespoke solutions is limited because of lack of sustainable resourcing coupled with the fact that the solutions have been developed to service communities across many institutions. Without an institutional "champion" providing ongoing support, many of these solutions are at risk.

There are also many scholars who are not well serviced with solutions to meet their specific research needs. In such cases, institutional funding does not tend to provide ongoing sustainable resources to develop and maintain these, e.g., lack of skilled staff to redevelop in-house desktop modeling software tools to meet the needs for a researcher to run larger or faster models on Amazon Web Services. This also occurs at the hardware level since many institutions have standardized infrastructure to drive down costs and leverage economies of scale in purchasing and support. This approach comes at the expense of flexibility. Researchers often require non-standard solutions for their purposes, such as software necessitating a non-standard hardware set up or a high speed network connection or the ability to host an application for their project community to use. All these constraints act as barriers for scholars seeking to leverage IT to increase their capacity or capability or to easily collaborate with colleagues across the globe. Central planners need to regard their infrastructure as a node in a global IT ecosystem rather than as just local, physical infrastructure built only for use within their own institution.

Many institutions attempt to address these issues by deploying new products only to find that uptake is low. Two common reasons are that (a) these projects tend to be limited in scope to just deploying the product and are not well resourced to assist end-users to leverage the product for their own use; and (b) the end-users themselves have little incentive to allocate time to learn how the new tools and services could be used to their advantage.

4.2.2. Strategies for Overcoming Barriers

The increasing use of cloud-based solutions has seen a new approach to designing and building IT and information architectures to support more flexibility, thereby allowing for easier integration and coupling of systems. This is also reflected in the development of relevant international standards.

There is also evidence of increasing collaboration to resolve some of these problems. For example, new solutions are emerging or are being addressed to manage identities whether between institutions (e.g., the Australian Access Federation [44]) or resolving multiple identities to a single individual (e.g., through an institutional and/or Open Researcher and Contributor ID (ORCID) [45] identity). Institution planners will need to actively participate in these activities.

National and international solutions are emerging for the sharing of resources through collaboration and partnerships. For example, in the Australian research environment, key stakeholders—including funding bodies such as the Australian Research Council and the National Health and Medical Research Council, research institutes and universities—have recognized the need to share knowledge. In building its national collaborative infrastructure, the Australian National Data Service has utilized a federated approach, which supports multi-layers, *i.e.*, Research Data Australia [46] aggregates at the national level data about Australian research, which has been aggregated at the local level.

Individual institutions are partnering and, in some cases, taking lead roles in developing new community-based solutions, such as the participation in the aforementioned Research Data Alliance or the development of national solutions, e.g., Biodiversity & Climate Change Virtual Laboratory [47]. Institutional decision makers will need to decide when it is best to collaborate and when the solution should be an institutional owned investment. Institutions will also need to decide how many resources should be allocated to support scholars using technology developed elsewhere.

The current approach to infrastructure planning is to plan from the center. New models will need to be developed in which disciplines and communities can articulate their infrastructure needs to be accommodated within the central resource allocation. This will require a planning model based on partnering between infrastructure providers and key stakeholder groups within the respective institutions. This will require the identification of key stakeholders within the institution.

It is already apparent that institutions need to preserve research outputs beyond the traditional text-based outputs. This will require a closer working relationship with researchers, e.g., primary research data sets, software, video, and websites.

4.3. Digital Artifacts

Digital artifacts are the digital assets, *i.e.*, the content, required to develop new knowledge. These need to be created/acquired, stored, delivered, and used as appropriate in a timely manner while respecting the terms of the artifact owner. The institution has a responsibility for making these artifacts available in formats and context suitable for interpretation, analysis and manipulation for scholars across disciplines, internal and external to the institution.

4.3.1. Current Approaches and Constraints

The typical approach to preserving digital artifacts is to address this issue at the end of the project, at a time when resources are limited, enthusiasm is waning and there is no incentive to curate and clean up the data for preservation. In addition, there are few, if any, skilled people available with the curation and preservation skills required to assist the researchers in making these artifacts available in formats and context suitable for discovery, interpretation, analysis and manipulation for scholars across disciplines and across the globe.

There is a specific issue in relation to properly describing and preserving details around IP, licensing and other regulatory, legal and compliance materials such as ethics clearances. Unfortunately licensing and data sharing agreements tend to be on a project-by-project basis. The preservation task would be less onerous if licensing or data sharing were mandated at the government or institutional/ agency level. Additionally, within institutions all these materials tend to reside in different repository siloes, e.g., legal agreements are retained in corporate record archives but the data collected as a result of such agreements is stored elsewhere with no cross referencing.

Generally institutions do not have expertise or strategies in digital preservation. There are a number of reasons for this, such as:

- the needs to date have not warranted it
- the level of resources required, e.g., refreshing old formats is both labor-intensive and expensive
- the evolving nature of the problem (e.g., archiving of digital material regarded as a storage problem under the responsibility of the IT department who traditionally do not have preservation/archival expertise), and
- lack of institutional policies and guidelines about what to retain and what to discard.

In support services, there is a lack of processes to intervene in the research lifecycle to provide assistance at the right time. For example, processes to alert support services when a researcher is:

- drafting a research grant proposal, so as to assist in developing a data management strategy, or
- about to publish a paper, so as to check whether there is supporting data that needs to be published.

There is also a constraint in that some artifacts, by their inherent nature, do not lend themselves easily to sharing or to typical preservation processes, for example, a piece of software or a very large data set [48].

4.3.2. Strategies for Overcoming Barriers

Global movements in open scholarship, data, and access have the potential to address many of the licensing and IP issues. These movements are increasingly being supported with mandates from funding agencies (e.g., Wellcome Trust, National Science Foundation, Australian Research Council) about preserving data, open models, linking publications to grants to data, *etc*. With big questions now being asked universally in public forums (e.g., recent studies outlining how much money universities are paying for major publisher subscriptions), there is promise that some of the problems at the institutional level will be resolved at the national and international level.

Additionally, in many countries governments themselves are moving towards open data in relation to administrative data [49–51]. While this may not resolve IP and licensing problems with legacy artifacts, it does open the doors for much simpler preservation and access mechanisms for the future.

Preservation services are now being developed through national initiatives, e.g., National Collaborative Research Infrastructure Strategy (NCRIS) [52] in Australia, or within discipline communities or through third party offerings, e.g., Dryad [19] and Figshare [53].

While all of the above provides an encouraging picture for the preservation of scholarly outputs, it does not resolve the current inefficiencies and ineffectiveness of how data is captured, manipulated and finally stored and reused. An analogy can be made here in the industrial design response to recycling in which product design is increasingly moving to a cradle to the cradle approach, *i.e.*, you design the solution anticipating the product will be used until end of life and then will be diverted to be used as input to other products [54]. When scholars begin a project, they should be planning to capture, format, describe and preserve all the relevant data, inputs and outputs, from the activity so that they can be potentially used as inputs in future scholarly activities by other scholars. This will involve decisions about what needs to be kept and what can be deleted during and at the end of the project, based on knowledge about the data, e.g., what might be useful at some later date. The data retained may include data additional to what is cited in the published article from a specific research activity. For example, an article may only reference a subset of all the collected data.

The library within the institution is a logical potential source of skills and expertise in managing information and preservation. To be effective, however, will require a common approach and partnership with the IT department to (a) supply the hardware infrastructure to meet the needs either provisioned locally or through the cloud; (b) to leverage external services as needed, e.g., those funded by governments or specific discipline data repositories; and (c) collaboration and partnering with other institutions to develop cost-effective solutions. This will also need to extend to better engagement with key stakeholders within the institution so as to have better points of intervention.

4.4. People

The final component is the role of people as key to an infrastructure solution for digital scholarship. Not only do institutions need to develop the skills required in their support service personnel but also they have a role in developing the skills of scholars themselves in new methods and processes to create, manage and use born-digital artifacts. This also extends to building awareness about emerging organizational structures such as global standards and licensing frameworks. Scholars also need to find and join networks specific to their domain and gain an understanding of the global context of their research activities, e.g., lingual and cultural impacts, and opportunities for collaboration and data sharing.

4.4.1. Current Approaches and Constraints

Lynch [55] regards the biggest challenge for universities as the design and staffing of organizations that will work with academics to access local, national and global cyberinfrastructure services, assisting faculty to manage their data, prepare for handoff for curation and aiding them in data reuse, mining, and computation. While Lynch may have been thinking of big data—and particularly as it applies to the sciences—attributes such as volume, variety and complexity are equally applicable to all disciplines.

In the organization quadrant, we discussed the importance of "openness" which characterizes much of the work being done in digital scholarship and the importance for the institution to have a clearly articulated high-level commitment to this concept. That said, the idea of sharing resultant research outputs or collaborating in research is not necessarily part of the culture of every discipline, let alone individual researchers. This has been highlighted by the AHRC [20] in their view that "there will be greater need to bring arts and humanities researchers together to influence the context in which they

work; to build consortia, cross-disciplinary networks and multi-funder partnerships; and to support individual researchers to forge stronger relationships with academics overseas".

As also discussed within the organization quadrant, if there is not a high-level recognition of the value of digital scholarship to the institution, then there may be little incentive for a researcher to innovate or set aside time to develop new methods and techniques to improve the processes for creation, management and analysis of born-digital artifacts. This lack of knowledge and skills may extend to a researcher's potential lack of knowledge of international standards and frameworks as well as a lack of appreciation of the global context for their research activity.

In addition there is the overarching problem of the failure to break the text-based paradigm as the mode of delivery of publishing research [26]. Researchers may not set aside time to leverage either new channels or mediums, e.g., social media, or all the potential outputs from their research, such as publishing data [48].

The focus of support within the IT and library support services is typically internally focused, *i.e.*, delivering services and resources supplied by the institution. How do these support services become familiar with the offerings from sources external to the institution, whether they are widely used consumer based technologies and services or specific solutions developed within particular disciplines of scholars? This can be difficult to achieve when support services are constrained by internally developed standards, guidelines and policies, which do not allow for more loosely coupled solutions that blend or integrate internal and external offerings.

4.4.2. Strategies for Overcoming Barriers

Having a good understanding of key partners with whom scholars are collaborating would assist institutional planners to further refine their service offerings. For example, for institutions beginning to engage with Asian countries, institutional service planners may need to incorporate a response into their service delivery approach, e.g., providing services and resources in a number of specific languages, or addressing communication network and collaboration technology problems specific to those partner countries to better facilitate collaboration.

Assisting scholars to further develop their skills will require better targeted outreach services within the institution by addressing the specific needs of different cohorts (e.g., PhD students, early career scholars) and discipline groups (e.g., humanities, medicine). Having a well-defined and communicated vision and strategy at the institutional level should cascade down to the internal group and individual level and lend itself to skills development planning exercises. This could also lead to institutional initiatives to address specific issues, for example, the establishment of centers of expertise, such as the University of Southern California's Centre for Transformative Scholarship [28], and Columbia University Libraries' Digital Social Science Center [56] and Digital Humanities Center [57].

Better business intelligence would also be useful in targeting support service resources. For example, data librarians should know when scholars begin projects or when they publish in order to proactively intervene at key points to assist researchers during the research cycle. This would require the gathering of data and developing of processes to provide information to support services in a timely manner.

While the library may be able to assist with preservation, much of the knowledge and expertise required to decide what needs to be preserved and how it should be described and formatted for potential research still remains within the specific discipline. Developing the knowledge and skills base will require either information professionals acquiring discipline knowledge (e.g., a discipline data librarian) or scholars acquiring this knowledge and skills as part of their professional development.

Changing the behavior of individuals, the culture of institutions and developing new skills takes time and unfortunately is typically slower than the rapid change of technologies and globalization, which are driving these changes. Strategies will need to be developed to address the varying levels of awareness and skill sets within the institution.

4.5. Legacy Infrastructure

Star and Ruhleder [58] make the point that infrastructure is typically developed from an installed base, inheriting both strengths and limitations from that base. New systems are designed for backward compatibility; failing to account for these constraints may be fatal or distorting to new development processes. While Star and Ruhleder were mainly referring to built infrastructure, the same constraint applies to other components of the infrastructure. For example, infrastructure impacted could be artifacts licensed under old licensing regimes or data sets preserved using obsolete standards or formats or, as mentioned above, staff with out-of-date skills. A key challenge for institutional planners is responding to these legacy issues without compromising their vision.

5. Conclusions

The impact of disruptive technologies has been examined on research practice and publishing, with particular reference to the changing world of digital scholarship. If scholars are to maximize the full potential of new models for the creation and dissemination of their research, their parent institutions have a responsibility to build supporting institutional infrastructure and to validate digital scholarship as a valued model of scholarship.

The proposed model is based on the concept that technology development should have a synergistic relationship with organizational structure, people and digital artifacts. As each institution builds infrastructure in this new environment, it becomes a node in a global knowledge ecology based on open values.

Empowering scholarship through the creation of new knowledge, approaches and technologies is a work in progress, which requires profound change in practice. Juxtaposed is the continuation of conservative, traditional practices within highly complex, competitive academic reward systems. Although not without tension, this evolving landscape should be viewed as a period of transition in which scholars, institutions and other actors ultimately validate new models of scholarship.

Author Contributions

Malcom Wolski and Joanna Richardson contributed equally to the literature review and the development and analysis of the proposed model. The content of this paper is solely the responsibility of the authors.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Georges, G.; Goldsmith, S. Leading social innovation. *Innovations* **2010**, *5*, 13–21.
2. Austrom, D.R.; Lad, L.J. Problem-solving networks: Towards a synthesis of innovative approaches to social issues management. *Acad*. *Manag*. *Proc*. **1986**, *46*, 311–315.
3. Jordan, T.; Andersson, P.; Ringnér, H. The spectrum of responses to complex societal issues: Reflections on seven years of empirical inquiry. *Integr*. *Rev*. **2013**, *9*, 34–70.
4. Sandland, R. Introduction to ANDS. *Share: Newsl*. *Austr*. *Natl*. *Data Serv*. **2009**, *1*. Available online: http://ands.org.au/newsletters/newsletter-2009-07.pdf (accessed on 1 July 2014).
5. *Facilitating Interdisciplinary Research and Education: A Practical Guide*; Derrick, E.G., Falk-Krzesinski, H.J., Roberts, M.R., Eds.; American Association for the Advancement of Science: Washington, DC, USA, 2011.
6. Committee Encouraging Corporate Philosophy; McKinsey. *Shaping the Future: Solving Social Problems through Business Strategy*; CECP: New York, NY, USA, 2010.
7. Christensen, C.M. *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*; Harvard Business Review Press: Boston, MA, USA, 1997.
8. Bull, G.; Ferster, B.; Kjellstrom, W. Connected classroom-inventing the flipped classroom. *Learn*. *Lead*. *Technol*. **2012**, *40*, 10.
9. Disabato, N. Publication standards part 1: The fragmented present. *Dyn*. *Publ*. **2012**. Available online: http://alistapart.com/article/publication-standards-part-1-the-fragmented-present (accessed on 23 February 2014).
10. Weller, M. *The Digital Scholar: How Technology is Transforming Scholarly Practice*; Bloomsbury: London, UK, 2011.
11. Arts & Humanities Research Council. *The Academic Book of the Future: Call for Proposals*; AHRC: Swindon, UK, 2014. Available online: http://www.ahrc.ac.uk/Funding-Opportunities/Pages/Future-of-the-Academic-Book.aspx (accessed on 23 February 2014).
12. Mierzejewska, B.I. Disruptive innovations in book publishing-threat or opportunity? *Int*. *J*. *Bk*. **2010**, *7*, 51–60.
13. Owens, S. Is academic publishing industry on the verge of disruption? 2012. Available online: http://www.usnews.com/news/articles/2012/07/23/is-the-academic-publishing-industry-on-the-verge-of-disruption (accessed on 23 February 2014)

14. Daniels, J.; Thistlethwaite, P. *Engaging Academics and Reimagining Scholarly Communication for the Public Good: A Report*; The Graduate Center, CUNY, JustPublics@365: New York, NY, USA, 2014. Available online: http://library.gc.cuny.edu/aleph/JP365%20Report%20Final%20031014.pdf (accessed on 22 April 2014).
15. Welcome to OAPEN-UK. Jisc Collections: London, UK. Available online: http://oapen-uk.jiscebooks.org (accessed on 18 April 2014).
16. *Managing Research Data*; Pryor, G., Ed.; Facet: London, UK, 2012.
17. Faniel, I.M.; Zimmerman, A. Beyond the data deluge: A research agenda for large scale data sharing and re-use. *Int. J. Digit. Curat.* **2011**, *6*, 58–69.
18. GigaScience. Available online: http://www.gigasciencejournal.com (accessed on 18 April 2014).
19. Dryad Digital Repository. Available online: http://datadryad.org (accessed on 18 April 2014).
20. Arts & Humanities Research Council. *The Human World. The Arts and Humanities in Our Times. AHRC Strategy 2013–2018*; AHRC: Swindon, UK, 2013.
21. Diamond, R.M. Defining scholarship for the twenty-first century. *New Dir. Teach. Learn.* **2002**, *2002*, 73–80.
22. Boyer, E.L. *Scholarship Reconsidered: Priorities of the Professoriate*; Carnegie Foundation for the Advancement of Teaching: Princeton, NJ, USA, 1990.
23. Beattie, D.S. Expanding the view of scholarship: Introduction. *Acad. Med.* **2000**, *75*, 871–876.
24. Purdy, J.P.; Walker, J.R. Valuing digital scholarship: Exploring the changing realities of intellectual work. *Profession* **2010**, *2010*, 177–195.
25. Rumsey, A.S. New-model scholarly communication: Road map for change. In *Scholarly Communication Workshop 9*; University of Virginia: Charlottesville, VA, USA, 13–15 July 2011. Available online: http://www.uvasci.org/wp-content/uploads/2011/04/SCI9-report.pdf (accessed on 23 February 2014).
26. Ayres, E.L. Does digital scholarship have a future? *Educause Rev.* **2013**, *48*, 24–34.
27. Pearce, N.; Weller, M.; Scanlon, E.; Kinsley, S. Digital scholarship considered: How new technologies could transform academic work. *Education* **2012**, *16*, 33–44.
28. Mission Statement. University of Southern California Center for Transformative Scholarship: Los Angeles, US. Available online: http://transformative.usc.edu/?page_id=138 (accessed on 18 April 2014).
29. Edwards, P.N.; Jackson, S.J.; Chalmers, M.K.; Bowker, G.C.; Borgman, C.L.; Ribes, D.; Burton, M.; Calvert, S. *Knowledge Infrastructures: Intellectual Frameworks and Research Challenges*; Deep Blue: Ann Arbor, MI, USA, 2013. Available online: http://hdl.handle.net/2027.42/97552 (accessed on 23 February 2014).
30. Wilbanks, J. New metaphors in scientific communication: Libraries and the commons. In Proceedings of the International Association of Scientific and Technological University Libraries (IATUL 2007), Stockholm, Sweden, 11–14 July 2007.
31. *New Oxford American Dictionary*; Oxford University Press: Oxford, UK, 2013. Available online: http://www.oxfordreference.com/view/10.1093/acref/9780195392883.001.0001/m_en_us1258048?rskey=WWVKN4&result=40149 (accessed on 14 April 2014).

32. Edwards, P.N.; Jackson, S.J.; Bowker, G.C.; Knobel, C. *Understanding Infrastructure: Dynamics, Tensions and Design*; National Science Foundation Office of Cyberinfrastructure: Arlington, VA, USA, 2007. Available online: http://hdl.handle.net/2027.42/49353 (accessed on 14 April 2014).
33. Monteiro, E.; Pollock, N.; Hanseth, O.; Williams, R. From artefacts to infrastructures. *Comp. Support. Comp. W.* **2013**, *22*, 575–607.
34. Borgman, C.L. *Scholarship in the Digital Age*; MIT Press: Cambridge, MA, USA, 2007.
35. Organisation for Economic Co-operation and Development. *Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development*, 6th ed.; OECD: Paris, France, 2002.
36. QS World University Rankings. Available online: http://www.topuniversities.com/university-rankings (accessed on 18 July 2014).
37. Schmidt, B.; Kuchma, I. *Implementing Open Access Mandates in Europe: OpenAIRE Study on the Development of Open Access*; Universitätsverlag Göttingen: Gottingen, Germany, 2012. Available online: http://goedoc.uni-goettingen.de/goescholar/bitstream/handle/1/8962/oa_mandates.pdf?sequence=1 (accessed on 18 July 2014).
38. Maron, N.L.; Pickle, S. *Sustaining the Digital Humanities Host Institution Support beyond the Start-Up Phase*; Ithaka S+R: New York, NY, USA, 2014. Available online: http://www.sr.ithaka.org/sites/default/files/SR_Supporting_Digital_Humanities_20140618f.pdf (accessed on 18 July 2014).
39. O'Brien, L. Innovation and information infrastructure: Making sound investments for e-research. *ECAR Res. Bull.* **2010**, *22*, 1–12.
40. Luce, R.E. *A New Value Equation Challenge: The Emergence of eResearch and Roles for Research Libraries*; Council on Library and Information Resources: Washington, DC, USA, 2008.
41. MacColl, J. Library roles in university research assessment. *Liber. Q.* **2010**, *20*, 152–168.
42. Wolski, M.; Richardson, J.; Rebollo, R. Shared benefits from exposing research data. In Proceedings of the 32nd Annual IATUL Conference Proceedings, Warsaw, Poland, 29 May–2 June 2010. Available online: http://www.bg.pw.edu.pl/iatul2011/proceedings/ft/Wolski_M.pdf (accessed on 17 July 2014).
43. Research Data Alliance. Available online: https://rd-alliance.org/ (accessed on 18 July 2014).
44. Services Overview. Australian Access Federation: Brisbane, Australia. Available online: http://aaf.edu.au/services/services-overview/ (accessed on 18 July 2014).
45. ORCID (Open Researcher and Contributor ID). Available online: http://orcid.org/ (accessed on 18 July 2014).
46. Research Data Australia. Available online: https://researchdata.ands.org.au/ (accessed on 18 July 2014).
47. Biodiversity & Climate Change Virtual Laboratory. Available online: http://www.bccvl.org.au/ (accessed on 18 July 2014).
48. Barbour, V. PLoS, ORCIDs and article level metrics. Available online: http://www.youtube.com/watch?v=o7BP4KhRqj8 (accessed on 18 July 2014).
49. Data.gov. US General Services Administration: Washington, DC, US. Available online: https://www.data.gov/ (accessed on 18 July 2014).
50. Data.gov.uk. Available online: http://data.gov.uk/ (accessed on 18 July 2014).

51. Data.gov.au. Available online: http://data.gov.au/ (accessed on 18 July 2014).
52. National Collaborative Research Infrastructure Strategy. Available online: https://www.education.gov.au/national-collaborative-research-infrastructure-strategy-ncris (accessed on 18 July 2014).
53. About Figshare. Figshare: London, UK. Available online: http://figshare.com/ (accessed on 18 July 2014).
54. Braungart, M.; McDonough, W. *Cradle to Cradle: Remaking the Way We Make Things*; North Point Press: New York, NY, USA, 2001.
55. Lynch, C. The institutional challenges of cyberinfrastructure and e-research. *Educause Rev*. **2008**, *43*, 74–88.
56. Digital Social Science Center (Columbia University Libraries). Available online: http://library.columbia.edu/locations/dssc/about.html (accessed on 18 July 2014).
57. Mission and Program of the Digital Humanities Center. Columbia University Libraries: New York, NY, US. Available online: http://library.columbia.edu/locations/dhc/about/program_mission.html (accessed on 18 July 2014).
58. Star, S.L.; Ruhleder, K. Steps toward an ecology of infrastructure: Design and access for large information spaces. *Inf. Syst. Res*. **1996**, *7*, 111–134.