New Media Consortium Horizon Report: 2017 Library Edition Postprint

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Abstract

[Purpose/Significance] To explore the impact of key trends, significant challenges, and technological developments on the strategic, operational, and service dimensions of libraries in learning, innovative exploration, and information management, thereby providing a reference and technical planning guide for librarians, library directors, library staff, policymakers, and technical personnel. [Method/Process] An expert panel comprising education and technology specialists from 14 countries across five continents was convened, which through systematic review of literature related to emerging technologies, discussion of their applications, brainstorming sessions to focus the report's core content, and finally, based on a modified Delphi method, determined the content to be included in the report. [Results/Conclusions] Six key trends, six significant challenges, and six major technological developments are proposed, primarily including: libraries remain gatekeepers of rich information and knowledge; integrating new media and technologies into strategic planning is crucial; libraries must adapt to and keep pace with the evolving development of data storage and publication, as well as the formats of scholarly records and publications; open access represents a potential solution for libraries to address financial constraints; libraries must balance their spatial functions as venues for both independent learning and collaboration; digital scholarship technologies support the continuous evolution of research fields within the library community; artificial intelligence and the Internet of Things will expand the utility and boundaries of library services, among others.

Full Text

Preamble

Starting with this issue, the journal is launching a new column titled "Overseas Observations," which will primarily publish copyrighted translations of important foreign research reports or academic papers, introductory articles on

overseas library and information science theory and practice, reflections and commentaries, and original English research papers by foreign scholars. This column aims to provide a window for domestic (mainland) scholars and practitioners to understand the latest developments and changes in overseas library and information science theory and practice. We warmly welcome submissions from Chinese and foreign experts and scholars with overseas study and research experience or a solid research foundation in overseas library and information science. This issue proudly presents the highly influential *NMC Horizon Report: 2017 Library Edition* (translated with authorization) translated by Zhao Yan and colleagues for our readers. Please follow and share.

NMC Horizon Report: 2017 Library Edition

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Abstract

[**Purpose/Significance**] This report examines how key trends, significant challenges, and technological developments will impact the strategies, operations, and services of academic and research libraries in learning, creative inquiry, and information management. It serves as a reference and technology planning guide for librarians, library directors, library staff, policymakers, and technologists. [**Method/Process**] An expert panel composed of education and technology experts from 14 countries across five continents systematically reviewed literature related to emerging technologies, discussed their applications, brainstormed core content for the report, and finalized the included content using a modified Delphi method. [**Result/Conclusion**] The report identifies six key trends, six significant challenges, and six important technological developments, including: libraries remaining gatekeepers of rich information and knowledge; the critical importance of incorporating new media and technologies into strategic planning; libraries' need to adapt to evolving data storage and publishing, and formats of scholarly records and publications; open access as a potential solution to financial constraints; libraries' need to balance their spatial functions as venues for both independent learning and collaboration; digital scholarship technologies

supporting the evolving research landscape in the library community; and artificial intelligence and the Internet of Things expanding the utility and boundaries of library services.

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What will academic and research libraries look like in five years? Which trends and technological developments will drive library transformation? What are the main challenges facing libraries, and how can they develop solutions to address these difficulties and challenges? These questions about technology application and educational transformation sparked discussions among 77 experts, leading to the launch of the *NMC Horizon Report: 2017 Library Edition* in collaboration with the University of Applied Sciences Chur (Switzerland), the German National Library of Science and Technology, ETH Zurich Library, and the Association of College & Research Libraries (ACRL). The Horizon series reports depict the profound impact of innovative practices and technologies on global academic and research libraries over the next five years. After 15 years of research and publication, the New Media Consortium (NMC) Horizon Project has been recognized as a persistent exploration of emerging technology trends and applications in the education sector.

The six key trends, six significant challenges, and six technological developments presented in this report will influence library strategies, operations, and services in learning, creative inquiry, and information management. The report's three sections provide reference and technology planning guides for librarians, library directors, library staff, policymakers, and technologists. The following 10 highlights roughly reflect 18 key areas of organizational change:

1. Libraries remain gatekeepers of rich information and knowledge. As network resources increase, libraries are obligated to explore new methods to organize and disseminate information so users can more easily discover, absorb, and track resources.
2. Incorporating new media and technologies into strategic planning is critical. Libraries must adapt to and keep pace with the evolution of data storage and publishing, and formats of scholarly records and publications, to meet users' growing social consumption demands for video, visualization, virtual reality, and other resources.
3. Open access is a potential solution for libraries facing financial constraints. Open access resources and publishing models can alleviate problems caused by rising subscription costs for paywalled journals and continuously increase the accessibility of academic research outputs. Although not newly launched, existing methods and practices have not yet maximized their effectiveness.
4. Libraries must balance their spatial functions as venues for independent learning and collaboration. As hubs of university campuses, libraries are

no longer limited to being places for quiet reflection; the flexibility of their physical spaces is becoming increasingly important.

5. Effectively meeting user needs requires user-centered top-level design. Adopting universal design principles and establishing programs for continuously collecting user needs data will help libraries achieve their ultimate goals of learning support and research output.
6. Promoting digital literacy is a core responsibility of libraries. Libraries should be positioned to cultivate users' digital citizenship capabilities, ensuring they master reliable and creative technologies, including online identity, communication etiquette, rights, and responsibilities.
7. Libraries must actively defend their fundamental values. During times of economic and political turbulence, libraries will face many challenges in maintaining information privacy and intellectual freedom while advocating against policies that undermine the public interest and net neutrality.
8. Advancing innovative services and operations requires restructuring library organizational frameworks. Rigid hierarchies are no longer effective. To meet user needs, libraries must draw knowledge from different functional areas and expertise, adopting flexible matrix management paradigms.
9. Research landscapes are continuously evolving with support from digital scholarship technologies. GIS data, data visualization, and big data are expanding methods of information collection and sharing. These tools provide more collaboration opportunities while helping libraries preserve and mine their collections.
10. Artificial intelligence and the Internet of Things will expand the utility and boundaries of library services. These emerging technologies can help users more effectively find the resources they most need, providing personalized user experience services.

The NMC hopes this analysis will help academic and research libraries gain more choices in improving, supporting, or expanding learning and research. Just as education decision-makers worldwide expect from NMC Horizon publications, we hope the *NMC Horizon Report: 2017 Library Edition* will provide reference for technology planning.

The Horizon series reports, internationally recognized, and regional NMC Technology Outlook series reports are part of the NMC Horizon Project, launched in 2002 to interpret the significant impact of emerging technologies on technology planning and decision-making support in global education. NMC publishes four Horizon Report versions annually—Higher Education Edition, K-12 Education Edition, Museum Edition, and Library Edition—focusing on six key trends, six challenges, and six technological developments or application practices most likely to become mainstream applications over the next five years (2017-2021).

The following report content presents 18 technology application themes related to learning, research, and information management selected by the library expert panel in 2017. Using concise, objective, non-technical language, the re-

port elaborates in detail on how these themes may impact the core business of academic and research libraries. Each theme focuses on policy, leadership, or practice-related core issues.

Tracing history is important for planning the future. Reviewing three previously published NMC Horizon Report Library Editions reveals recurring major research themes such as scientific data management and the need to respond to radical change. These themes were regularly voted on by large research teams composed of education technology leaders and technology experts. Table 1 lists research findings from the 2014, 2015, and 2017 Library Editions. (For consistency, some theme names have been slightly modified from their original versions.)

Table 1 NMC Horizon Report: Three Library Editions

2014 Edition	2015 Edition	2017 Edition
Technology standards and infrastructure advances	Increasing accessibility of research content	Evolving nature of scholarly record
User as creator	User as creator	User as creator
Cross-institution collaboration	Cross-institution collaboration	Cross-institution collaboration
Optimizing mobile content and discovery	Optimizing mobile content and discovery	Scientific data management
Scientific data management	Scientific data management	Emphasis on user experience
Rethinking library spaces	Rethinking library spaces	Rethinking library spaces
Rise of new forms of interdisciplinary research	Rise of new forms of interdisciplinary research	Digital scholarship technologies
Emphasis on user experience	Emphasis on user experience	Artificial intelligence and IoT
Bibliometrics and citation technologies	Digital scholarship technologies	

For overlapping themes across versions, note that while some research themes recur, they only represent a general framework for library transformation. Each trend, challenge, and technological development evolves over time, with new perspectives and dimensions emerging annually. For example, the latest research content on scholarly records differs from previous versions. New developments in open access and new research models have expanded the possibilities for information storage, access, and communication.

Themes that almost made but were not selected for the research report are also noteworthy. Since the expert panel only selected the 18 themes they believed

would have the most profound impact, some themes that failed to be selected still received many votes. Table 2 lists themes not selected for the NMC Horizon Report that remain valuable for reference in future years. Definitions and group discussion content for these themes can be viewed at library.wiki.nmc.org. Related important content has been integrated into the 18 themes of this report.

Table 2 Mid-List Themes for NMC Horizon Report: 2017 Library Edition

- Accessibility of library services and resources
- Transforming organizational structures for future work
- Collecting and preserving research digital outputs as collection materials
- Competition from alternative knowledge discovery methods
- Economic and political pressures
- Embedding academic and research library services in curricula
- Need to respond to radical change
- Improving digital literacy
- Continuous development of library integration, interoperability, and collaboration projects
- Managing knowledge obsolescence
- Rethinking librarian roles and skills
- Major technology advances
- Advancing innovation culture
- Addressing social challenges
- Adaptive learning technologies
- Collaborative learning methods
- Challenges of alternative knowledge discovery methods
- Information visualization
- Enhancing research content accessibility
- Integrating academic and research libraries into curricula
- Optimizing mobile content and discovery
- Managing aging knowledge
- Disseminating open educational resources
- Marketing and promoting library services
- Rethinking librarian roles and functions
- Wearable technologies

For easy reference and use, content for each selected theme is limited to two pages, serving as independent chapters and guides. By comparison, integrating these themes to form a panoramic research framework is more important. In some cases, “challenges” hinder the development of “positive trends,” while “technologies” act as accelerators. This also demonstrates the convergence relationship among the three sections of this report.

Overall, the themes revealed in each annual Library Edition tell a larger story of how they drive or hinder learning, research, and information management. Particularly in the higher education context, each theme can be classified into one or more of six meta-categories reflecting activities in academic and research

libraries.

Six Meta-Categories of NMC Horizon Reports:

1. **Expanding Access and Convenience of Information**
   People expect to access learning resources anytime, anywhere, and connect with others. Academic and research libraries have made tremendous progress in providing more methods and platforms for seamless collaboration among students, faculty, and researchers. Mobile devices have provided more flexibility in how, when, and where people learn and research, prompting many libraries to update their IT infrastructure accordingly. Additionally, libraries must continuously update policies and services to meet the needs of all users, including people with disabilities.

2. **Sparking Innovation**
   To expand practices and develop 21st-century library services, library organizations must be flexible to effectively stimulate creativity and entrepreneurial thinking. Although digital scholarship culture is typically initiated and led by academia, the library community is at the new frontier of digital academic research. To continuously generate new ideas and promote service and management improvements, libraries need to adopt more flexible organizational structures.

3. **Fostering Authentic Learning and Discovery**
   Higher education is increasingly student-centered, creating richer, more practical, and authentic learning experiences. As important centers of campus activity, libraries have a responsibility to drive these positive explorations by transforming physical spaces and rethinking the types of activities and training they provide. Similarly, research activities are increasingly collaborative, with interdisciplinary teams needing technology-supported formats to process and document data. Libraries are well-positioned to support these activities by providing new digital tools and establishing processes for storing and disseminating expanding data and research outputs.

4. **Balancing Social Shifts**
   As scholarly records in various formats proliferate online, libraries play an important role in understanding their impact on the research community. Traditional methods evaluate works based on publishing institutions and prominence. However, more libraries are assessing impact through altmetrics—measuring research impact across different media beyond formal publications and citations. Just as research can be tracked and evaluated, libraries are also becoming more adept at integrating analytics and feedback loops into services and operations to better understand user behavior and needs, making adjustments accordingly.

5. **Tracking Research and User Data**
   With the proliferation of different formats of scholarly records online, libraries play an important role in understanding their impact on the re-

search community. Traditional methods evaluate works based on publishing institutions and prominence. However, more libraries are assessing impact through altmetrics—measuring research impact across different media beyond formal publications and citations. Just as research can be tracked and evaluated, libraries are also becoming more adept at integrating analytics and feedback loops into services and operations to better understand user behavior and needs, making adjustments accordingly.

6. **Advancing Digital Literacy**
   Technology and digital tools are ubiquitous, but their utility only becomes apparent when embedded meaningfully in learning and research processes. Contemporary industry and academia have an increasingly strong demand for digitally skilled talent who can seamlessly use various emerging media and technologies. A major factor in cultivating these digital skills is recognizing that simply knowing how to use devices or software is insufficient; people must be able to connect tools with intended outcomes, using technology creatively and adapting it intuitively to different contexts. As centers of information literacy and knowledge discovery, libraries are indispensable in advancing this mission, working with school leaders, faculty, and staff to embed digital skills more deeply into teaching and research.

In the following report, icons next to each theme indicate their meta-category for clearer illustration of connections between themes. The first two sections focus on analyzing trends that drive technology decision support and planning, and challenges that may hinder new technology adoption. Each theme details impacts on policy, leadership, and practice in academic and research libraries and library organizations. These three elements also indicate the need to integrate management, vision, and action to advance positive trends and overcome urgent challenges. Each theme also includes relevant cases and recommended reading materials.

The third section of the report focuses on important technology developments—consumer technologies, digital strategies, enabling technologies, Internet technologies, learning technologies, social media technologies, and visualization technologies—that will impact libraries within the next five years. Each technology development includes a discussion of its relevance to academic and research libraries, along with a set of project examples and recommended reading materials.

In summary, these three sections provide an intuitive reference guide for strategic planning and decision-making for directors of global academic and research libraries.

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3. Key Trends Driving Technology Adoption in Academic and Research Libraries

Based on the Delphi method, after several rounds of research, discussion, voting, and theme refinement, the project expert panel selected six trends that will likely drive technology planning and decision-making over the next five years. These representative trends are divided into three categories: long-term trends already affecting and continuing to affect decision-making over the next five years; mid-term trends likely to continue affecting decision-making over the next 3-5 years; and short-term trends driving technology adoption and likely to continue affecting but become normalized or disappear within the next 1-2 years.

The NMC Horizon Project model primarily discusses trends and challenges from three dimensions: policy, leadership, and practice. Policy refers to formal laws, regulations, rules, and guidelines applicable to libraries. Leadership refers to experts' visions for libraries' future based on research and deep thinking. Practice refers to new ideas and services already implemented by libraries and related departments. The following sections explore six key trends in depth, providing cited literature and resources.

3.1 Overview

3.1.1 Long-Term Trends: Driving Academic and Research Library Technology Adoption Over the Next Five Years and Beyond Cross-Institution Collaboration. Building collections through institutional collaboration is increasingly important for the future development of academic and research libraries. Globalization provides conditions for institutions to conduct international cooperation and achieve common goals in technology, research, and values. In an environment of budget reductions and increasing emphasis on digital collections, cross-institution collaboration can improve libraries' ability to access academic materials and participate in mission-oriented cooperative projects. More libraries are integrating resources by joining consortia or strategically innovating to integrate into the higher education environment. Support for technology-driven learning has promoted the formation of open communities and alliances, such as libraries, educators, and technology experts jointly developing platforms and software to support institutional data integration and storage, thereby achieving sustainable access and preservation.

3.1.2 Mid-Term Trends: Driving Academic and Research Library Technology Adoption Over the Next 3-5 Years User as Creator. Universities worldwide are undergoing pedagogical transformations where students, faculty, and interdisciplinary researchers learn by creating content rather than merely consuming it. The continuous growth of user-created videos, maker communities, and crowdfunding projects in recent years demonstrates that creation is becoming an important form of active, practical learning. People now expect libraries to help and provide tools for developing new skills. Libraries are ideal

choices for school creativity service centers, representing a natural extension of libraries' traditional functions as knowledge creation facilities and spaces for scholar engagement. To stimulate creativity, many library makerspaces are applying emerging technologies such as 3D printers, flexible displays, multimedia production tools, and natural user interfaces. Driven by this trend, libraries are gradually beginning to manage various types of tangible creative products.

Rethinking Library Spaces. In an age of ubiquitous discovery, students are increasingly less dependent on libraries as the sole source of information and increasingly view libraries as productive spaces. EBSCO's survey on how college students conduct research shows that 68% use Google and Wikipedia to begin research. Therefore, institutional leaders are rethinking how to design library spaces to better support face-to-face interactive services. Librarians are examining user behavior to provide decision-making basis for strategic planning and budgeting. Many libraries provide active learning rooms, multimedia production studios, makerspaces, and other venues conducive to collaboration and practical work. These changes reflect the transformation of higher education teaching methods toward guiding students to develop practical skills and concrete applications.

3.1.3 Short-Term Trends: Driving Academic and Research Library Technology Adoption Over the Next 1-2 Years Scientific Data Management. As libraries' online databases provide increasing access to research reports, students, faculty, and researchers can more easily access and understand existing ideas and work. An important function of publishing reports is archiving discoveries that can inspire new ideas. Enhanced formats and processes for electronic publishing enable the presentation of experiments, tests, and simulation data through multimedia and visualization methods such as audio and video. The emergence of these formats has prompted libraries to reconsider data management throughout the research lifecycle, including collection, analysis, visualization, and preservation. The development of data management has led to more accurate subject search results and citations, while helping libraries more effectively manage and display resources relevant to users. To continuously update data formats in knowledge repositories, libraries must recognize the future development of scientific data management in higher education and prepare to integrate cutting-edge technologies and data management methods.

Emphasis on User Experience. User experience refers to the quality of interaction between users and services and products, commonly used to evaluate user interaction with networks, mobile devices, operating systems, etc. Libraries should apply the same usability principles to physical spaces. In the digital domain, convenient navigation, easy-to-use content, and practical functions constitute effective website and database design. Companies like Amazon and Google are also studying user online behavior patterns to provide more precise search results. Rankings on websites like Netflix and TripAdvisor based on direct user feedback help customize content and adjust user interface design.

Users need more effective and personalized experiences. Librarians also prefer user-centered approaches, using user click data to identify needs and develop high-quality, engaging experiences. Library publishing services can also benefit from understanding how user interface and design decisions impact authors and readers.

3.2 Long-Term Trends

3.2.1 Cross-Institution Collaboration Building collections through institutional collaboration is increasingly important for the future development of academic and research libraries. Globalization provides conditions for institutions to conduct international cooperation and achieve common goals in technology, research, and values. In an environment of budget reductions and increasing emphasis on digital collections, cross-institution collaboration can improve libraries' ability to access academic materials and participate in mission-oriented cooperative projects. More libraries are integrating resources by joining consortia or strategically innovating to integrate into the higher education environment. Support for technology-driven learning has promoted the formation of open communities and alliances, such as libraries, educators, and technology experts jointly developing platforms and software to support institutional data integration and storage, thereby achieving sustainable access and preservation.

3.2.1.1 Overview Interlibrary loan cooperation has become routine. IFLA's *Best Practice Guidelines for Interlibrary Loan and Document Delivery* provides recommendations based on research from the late 1990s to early 2000s. The Borrow Direct program launched in 1999, covering all Ivy League institutions plus MIT, Duke, Johns Hopkins, and the University of Chicago, is one of the longest-standing services. Library organizations are also exploring electronic resource sharing. For example, members of the Lebanese Academic Library Consortium benefit from economies of scale in cooperative subscription purchases of important databases. This type of cooperation has potential influence on participating libraries. Because donation funds are not always designed to accommodate innovative initiatives, library decision-makers may choose not to duplicate resources already collected by other members, allowing greater flexibility when purchasing digital technologies.

When collaborating with professionals from other institutions, libraries may also encounter challenges such as conflicting priorities or disputes over funding responsibilities. However, due to funding limitations, cooperative projects are becoming increasingly common in the library community. Through collaboration, libraries can leverage subject knowledge skills that their own staff currently do not possess to more effectively develop promising projects and solve problems that individual institutions cannot address alone. In the *Strategic Thinking and Design Project* report, the Association of Research Libraries (ARL) interviewed leaders of large library cooperative organizations such as HathiTrust, Europeana, and DPLA. The report reflected important lessons learned: foster-

ing a non-competitive culture within project scope, establishing shared visions that drive work, and focusing on higher education-related issues emerging at participating institutions. These leaders also indicated that as technologies evolve and mature, more collaborative academic cooperation models are forming, and libraries serving multiple institutions are part of this environmental transformation.

Libraries also collaborate to develop new technologies, build cooperative collections, and improve library services. MIT, New York University, Princeton University, and Stanford University libraries collaborated to develop the open-source geospatial search application GeoBlacklight, which enabled initiatives like the "Big Ten Academic Alliance Geospatial Data Project." In this project, librarians and geospatial experts from ten institutions reached consensus to jointly build GIS dataset collections and digital historical map discovery sets. The Open Library Foundation also 致力于 providing infrastructure that promotes cooperation and community practice, thereby driving innovation. The FOLIO initiative aims to provide a next-generation platform for librarians, technology experts, and service providers to discuss and collaboratively develop open-source software that meets library needs.

3.2.1.2 Implications for Policy, Leadership, or Practice The European Commission recently met to discuss the next development direction of Europeana, the EU digital retrieval platform and virtual exhibition space for cultural heritage content, recommending changes to funding structures from primarily member state funding to the EU bearing major operational costs. At the institutional level, library leaders must consider developing funding management and resource sharing policies. Decision-makers may choose to cooperate with legal entities outside their institutions. For example, Emory University Library and Georgia Tech Library jointly established the Library Service Center (LSC) through a 501(c)(3) non-profit organization EmTech to support facility construction and share operational costs. Both libraries provide shared collection services to faculty, staff, and students through a warehousing service center located at Emory.

Cross-institution collaboration in academic and research libraries is supported by various organizations and initiatives. The Electronic Information for Libraries (EIFL), a non-profit library and consortium network across Europe, Asia, and Africa, provides professional development opportunities and resources to strengthen knowledge sharing and cooperation. Librarians can access toolkits, webinars, and white papers related to consortium building and open educational resources. As part of the Laura Bush 21st Century Librarian Program, the Biodiversity Heritage Library (BHL), with over 30 member institutions including research, natural history, and botanical libraries, received IMLS funding to establish a National Digital Stewardship Residency (NDSR) for five member institutions. Project members hope to improve BHL's digital tools and processes for creating the next version of its online open-access biodiversity literature

collection. Digital library best practices developed in the project will inform large-scale projects like the Digital Public Library of America and Europeana.

Nine institutions in Myanmar collaborated through EIFL to establish the Myanmar Academic Library Consortium, dedicated to professional development for library staff and sharing electronic resources. Eight Hong Kong universities received support from the Hong Kong University Grants Committee to cooperate in improving student information literacy. Each university is responsible for developing one module of an interactive curriculum on a shared platform, with participating librarians jointly developing strategies for integrating modules into courses in collaboration with faculty. Libraries are also cooperating to develop comprehensive digital preservation capabilities. The California Digital Library, Harvard University Library, and UCLA Library developed the open-source platform Cobweb with IMLS funding to capture and archive web content metadata, providing participants with a window into the work of other libraries and archives. This platform will help developers avoid duplication and prevent legacy gaps. Cobweb is committed to promoting library cooperation and effective resource allocation.

3.2.1.3 Recommended Reading The following resources are recommended for those wishing to learn more about cross-institution collaboration:

1. **Challenges Facing Library Cooperation and Resource Sharing**
   go.nmc.org/tanzlib (Jaffar Msafiri Ponera, *International Journal of Research*, January 2017.)
   The author studied cooperation between two Tanzanian university libraries, recommending formal institutional cooperation policies and memoranda of agreement specifying information resource sharing.

2. **Development of a Cross-Institutional Digital Repository (PDF)**
   go.nmc.org/crossdep (Maggie Farrell, IFLA World Library and Information Congress 2015, August 2015.)
   Through participation in multi-institutional digital repository construction, different skills are applied to complete applicable technology and effective resource construction, identifying best practices for cooperative management.

3. **Digital Resources Management in Libraries: Steps toward Digital Bangladesh**
   go.nmc.org/bangla (A.I.M. Rahman et al., *Proceedings of the National Seminar on Cross-talk of Digital Resources Management*, 2015.)
   To achieve future goals of developing a national joint interface for digital resources, this article recommends that academic and research libraries conduct small-scale cross-institutional cooperation experiments to develop standards and guidelines based on lessons learned.

4. **The Myanmar Academic Library Consortium is Born**
   go.nmc.org/myanlib (Electronic Information for Libraries, 13 December

2016.)
EIFL's convening power laid the foundation for nine institutions in Myanmar to jointly establish the Myanmar Academic Library Consortium, dedicated to professional development for library staff and sharing consortium electronic resources.

5. **New UK-Wide Service Will Transform Library Collaboration**
go.nmc.org/jiscserv (Jisc, 3 February 2017.)
Jisc is collaborating with OCLC to build a system supporting the creation of a UK catalog knowledge base, using technology from OCLC's WorldCat database to integrate digital resources and metadata, ensuring sustainable access for scholars.

6. **Open Pathways to Student Success**
go.nmc.org/acadoer (Joseph A. Salem Jr., *The Journal of Academic Librarianship*, January 2017.)
Libraries lead their institutions in building open educational resource repositories to improve student academic capabilities. This article describes progress in multi-institutional cooperation such as the Open Textbook Network.

3.2.2 Evolving Nature of Scholarly Records Once limited to print journals and monographs, scholarly communication now relies on network environments and is accessible through a wide range of publishing platforms. The Internet is disrupting traditional academic systems based on physical printing and distribution processes. Currently, scholarly records can be published after peer review, making academic exchange more frequent and public. Scholarly works are no longer limited to text but include research datasets, interactive projects, complex visualization products, other intermediate research outputs, and online exchanges through social media. This has profound implications for libraries, especially those seeking alternative channels to traditional high-priced publishers. As diverse scholarly communication methods become popular online, librarians must identify the legitimacy of these innovative methods and evaluate the impact of these research outputs on the research community through emerging altmetrics tools.

3.2.2.1 Overview This trend reflects developments in many important areas such as digital scholarship, altmetrics, and open access resources. Libraries are gradually becoming gatekeepers of academic research outputs and scholarly works. Historically, this function was established through subscription-based academic journals and university presses. Academia remains immersed in the inherent prestige of traditional methods; how and where to publish remain important factors in evaluating work quality and impact. However, technology has gradually but dramatically changed how information is collected, verified, and disseminated, spawning many alternative publishing models. The digitization of scholarly records and the shift from text formats to rich, dynamic formats are

also key to this revolution. In this new environment, scholars need librarians to provide support in demonstrating the impact of various scholarly outputs in tenure and promotion reviews.

Under this trend's influence, libraries continuously focus on knowledge repository management, research data management, and open data sharing development. The Canadian Association of Research Libraries and Canadian Research Knowledge Network advocate for and support institutional leaders in understanding changes in scholarly communication, particularly open access. In 2016, CRKN launched the Institutional Mobilization Toolkit project to help libraries explore research resource costs and availability. Additionally, libraries must pay attention to altmetrics—digital indicators showing the quantity and quality of output activity and engagement. Traditional citation tools reveal how frequently researchers cite works, while altmetrics reveal how scholarly outputs influence policy and practice.

Changes in academic publishing have triggered discussions about the future of peer review. Open peer review is emerging as a means to address long-term issues such as efficiency and reviewer responsibility by publicly identifying authors and reviewers. PeerJ is a journal dedicated to accelerating the peer review process while minimizing costs; authors can enjoy unlimited free publishing by joining a lifetime membership, with works published under CC licenses. In F1000Research's open research platform, all articles receive transparent peer review and benefit from all source data. Certification can also be conducted online through platforms like PubPeer. This model has not yet scaled in the scientific community, but supporters argue that open review accurately reflects that "all research is work in progress."

The scaled development of the open publishing movement requires leadership from organizations and alliances. Fifty-five EU institutions collaborated to release OpenAIRE2020, hoping to promote open scholarship development by improving research data discoverability and reusability. Research libraries, national e-infrastructure and data experts, and legal researchers used the OpenAIRE online platform to establish open scholarly workflows and guidelines widely adopted by general knowledge repositories. Another pioneer in this arena is the National Science Communication Institute, which has a long-term cooperative relationship with UNESCO to implement the Open Scholarship Initiative (OSI). They are working to address open access barriers, improve journal cost affordability, and expand global knowledge coverage through institutional repositories by promoting cooperation.

Traditional publishing processes are transforming toward new models focused on supporting the future. The University of Cape Town Library was the first higher education institution in Africa to use the Open Book Platform to publish open monographs, sparking a movement of libraries as open publishers. The University of Illinois "Publishing Without Walls" project is committed to pioneering library-based scholarly publishing models, providing university libraries with integrated support and resources for open, scalable, and sustainable publishing

services to better meet scholars' needs. Additionally, more libraries are using information visualization technologies to display scholarly achievements and reveal research relationships. At the Coalition for Networked Information (CNI) 2016 Fall Meeting, Cornell University Library demonstrated Scholars@Cornell's data and visualization services, aiming to increase the visibility of the institution's research while clarifying the reality and potential patterns of scholarly collaboration.

3.2.2.2 Implications for Policy, Leadership, or Practice As new forms of scholarly records develop, more libraries are evaluating impact through altmetrics, but standardized altmetrics indicators have not yet been formed. The National Information Standards Organization (NISO) launched the Altmetrics Assessment Metrics Project, aiming to develop policies by studying best practices. The project's resulting report made several recommendations: metrics for research data utilization should be popularized; citations in altmetrics must include machine-identifiable persistent identifiers; algorithms should reflect the growth trend of non-human downloads. Additionally, altmetrics are significant for connecting research outputs with specific policies. London-based Altmetric LLP released *Understanding the Impact of Research on Policy Using Altmetric Data*, demonstrating how its Altmetric Policy Miner tool helps the World Bank Group and Cochrane UK better understand how knowledge embedded in reports, papers, and articles influences global decision-makers.

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2016 Fall Meeting, Cornell University Library demonstrated Scholars@Cornell's data and visualization services, aiming to increase the visibility of the institution's research while clarifying the reality and potential patterns of scholarly collaboration.

3.2.2.3 Recommended Reading The following resources are recommended for those wishing to learn more about the evolving nature of scholarly records:

1. **ACRL Scholarly Communication Toolkit**
   go.nmc.org/acrlsct (Association of College & Research Libraries, accessed 9 February 2017.)
   This innovative toolkit helps librarians integrate scholarly communication perspectives into library operations and plans, and prepare presentations on related issues.

2. **Altmetrics in the Library (PDF)**
   go.nmc.org/altmet (Anne E. Rauh, Syracuse University SURFACE, 21 August 2016.)
   Provides scenarios for science and engineering librarians to demonstrate libraries' important role in integrating altmetrics.

3. **The Cost of Open Access to Journals: Pay It Forward Project Findings**
   go.nmc.org/costof (MacKenzie Smith, CNI, 30 November 2016.)
   The Pay It Forward project studied the feasibility of open access by investigating institutional costs, staff and student perceptions, and economic models supporting APCs.

4. **Five Librarians Discuss the Future of the Academic Book (PDF)**
   go.nmc.org/fivelib (Christina Kamposiori, *British Academy Review*, January 2017.)
   The Research Libraries UK project leader interviewed academic librarians from different backgrounds to understand their vision for future scholarly work, finding libraries in an active position in displaying resources and content design.

5. **Scholarly Communication/Publication: Scholarly Communication & OA**
   go.nmc.org/witsza (University of the Witwatersrand Johannesburg, accessed 9 February 2017.)
   South African institutions developed library guides to help researchers and students understand diverse publishing models, including checklists and OA resources.

6. **What are the Challenges of Open Peer Review?**
   go.nmc.org/oprchall (Stephanie Boughton, *BioMed Central*, 15 June 2016.)
   The author explores questions about open peer review, arguing for

research on emerging models and peer review universality, suggesting the first step is clearly defining open peer review.

3.3 Mid-Term Trends

3.3.1 User as Creator Universities worldwide are undergoing pedagogical transformations where students, faculty, and interdisciplinary researchers learn by creating content rather than merely consuming it. The continuous growth of user-created videos, maker communities, and crowdfunding projects in recent years demonstrates that creation is becoming an important form of active, practical learning. People now expect libraries to help and provide tools for developing new skills. Libraries are ideal choices for school creativity service centers, representing a natural extension of libraries' traditional functions as knowledge creation facilities and spaces for scholar engagement. To stimulate creativity, many library makerspaces are applying emerging technologies such as 3D printers, flexible displays, multimedia production tools, and natural user interfaces. Driven by this trend, libraries are gradually beginning to manage various types of tangible creative products.

3.3.1.1 Overview The traditional view of libraries as quiet places for research and independent learning has changed, with a greater emphasis on libraries as environments that stress collaboration and practice. Social trends toward participatory culture drive libraries to position users as innovators and redesign spaces and resources to support their creative work. Libraries are well-prepared to serve as school makerspaces, equipped with 3D printers and scanners, computer-aided design (CAD) software, and other tools to support users in practical and interdisciplinary learning, discovering new knowledge and interests, and conducting new research or entrepreneurial activities. For example, Kent State University at Tuscarawas' makerspace helps users transform ideas into commercial practices and marketable products, while also serving as a service outlet for the Ohio Small Business Development Center to help users improve digital and entrepreneurial literacy.

The latest survey by the Association of Research Libraries (ARL) shows that among participating North American libraries, 64% already provide, plan, or pilot maker services; another 17% plan to investigate such services. Many libraries integrate core services such as reference, training, hardware, scanning, and repositories, while emphasizing 3D printing, printing, and scanning services. However, seizing opportunities for technology-driven creation requires human support. Most surveyed libraries already or plan to provide on-site technical training and skills-building workshops. Additionally, 75% provide digital resources for guiding users in design, modeling, and software development. Based on this survey, ARL established the Rapid Fabrication/Makerspace Services SPEC Kit project. This trend is gaining momentum, and libraries are adjusting budgets, shifting from traditional collection building to user-driven acquisition.

More and more academic and research libraries are validating this trend. New

York University provides data services in the form of art studios; in open laboratory spaces supported jointly by data librarians and technology experts, hardware, data resources, and training services are provided to facilitate user discovery and creation. The German National Library of Science and Technology in Hanover organizes workshops to help scientists and engineers create short video summaries using mobile or free web applications, guiding them in selecting appropriate licensing formats and online publishing sites. Ryerson University in Canada launched the first library makerspace, the Isaac Olowolafe Digital Media Experience (DME) Lab, enabling mutual learning service models through Oculus virtual reality helmets and other technologies for students, while hosting various workshops and individual guidance on advanced media production tool usage.

3.3.1.2 Implications for Policy, Leadership, or Practice Many libraries have developed policies for using creative tools such as 3D printing, restricting student use under conditions that do not involve legal violations, danger, or intellectual property infringement. Generally, users must submit designs for approval before library staff can operate 3D equipment. Some institutions have established priorities for printing project use based on academic importance, course deadlines, or application approval times. At the University of Toronto's Gerstein Science Information Centre, students can independently operate 3D printers after completing safety and training courses, but must schedule usage times.

Libraries are launching projects in collaboration with university faculty or other institutions to promote active learning and innovation. With funding from the Andrew W. Mellon Foundation, the University of Virginia Library's Scholars' Lab launched the Praxis Program, providing fellowships for graduate students to design and develop digital humanities projects or specific software tools under the guidance of library staff. Participating students developed Prism, a software tool that expands text capabilities through collaborative work. To enable skilled, creative students to play greater roles in library innovation, UCLA launched the Simul8 project, supporting participating students in developing applications to improve library collection sharing convenience. This trend's most important impact in library practice is enhancing user creativity and innovation. At the National University of Ireland Galway, students use 3D design software and printers in library makerspaces to create various sculptures and print molecular models. At Curtin University's Robertson Library makerspace in Australia, users experiment with connecting circuits using batteries, LEDs, and conductive wires, adding them to clothing or soft objects. At Carnegie Mellon University, students at the Hunt Library's IdeaTe Experimental Fabrication Lab collaborated to develop a virtual reality tank game, combining electronics, mechanics, and game design technologies. The invention designed a physical chair system requiring players to use hands and feet to operate the game, simulating turns and allowing multi-player participation. As recognition for their achievements, students received the school's specially established annual Build18 Outstanding

Project Award.

3.3.1.3 Recommended Reading The following resources are recommended for those wishing to learn more about user as creator:

1. **Ascending Bloom's Pyramid: Fostering Student Creativity and Innovation in Academic Library Spaces**
   go.nmc.org/ascend (Mark Bieraugeland Stern Neill, *College & Research Libraries*, February 2016.)
   The author studies how space design enhances and hinders creative processes and behaviors.

2. **The Knowledge Lab**
   go.nmc.org/knowledgelab (Nielson Library Knowledge Lab, accessed 2 March 2017.)
   Smith College Library's Knowledge Lab is a participatory space for undergraduates to practice knowledge production and sharing, serving as a platform to showcase achievements of creative students funded by small grants and to implement academic and experimental outcomes.

3. **MLab**
   go.nmc.org/mlabuv (Maker Lab in the Humanities, University of Victoria, accessed 7 February 2017.)
   Many library makerspaces focus on providing in-depth services for specific disciplines and research fields. The University of Victoria's M Lab focuses on cultural criticism, experimental prototyping, and electronic product interaction.

4. **NC State Libraries Code + Art Student Visualization Contest**
   go.nmc.org/codeart (North Carolina State University, accessed 7 February 2017.)
   North Carolina State University Libraries' Code + Art Student Visualization Contest has students create a series of data visualization products, particularly gaming environments and virtual/augmented reality experiences.

5. **SLUB Makerspace**
   go.nmc.org/slabde (Dresden Technology Portal, accessed 7 February 2017.)
   The Saxon State and University Library Dresden (SLUB), as a three-branch library serving Dresden University of Technology, provides a user makerspace for experimenting with and realizing creative projects and cultivating communities with shared interests.

6. **The State of Library Makerspaces**
   go.nmc.org/thestate (Fangmin Wang et al., *International Journal of Librarianship*, 2016.)
   The article reviews the maker culture in academic libraries, showcasing

examples from North Carolina State University, Ryerson University, and the University of Nevada, Reno.

3.3.2 Rethinking Library Spaces In an age of ubiquitous discovery, students are increasingly less dependent on libraries as the sole source of information and increasingly view libraries as productive spaces. EBSCO's survey on how college students conduct research shows that 68% use Google and Wikipedia to begin research. Therefore, institutional leaders are rethinking how to design library spaces to better support face-to-face interactive services. Librarians are examining user behavior to provide decision-making basis for strategic planning and budgeting. Many libraries provide active learning rooms, multimedia production studios, makerspaces, and other venues conducive to collaboration and practical work. These changes reflect the transformation of higher education teaching methods toward guiding students to develop practical skills and concrete applications.

3.3.2.1 Overview In higher education, physical space transformation is an important trend. Library space reengineering was listed as a long-term trend in the *NMC Horizon Report: 2015 Library Edition*. Recent research helps understand how these changes are occurring. For example, the report *Academic Library Space Planning and Design* elaborates new approaches, challenges, and best practices for designing academic library learning spaces. Through a series of interviews, the authors found that 77% of architects and 50% of librarians prioritize space flexibility, favoring movable and customizable spaces; another consensus is supporting learning needs. Most respondents indicated new library space designs should support academic learning activities, including collaborative learning (83%), individual learning (73%), and point-of-need services (63%).

Information technology and communication technology development have profoundly impacted space design. To better understand the role of library physical spaces, researchers at the University of Tampere in Finland conducted the study *Libraries as Multi-Dimensional Spaces in the Digital Age*. Through interviews and consultation of planning documents, results showed that libraries are viewed as composite environments integrating physical, social, and digital spaces and services. The University of Helsinki Library construction project analysis indicated that stakeholder opinions, including users, are factors considered in the space design process. Physical space size must account for multiple functions, social space dimensions should suit face-to-face communication, and digital space dimensions should promote responsive user mobile devices.

Academic and research libraries are actively renovating spaces and creating new spaces to support innovative development visions planned by leaders. The University of Newcastle in Australia's newly opened Auchmuty Library Learning Room is a 24-hour team research space supporting bring-your-own-device, equipped with "survival stations" providing hot water and microwaves. The Claremont Colleges Library is the university center for digital humanities and

digital knowledge. To further focus on this area, the library established Digital ToolShed, an incubator for innovative digital research, teaching, and learning. Additionally, Virginia Commonwealth University's new Cabell Library is under construction, with 90% of space for student use rather than housing books and materials, designed flexibly to support new technologies and student needs.

3.3.2.2 Implications for Policy, Leadership, or Practice Policymakers at different levels can apply research on this trend to support reform policies for academic libraries. Since 2007, New Zealand's Ministry of Education, in conjunction with the local Building Research Association, has released a series of *Digital Quality Learning Spaces* (DQLS) documents. Version 2.0 made significant improvements over 1.0, reflecting the introduction of new teaching methods and greater interest in flexible learning spaces, rewriting work introductions for architects, designers, and engineers. At the institutional level, SUNY Stony Brook revised its strategic goals toward building a 21st-century library meeting diverse user needs. The library configured technology matching physical spaces and furniture, providing users with sufficient power outlets, charging stations, and high-speed Wi-Fi to support the bring-your-own-device movement.

Many authoritative institutions have begun developing resources to help global libraries plan and evaluate spaces. Since 2012, a core team composed of EDUCAUSE Learning Initiative, SUNY System, MERLOT, and the Society for College and University Planning has helped create the FLEXspace Flexible Learning Environment Exchange Initiative, providing an open-access knowledge base of specific cases developing and showcasing innovative learning spaces. FLEXspace describes space types most suitable for supporting active learning based on contemporary teaching methods. Similarly, the Universities and Colleges Information Systems Association uses the UK Higher Education Learning Space Toolkit as a practical guide for sharing best practices in creating learning spaces. The Learning Space Rating System (LSRS), with assessment as its core function, is a tool for evaluating how formal learning spaces enhance active learning effectiveness and efficiency, usable when renovating or launching new library construction projects.

Academic and research libraries are actively renovating spaces and creating new spaces to support innovative development visions planned by leaders. The University of Newcastle in Australia's newly opened Auchmuty Library Learning Room is a 24-hour team research space supporting bring-your-own-device, equipped with "survival stations" providing hot water and microwaves. The Claremont Colleges Library is the university center for digital humanities and digital knowledge. To further focus on this area, the library established Digital ToolShed, an incubator for innovative digital research, teaching, and learning. Additionally, Virginia Commonwealth University's new Cabell Library is under construction, with 90% of space for student use rather than housing books and materials, designed flexibly to support new technologies and student needs.

3.3.2.3 Recommended Reading The following resources are recommended for those wishing to learn more about rethinking library spaces:

1. **Coalition for Networked Information Introduction and Program Plan 2016-17**
   go.nmc.org/cnipro (Consortium of Networked Information, accessed 20 February 2017.)
   The Coalition for Networked Information developed a program plan for three major entities—organizations, experts, and individuals—requiring spaces and services to support technology-enhanced research and learning.

2. **Evaluating and Designing Learning Spaces Guide**
   go.nmc.org/jisceval (Jisc, accessed 20 February 2017.)
   The Jisc website provides guides for learning space evaluation and design, including assessment methods, project management, and design processes.

3. **Imagine Our Library**
   go.nmc.org/ucdlib (UC Davis University Library, accessed 20 February 2017.)
   UC Davis Library solicits input from students, faculty, and researchers on how library spaces, technology, and services can best meet their needs. The first phase focuses on vision, the second on specific planning, and the third on actual design.

4. **Learning Spaces Collaboratory**
   go.nmc.org/lsc (Learning Spaces Collaboratory, accessed 20 February 2017.)
   The Learning Spaces Collaboratory synthesizes research and practical results on learning space design to build resources shaping and evaluating undergraduate learning environments, such as "emerging templates for evaluating learning spaces."

5. **Library Refurbishments**
   go.nmc.org/refurbish (The University of Western Australia Library, accessed 20 February 2017.)
   The University of Western Australia Library is transitioning to provide more interactive, flexible collaborative spaces. When print collections are involved, medical and dental libraries will be renovated into areas equipped with e-learning suites, computer training equipment, and collaborative learning zones.

6. **Measure the Future**
   go.nmc.org/measure (Measure the Future, accessed 20 February 2017.)
   This project uses inexpensive sensors to collect building usage data, helping libraries track visitor numbers, browsing patterns, and most-visited spaces, supporting strategic decision-making and generating more effective operational outcomes.

3.4 Short-Term Trends

3.4.1 Scientific Data Management As libraries' online databases provide increasing access to research reports, students, faculty, and researchers can more easily access and understand existing ideas and work. An important function of publishing reports is archiving discoveries that can inspire new ideas. Enhanced formats and processes for electronic publishing enable the presentation of experiments, tests, and simulation data through multimedia and visualization methods such as audio and video. The emergence of these formats has prompted libraries to reconsider data management throughout the research lifecycle, including collection, analysis, visualization, and preservation. The development of data management has led to more accurate subject search results and citations, while helping libraries more effectively manage and display resources relevant to users. To continuously update data formats in knowledge repositories, libraries must recognize the future development of scientific data management in higher education and prepare to integrate cutting-edge technologies and data management methods.

3.4.1.1 Overview Data generation methods and data storage capabilities continue to develop. The focus of academic and research libraries has evolved from electronic publishing in the 2014 edition, to metadata standards impact in the 2015 edition, to librarians' roles in the research lifecycle and methods for accessing new media data in the 2017 edition. Although no longer new, this trend has also developed as open publishing and increasing digital collections consolidate libraries' roles in research data management (RDM). LIBER and DataOne research shows that European university libraries already provide RDM support and training for staff. Using nearly three years of research as a baseline, this research reflects that most libraries have developed RDM policies and guidelines through self-built or collaborative approaches.

In cooperation with other university departments, libraries are defined in three main roles: access, support, and data management. Access, as libraries' most traditional function, includes providing learners with relevant data repositories for application in existing research and providing up-to-date standards for citation and reference. To ensure long-term discoverability of research outputs, librarians have expanded their scope to data support. One of the most important support forms is libraries' mastery of metadata standards, recording information about data sources, purposes, and methods. The third role is data management, which includes both access and support, while emphasizing storage planning for data and management "from the research project lifecycle to potential data reuse, preserving data and achieving value-added."

Technology development has enabled diversification of data formats, including images, audio, and video, creating frameworks for storing, preserving, and managing new media data. Digital asset management (DAM) is part of research data management, focusing on building processes for storing digital formats and creating metadata standards for new formats. The International Press Telecommu-

nications Council recently released video metadata recommendations, including specifications for content attributes and technical implementation standards. Some projects have begun incorporating digital data into library knowledge repository management. Smith College recently launched the Collaboration for Technology Enhanced Learning, calling for cross-domain cooperation to develop systems that extract multimedia data from research projects. To prepare for managing new format data, libraries can also continuously monitor emerging technologies such as virtual reality and artificial intelligence for reference.

3.4.1.2 Implications for Policy, Leadership, or Practice The White Rose University Consortium's international survey shows that most RDM policies in North American, Australian, and European institutions originate from university libraries, but policy development processes involve multiple stakeholders including IT departments, research leaders, and legal staff. As new formats emerge and technologies develop, universities must develop guidelines to ensure data is produced in thoughtful ways. Monash University in Australia and Imperial College London provide resources on library websites to guide researchers in applying best practices, understanding RDM legality, and promoting data storage. As data sharing develops, privacy issues have also become cutting-edge topics. Jisc's SafeShare Pilot project in cooperation with Farr Institute universities ensures secure sharing of sensitive data.

RDM work has received recognition and support from multiple foundation-funded projects. The Institute of Museum and Library Services (IMLS) invested $200,000 in three academic library RDM projects. These projects are primarily undertaken by U.S. universities, focusing on developing data management tools and services. The University of Michigan Library plans to provide a series of research data management services, including repositories covering the entire research lifecycle for researchers. This Deep Blue Data project expands existing repositories and will develop data management plans, principle diagrams, and preservation strategies through a consortium of over 50 libraries.

Academic and research libraries that have successfully implemented RDM strategies are exploring the impact of these strategies on research disciplines. In South Africa, libraries have launched initiatives to build strategic frameworks including effective policies, infrastructure, and staff training. For example, Cape Peninsula University of Technology Library published research investigating e-research applications in biomedical research and how university libraries develop data management tools to provide support. Another prominent case is North Carolina State University Library, which, despite budget constraints preventing hiring dedicated data librarians, still trains existing librarians through data management review services to support multidisciplinary RDM.

3.4.1.3 Recommended Reading The following resources are recommended for those wishing to learn more about scientific data management:

1. **Academic Libraries and the EDUCAUSE 2017 Top 10 IT Issues**

go.nmc.org/itlib (Bohyun Kim, *EDUCAUSE Review*, 17 January 2017.)
Both academic libraries and institutional IT departments face data management challenges. Staff from different departments must cooperate to develop guidelines supporting data-driven decision-making, improving student success and operational efficiency.

2. **Diving into Data: Planning a Research Data Management Event**
go.nmc.org/datares (Robyn B. Reed, *Journal of eScience Librarianship*, 16 July 2015.)
Librarians can use data management work to support their institution's research and academic work. In organizing data management workshops, librarians at Penn State Hershey join researcher communication circles to identify unmet needs and topics of interest.

3. **Researcher-Library Collaborations: Data Repositories as a Service for Researchers**
go.nmc.org/datarep (Andrew S. Gordone et al., *Journal of Librarianship and Scholarly Communication*, 22 September 2015.)
The data repository Databrary has cooperated with the NYU library system to train librarians in building data management and sharing technical infrastructure skills. Libraries can also benefit from adopting Databrary's approach to collaborating with scholars to better understand how to support their research processes.

4. **UO Libraries Invites Researchers to 'Love Your Data' This Week**
go.nmc.org/lovedata (University of Oregon, 13 February 2017.)
The second "Love Your Data" week event is an activity to quickly apply RDM best practices and cultivate data management awareness.

5. **Using Scenarios in Introductory Research Data Management Workshops for Library Staff**
go.nmc.org/pdscen (Sam Searle, *D-Lib Magazine*, November 2015.)
As academic and research libraries increasingly focus on RDM, staff need to develop necessary competencies. One professional development model is scenario-based learning to identify data management challenges and find solutions.

3.4.2 Emphasis on User Experience User experience refers to the quality of interaction between users and services and products, commonly used to evaluate user interaction with networks, mobile devices, operating systems, etc. Libraries should apply the same usability principles to physical spaces. In the digital domain, convenient navigation, easy-to-use content, and practical functions constitute effective website and database design. Companies like Amazon and Google are also studying user online behavior patterns to provide more precise search results. Rankings on websites like Netflix and TripAdvisor based on direct user feedback help customize content and adjust user interface design. Users need more effective and personalized experiences. Librarians also prefer

user-centered approaches, using user click data to identify needs and develop high-quality, engaging experiences. Library publishing services can also benefit from understanding how user interface and design decisions impact authors and readers.

3.4.2.1 Overview User experience includes ethnographic research methods and design approaches for understanding and improving user experiences with library services. For example, the ERIAL project at Illinois academic libraries used anthropological research on student research behavior to focus on how libraries can consider student needs in service design. Ethnographic research methods for understanding how users work and the challenges they face can be divided into observational and participatory approaches, but librarians need to adopt more unified methods. For instance, expectations are the most important aspect of user experience, including aesthetics, mood, and interpersonal relationships.

In addition to clear, concise, and friendly website documentation, proactive user services also affect library service usage. Using virtual customer service robots can quickly respond to user questions, guiding them to appropriate services, databases, and papers.

To better improve user experience, many libraries also utilize design thinking—that is, using technically feasible strategies according to design principles to meet people's needs. This model helps define and solve problems based on the needs and expectations of users and potential users. The University of Technology Sydney recently used design thinking methods to document user behavior and continuously understand user experience through informal conversations over several months. They found that library staff mistakenly believed many student questions at the reference desk had been resolved, but this was not the case—the main problem was too many gestures and confusing language. Additionally, information previously visible in physical spaces is related to network or mobile experiences, such as how to connect and print from laptops, tablets, or phones. Transforming library websites has become an important part of strategies to improve user experience.

3.4.2.2 Implications for Policy, Leadership, or Practice No government policies specifically regulate UX quality in institutional services yet, but academic libraries expect to use the IDEO Library Design Thinking Toolkit to develop or implement corresponding standards. IDEO, in cooperation with Chicago Public Library and Aarhus Public Library, continuously develops toolkits to help libraries implement design thinking by inspiring inspiration, enhancing ideation capabilities, and iteration through observing librarians in 10 countries. Library stakeholders can view challenges as opportunities to generate and test new ideas to improve planning and design and implement ideas beneficial to users.

More libraries are adopting more flexible models to address this challenge.

For example, the University of Manchester Library abandoned its traditional team model oriented toward five major disciplines, switching to three functional teams: research services, teaching, and academic engagement. This transformation enables them to directly serve university strategies by leveraging different expertise. Although change agents anticipated challenges, they were confident that this reorganization would eliminate redundancy and help libraries adapt to changing needs. They have already seen progress in building and strengthening service capabilities. For example, the new functional teams developed Manchester eScholar, the institutional repository service. These teams also participated in a project to monitor, disseminate, and develop publishing strategies to increase citations for their researchers.

Many libraries are establishing new positions or departments to ensure user experience plays a role in library decision-making and planning. North Carolina State University Library established a User Experience Department focusing on better experiences with library spaces, services, and collections.

Prioritizing user experience requires library leadership recognition and promotion of effective practices that meet user needs into library services. The User Experience Working Group is using digital collaboration tools to develop guidelines and best practices for digital library user and usage research through monthly meetings; they share resources and skills to help library leaders understand user behavior and the learnability and accessibility of library services.

In terms of face-to-face training and professional development, the UXLibs conference convenes librarians from multiple types of libraries globally to discuss ethnographic research methods, usability, and human-centered design, sharing research results. Some library leaders are developing tools to improve resource interaction efficiency and personalization. For example, the EEXCESS project analyzes research results from databases such as Europeana, EconBiz, and Mendeley to automatically recommend library content to users. This tool can embed additional background information sources and infographics into Wikipedia or WordPress pages.

3.4.2.3 Recommended Reading The following resources are recommended for those wishing to learn more about emphasis on user experience:

1. **Designing the Future: A Design Thinking Workshop**
   go.nmc.org/libjourn (*Library Journal*, 5 October 2016.)
   Library Journal provides professional development opportunities focusing on user experience, offering library staff design thinking workshops to understand library user strategies through observation and scenario exercises.

2. **Explora**
   go.nmc.org/explora (ETH Library, accessed 20 March 2017.)
   The Explora platform re-examines how to present information to library

users by writing short stories about ETH Library's multimedia content, collections, and services, enhancing data visualization and infographics.

3. **Improving Library Websites**
   go.nmc.org/implib (Carrie Smith, *American Libraries Magazine*, 3 January 2017.)
   Libraries seeking to optimize user experience on websites can deeply study these recommendations and product suggestions to help users more effectively access broader online catalogs.

4. **Library Collections in the Life of the User: Two Directions**
   go.nmc.org/inthelife (Lorcan Dempsey, *Liber Quarterly*, 11 October 2016.)
   In the current digital, networked environment, libraries are developing toward greater emphasis on user activities. To this end, libraries are playing an increasingly important role in managing research outputs and promoting access to broader resources.

5. **Mobile Website Ease of Use: An Analysis of Orbis Cascade Alliance Member Websites**
   go.nmc.org/easof (Zebulon Evelhoch, *Digital Commons*, 2016.)
   Based on analysis of Orbis Cascade Alliance member websites, this paper explains ways to improve mobile website experiences for academic libraries.

6. **Speed Matters: Performance Enhancements for Library Websites**
   go.nmc.org/speed (Scott W.H. Young, *Weave: Journal of Library User Experience*, 2016.)
   Researchers at Montana State University developed and implemented a seven-step "library website performance enhancement plan" to improve webpage acceleration, optimization, webpage weight, and HTTP request speed, saving time for users.

7. **User Experience in Libraries: Can Ethnography Help?**
   go.nmc.org/canethn (Helen Edwards, *referisg*, 2 July 2016.)
   Ethnography can be a valuable approach to broader UX understanding in libraries. It focuses on how users behave, not just their direct feedback; in some cases, users cannot express their needs or correctly predict how they will use services.

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4. Important Challenges Affecting Technology Adoption in Academic and Research Libraries

The following six challenges were selected by the project expert panel using the Delphi method through a series of discussions, refinements, and votes. The expert panel reached consensus that if these challenges are not resolved, each will

likely hinder the adoption of one or more new technologies. Full records of discussions and related materials can be queried at horizon.wiki.nmc.org/Challenges.

Based on the nature of their impact, this report divides challenges into three categories: Solvable challenges: those that are understood and know how to solve; Difficult challenges: those that are understood but difficult to solve; and Wicked challenges: the most difficult to solve, complex and ill-defined, requiring more data and perspectives to propose possible solutions. After the challenge list is determined, this report examines its impact on policy, leadership, and practice through three meta-expressions. The following sections explore six key challenges in depth, providing cited literature and resources.

4.1 Overview

4.1.1 Solvable Challenges: Those That Are Understood and Know How to Solve Improving Accessibility of Library Services and Resources. While libraries have performed well in addressing barriers for people with disabilities, technology changes in how users access information have created new barriers. The increasing emphasis on digital resource accessibility will also affect the types of essential skills required of library professionals. To comply with anti-discrimination laws and institutional policy requirements, librarians will also face challenges in implementing technologies and learning resources triggered by multiple potential needs. Integrating universal design principles into library programs can improve user experience for all users. Other adoptable strategies include usability testing, digital accessibility audits, and developing accessibility standard learning technologies. Listening to student opinions is crucial for meeting this challenge. Libraries can cooperate with other institutional stakeholders to ensure equal opportunities for students, faculty, and scholars with disabilities.

Improving Digital Literacy. In 21st-century practice, productive and innovative use of technology is crucial for success in all fields. Digital literacy goes beyond isolated technical skills, including both deep understanding of digital environments that enables people to adapt to new environments and co-create content with others, and understanding and recognizing the freedoms and risks that digital interactions may bring. Libraries are obligated to help students establish digital citizenship and ensure responsible and appropriate use of technologies such as online identity, social etiquette, rights, and responsibilities. These competencies affect curriculum design, professional development, and services and resources for students. Due to the many factors involved in digital literacy, library leadership faces the challenge of advocating for institutional-wide efforts to provide more training opportunities for students and staff. Libraries play an important role in developing and implementing digital literacy strategies.

4.1.2 Difficult Challenges: Those That Are Understood but Difficult to Solve Transforming Organizational Structures to Meet Future Work Needs. Academic and research libraries are increasingly focusing

on organizational structures due to the pursuit of flexibility and requirements for 21st-century future work practices. Shifts in technology, information needs, and evolving librarian roles force them to reflect on traditional functional hierarchies. Libraries must adopt more flexible, team-based matrix structures to maintain innovation and respond to school and user needs. Ithaka S+R researchers are studying how academic library organizational structures impact decision-making. Research results have implications for institutional structures and policies. To adapt to changes, libraries are also examining incentives for flexible design but must face steep learning curves and resistance from staff.

Continuously Developing Library Integration, Interoperability, and Collaboration Projects. To obtain funding, research institutions increasingly rely on partnerships with other institutions to improve their visibility and strengthen their positions. In this context, libraries face tremendous pressure to conduct high-quality research and quantify outputs. Although improvements have been made in recent years, existing publishing and dissemination infrastructure often requires researchers to work collaboratively. More academic and research libraries are striving to improve the research ecosystem, meet funder requirements, and reduce administrative burdens on researchers. In this situation, strengthening interoperability has become an urgent priority. To some extent, interoperability enables research systems to work in harmony, enabling seamless exchange of scientific knowledge and data across institutions, departments, and disciplines. The ultimate goal is to improve convenience for institutions to share research results with funders and other stakeholders.

4.1.3 Wicked Challenges: Those That Are Complex and Difficult to Define and Solve Economic and Political Pressures. Flat or declining university enrollment rates, rising subscription and publishing expenses, and reduced government support have increased the complexity of the environment facing academic and research libraries. Consequently, they are increasingly emphasizing technologies and digital resources that can compress service costs. The complexity of this challenge lies in that technology applications may trigger various costs. The adoption and creation of open educational resources (OER) are seen as potential solutions to reduce costs. Open access is a strategy that can not only combat rising paywalled journal subscription costs but also expand the accessibility of research results, thereby changing how libraries handle scholarly outputs. Increased functions without corresponding resource increases also bring economic and political pressures, such as providing scholar profiling systems and open data repository services for institutions. Additionally, some newly introduced administrative and management policies challenge the core principles of academic libraries in maintaining intellectual freedom and warrant attention.

Need to Respond to Radical Change. Academic and research libraries are facing continuous leadership issues affecting all aspects of their facilities and services, including updating staffing models and addressing shortages of

financial resources. The emergence of mobile technology is affecting information accessibility: users can now search from their personal devices without coming to the library. As information is increasingly stored in the cloud rather than in tangible formats, libraries are rethinking collection strategies and how to best utilize physical spaces. Additionally, libraries must design new services that align with institutional priorities to meet student success needs. Librarians face the challenge of helping faculty and students understand and maximize library value and encouraging them to integrate library products into academics and teaching.

4.2 Solvable Challenges

4.2.1 Improving Accessibility of Library Services and Resources

While libraries have performed well in addressing barriers for people with disabilities, technology changes in how users access information have created new barriers. The increasing emphasis on digital resource accessibility will also affect the types of essential skills required of library professionals. To comply with anti-discrimination laws and institutional policy requirements, librarians will also face challenges in implementing technologies and learning resources triggered by multiple potential needs. Integrating universal design principles into library programs can improve user experience for all users. Other adoptable strategies include usability testing, digital accessibility audits, and developing accessibility standard learning technologies. Listening to student opinions is crucial for meeting this challenge. Libraries can cooperate with other institutional stakeholders to ensure equal opportunities for students, faculty, and scholars with disabilities.

4.2.1.1 Overview The library community has long been committed to serving people with disabilities and promoting their inclusion. This awareness was formed over 100 years ago when ALA established its first committee on services for people with disabilities. As technology develops, the skills and digital competencies required to meet users' needs with disabilities also continuously change. The Ontario Library Association has noticed that job listings for Canadian library positions increasingly include requirements for creating accessible websites and conducting usability testing. Libraries can select technologies and create programs based on universal design principles for learning. These guidelines are based on flexibility and recognition of learner differences in curriculum development, helping libraries better serve all users by eliminating barriers and promoting broad accessibility.

Many countries have legislation prohibiting discrimination against people with disabilities, requiring equal access to education and employment opportunities, and institutions are working to comply with these legal requirements. As libraries lease digital resources instead of purchasing physical resources, they must find ways to improve the accessibility of resources in subscribed databases. Commercial publishers and educational technology companies are not obligated

to create accessible products, creating a burden for decision-makers in selecting learning resources and reviewing their accessibility policies; they must ensure that assistive technologies such as text or speech are compatible with selected products. How to incorporate these responsibilities into workflows while adding other priorities such as improving digital literacy and supporting curriculum design is a challenge facing library staff.

4.2.1.2 Implications for Policy, Leadership, or Practice Recent policy developments have significantly improved print material accessibility for people with disabilities. The Marrakesh Treaty, which facilitates access to published works for people who are blind, visually impaired, or have other print disabilities, recently took effect in 22 countries. This treaty requires participating countries to develop laws allowing the creation and domestic sharing of accessible format versions of copyrighted works. Additionally, it allows libraries to distribute copies across borders to expand collections in cooperating countries.

Although the United States and EU have not yet ratified the Marrakesh Treaty, proposed U.S. legislation aims to clarify challenges faced by libraries and other higher education stakeholders in deploying accessible technologies on campus. The *Accessible Instructional Materials in Higher Education Act* introduced in the U.S. House of Representatives in 2016 would convene a committee to develop a set of voluntary accessibility standards for e-learning resources and technologies, potentially reshaping the vendor market and ultimately improving educational opportunities for students with disabilities.

Exploring best practices and professional development will help libraries meet this challenge. The University of Wisconsin-Milwaukee received an IMLS National Leadership Grant for helping digital libraries provide services for blind and visually impaired (BVI) individuals under the Americans with Disabilities Act. A research team will investigate digital libraries' efforts to assist BVI users in achieving query accessibility and usability. These findings will guide the development of design guidelines to better meet BVI user needs. Librarians can also review the Ontario Council of University Libraries' Accessibility Information Toolkit to understand how to meet different needs. The Lithuanian Library for the Blind recently held an inclusive society library conference on themes including connections between libraries and people with disabilities, organizational strategies for strengthening library service accessibility, and the impact of the Marrakesh Treaty.

To understand barriers in library online resources, Western Washington University ran an automated accessibility checking tool on its most commonly used systems, using results to prioritize solution development. Libraries are planning partnerships with student-run disability outreach centers to conduct usability testing and improve responsiveness. The University of Central Florida provides multiple services to improve accessibility. The library's streaming video collection is equipped with audio transcripts, allowing faculty to easily edit according to their work needs. Users can also request one-on-one research support services

from library staff based on their cognitive and physical disabilities. Additionally, every public computer in the library has an "Easy Access" folder encompassing text magnification and narration tools.

4.2.1.3 Recommended Reading The following resources are recommended for those wishing to learn more about improving accessibility of library services and resources:

1. **Access Is Not Problem Solving: Disability Justice and Libraries (PDF)**
   go.nmc.org/accessjust (Alana Kumbier and Julia Starkey, *Library Trends*, Winter 2016.)
   The authors view equal user access to information as a transformative way for libraries to strengthen institutional diversity and promote social justice.

2. **Dispelling the Top 5 Myths of Library Web Accessibility (Video)**
   go.nmc.org/libmyths (Marc Zablatsky, ALA Midwinter Conference 2016, 3 March 2016.)
   This presentation analyzes the limitations of compliance rules in meeting disabled users' needs and proposes actionable solutions to help libraries improve accessibility of their online resources.

3. **Feds Single Out Library as International Model for Disabled Patrons**
   go.nmc.org/libmodel (Mike Nichols, *Grand Rapids Business Journal*, 11 April 2016.)
   The U.S. State Department cooperates with international peers to promote knowledge sharing between U.S. and international disability rights advocates. Representatives from the Middle East and Africa recently visited Michigan libraries to learn about their accessible process design.

4. **Obtaining Alternative Formats**
   go.nmc.org/altforms (Jisc, 27 February 2016.)
   This resource provides a workflow to meet user requests for accessible format written materials to promote learner independence. Strategies vary depending on the amount of text involved.

5. **Web Accessibility Toolkit**
   go.nmc.org/arltools (Association of Research Libraries, accessed 17 February 2017.)
   This guide is important for helping research libraries meet inclusivity in digital spaces, providing guidance on universal design and technical standards to improve web content accessibility. Users can also view other institutional policies addressing these challenges.

6. **World Book Day: ABC Award Winners on the Importance of Accessible Books**

go.nmc.org/nepalaccess (Accessible Books Consortium, 22 April 2016.) The Accessible Books Consortium (ABC) recognized a Nepalese NGO's work in disability rights and development action, awarding it the ABC International Accessible Publishing Award. The organization was selected for its commitment to providing Braille books and audiobooks to disabled students after the 2015 Nepal earthquake.

4.2.2 Improving Digital Literacy In 21st-century practice, productive and innovative use of technology is crucial for success in all fields. Digital literacy goes beyond isolated technical skills, including both deep understanding of digital environments that enables people to adapt to new environments and co-create content with others, and understanding and recognizing the freedoms and risks that digital interactions may bring. Libraries are obligated to help students establish digital citizenship and ensure responsible and appropriate use of technologies such as online identity, social etiquette, rights, and responsibilities. These competencies affect curriculum design, professional development, and services and resources for students. Due to the many factors involved in digital literacy, library leadership faces the challenge of advocating for institutional-wide efforts to provide more training opportunities for students and staff. Libraries play an important role in developing and implementing digital literacy strategies.

4.2.2.1 Overview Today's digital information environment expects library staff, faculty, and students to evaluate information through the credibility of information usage contexts. Although they are usually familiar with various digital tools and platforms, they may not be accustomed to critically thinking about how to use resources, interpret information, and prepare content for online sharing. As social network platforms continuously develop and digital interactions increase, opportunities for spreading misinformation, infringing copyright, and violating privacy also increase. Libraries cannot solve this challenge alone; interdisciplinary teams can help improve research capabilities. For example, Project Information Literacy has organized faculty, library staff, and other experts to conduct national research on how youth discover, evaluate, and select information in educational environments.

As an aspect of digital literacy, wise media consumption has proven key to combating "fake news." A report released by the Stanford History Education Group shows that many students face difficulties distinguishing reliable sources from unreliable ones. The recent widespread dissemination of fake news and resources has accelerated social division and dangerous activities, such as anti-abortion organizations in France disguised as health management organizations, or anti-Islamic groups spreading lies about refugees committing crimes in Germany. How to use current public attention on these hot issues to promote embedding digital literacy into university curricula is a challenge facing libraries. These competency developments must be truly integrated into all curricula to help

students appropriately manage and disseminate knowledge while showing empathy.

Libraries, as information literacy leaders, help navigate schools' digital literacy activities. The UK Open University Library has launched a university-wide project aimed at building resources and methods to improve digital capabilities among university staff, instructors, researchers, and students. They are developing a training program for basic digital literacy competencies, helping staff and students build these capabilities through training. Penn State University Library implemented an information literacy digital badge program, supporting students in building competencies through personalized, flexible activities. Although the expert panel considers this challenge solvable, digital literacy work will continue as technology advances and the actual skills of the workforce continuously develop. Jisc broadly defines digital literacy as "the ability to live, learn, and work in a digital society." Tools like Jisc's Student Digital Experience Tracker can help libraries collect data on learners' digital experiences and changing needs while tracking changes over time. The University of Michigan School of Information also considers data and statistics as important interdisciplinary skills. They teach understanding of data practices in teaching strategies for future librarians, believing these capabilities will help learners develop new ways of thinking and communicating in digital environments.

4.2.2.2 Implications for Policy, Leadership, or Practice Governments are prioritizing digital literacy initiatives to encourage economic development and enable citizens to fully participate in digital society. Ireland launched a nationwide education project funded by the National Forum for the Enhancement of Teaching & Learning. By identifying the confident and creative skills needed by higher education teachers and graduates to learn and work in digital worlds, the project developed a national digital capability framework, digital badge program, and series of activities. Project outcomes will help modernize curricula for a digital future. Badges can be exported to students' LinkedIn profiles to display progress goals. Professional development can also be built on digital literacy services and initiatives. Library leadership is providing resources for this process, such as Library Intelligence, a free diagnostic tool that can assess library staff's digital literacy competencies and provide self-study courses.

Major institutions and organizations are developing resources to guide libraries in integrating digital literacy work into daily operations. ACRL's *Framework for Information Literacy for Higher Education* lays the foundation for defining today's graduates' general information literacy levels, helping form digital literacy initiatives. The Public Library Association's website DigitalLearn.org provides a series of self-learning tutorials for users to improve digital capabilities. This website is also a practice community for educators to share related materials and best practices. Libraries can also create their own digital literacy training websites, allowing learners to customize courses, track progress, and obtain certification.

4.2.2.3 Recommended Reading The following resources are recommended for those wishing to learn more about improving digital literacy:

1. **Beyond Library Walls: Supporting Academic Capacity Building with Digital Technologies**
   go.nmc.org/beyondlib (Sharon Chua, VALA 2016.)
   The author explains how librarians can support faculty by identifying methods to promote digital literacy capacity building, describing digital tools that helped Deakin University Library address skills gaps.

2. **DigiComp 2.0: The Digital Competence Framework for Citizens**
   go.nmc.org/digicomp (European Commission, 2016.)
   The DigiComp framework can serve as a good starting point for libraries to support curriculum modernization planning for a digital future. It describes digital competencies to help assess digital knowledge and support designing targeted teaching.

3. **DIY Digital Privacy and Security for Students**
   go.nmc.org/privsec (Adam Rogers, Knight Foundation, 21 March 2016.)
   North Carolina State University Library developed toolkit prototypes and workshop resources combining real-world assessments of privacy and security threats with suggestions for how students can more actively protect their digital lives.

4. **From Written to Digital: The New Literacy**
   go.nmc.org/newlit (Phillip Ventimiglia and George Pullman, *EDUCAUSE Review*, 7 March 2016.)
   Digital literacy enriches how students think and communicate, becoming a prerequisite for employment and intellectual independence. For example, Georgia State University has added digital literacy content to its honors English composition courses to better prepare graduates for understanding electronic publication choices.

5. **Opportunities for Academic and Research Libraries and Wikipedia**
   go.nmc.org/wikiped (The International Federation of Library Associations and Institutions, 2016.)
   This article introduces the potential for Wikipedia editors to cooperate with academic and research libraries to promote open knowledge resources, improve students' critical evaluation skills, and help develop and disseminate toolkits to reuse Wikipedia content and metadata.

6. **Rethinking Digital Literacy to Serve Library Staff and Users eCourse**
   go.nmc.org/ecour (American Library Association, 8 September 2016.)
   ALA is promoting a four-week online course to help participants incorporate evolving digital literacy definitions into learning opportunities and develop frameworks and design learning opportunities to promote digital literacy in their institutions.

4.3 Difficult Challenges

4.3.1 Transforming Organizational Structures to Meet Future Work Needs Academic and research libraries are increasingly focusing on organizational structures due to the pursuit of flexibility and requirements for 21st-century future work practices. Shifts in technology, information needs, and evolving librarian roles force them to reflect on traditional functional hierarchies. Libraries must adopt more flexible, team-based matrix structures to maintain innovation and respond to school and user needs. Ithaka S+R researchers are studying how academic library organizational structures impact decision-making. Research results have implications for institutional structures and policies. To adapt to changes, libraries are also examining incentives for flexible design but must face steep learning curves and resistance from staff.

4.3.1.1 Overview As contemporary society's workforce requirements develop toward higher social skills and analytical abilities, the nature of library work is also changing. Most historical organizational structures, including libraries, were hierarchical. In this context, a director supervises staff responsible for traditional services, managing according to strict hierarchies. This type of structure is simple but cannot accommodate the large amount of information libraries need to adjust in changing environments. Under this organizational structure, libraries face challenges in meeting the constantly changing expectations of diverse users.

To meet today's user needs, libraries must extract resources from different functional areas to form flexible matrix organizational structures. Matrix design facilitates bringing together experts from different functional areas into temporary or long-term collaborative teams. The matrix management model was originally developed by NASA and adopted by institutions such as IBM, Kaiser Permanente, and Citibank, achieving high returns in knowledge-related businesses. In 2016, approximately one-third of IMLS funding for digital library projects was invested in projects requiring experts with diverse expertise, including digitization, metadata, preservation, and technical solutions. The emergence of makerspaces (examples in the "User as Creator" section of this report) provides possibilities for creating conceptual and physical products. However, building ideal environments also requires library staff with diverse knowledge and skills, including instructional designers, technology experts, and social media specialists.

Although deploying this flexible structure has advantages such as seamless information exchange, improved technical capabilities, and more effective resource utilization, it hinders seamless adoption. For example, steep learning curves emerge as roles change, resistance to change occurs, and confusion arises when reporting to multiple bosses. Technical experts working in library makerspaces may feel overwhelmed managing time and demands across multiple reporting relationships while being responsible for both maker projects and regular teams. Libraries can consider implementing matrix structures that clarify relationships

between multiple managers, information management, and priorities. The University of Adelaide Library aims to achieve higher organizational agility by simplifying its organizational structure; leadership plans to cut redundant and nonessential positions and strengthen coordination among departments by forming four to five functional units to improve the library's ability to respond to complex changing environments. Productivity technologies like Slack may also strengthen and streamline project communication.

4.3.1.2 Implications for Policy, Leadership, or Practice Recently, some major organizations have implemented policies to strengthen the flexibility of matrix organizational structures. In March 2015, the Academic Library Planning and Revitalization Institute convened personnel from different departments of academic libraries to focus on meeting student needs, jointly identifying four areas of concern. One consensus was that libraries should function like learning communities. To accelerate achieving this goal, participants recommended that libraries encourage internal cooperation, provide comprehensive services, strengthen flexibility, and adopt interdisciplinary approaches to problem-solving. Matrix-like design is an important way to support this goal because it allows libraries to extract resources from many different professional fields while increasing interactivity and openness—two major elements for promoting innovation processes and learning.

Any system-wide change requires clear support and commitment from senior leadership. When addressing this challenge, leaders at all levels of libraries advocate for integrating greater flexibility into structures. For example, the new University Librarian and Library Director at the University of Virginia are eagerly promoting more cross-collaboration in research activities. The director expects librarians to cooperate with faculty who receive external research funding. Major funding agencies also recognize that the nature of effective initiatives is interdisciplinary. The National Institutes of Health provides funding for biomedical projects that include library information experts in research teams. The librarian's role in the team is to ensure effective documentation, preservation, storage, and circulation of data. Strategies for including librarians in external research projects require both flexible structures and important support from senior leadership.

To address this challenge, more libraries are trending toward more flexible models. For example, the University of Manchester Library abandoned its traditional team model oriented toward five major disciplines, switching to three functional teams: research services, teaching, and academic engagement. This transformation enables them to directly serve university strategies by leveraging different expertise. Although change agents anticipated challenges, they were confident that this reorganization would eliminate redundancy and help libraries adapt to changing needs. They have already seen progress in building and strengthening service capabilities. For example, the new functional teams developed Manchester eScholar, the institutional repository service. These teams

also participated in a project to monitor, disseminate, and develop publishing strategies to increase citations for their researchers.

4.3.1.3 Recommended Reading The following resources are recommended for those wishing to learn more about transforming organizational structures to meet future work needs:

1. **2016 Top Trends in Academic Libraries**
   go.nmc.org/top2016 (Association for College & Research Libraries, 2016.)
   This article discusses the latest trends in academic libraries, including research data services, digital scholarship, and agile collection assessment methods. Many trends indicate increasing demand for flexible organizational structure design.

2. **Changing Roles and Changing Needs for the Academic Librarian**
   go.nmc.org/changing (Danny Kingsley, University of Cambridge Office of Scholarly Communication, 29 November 2016.)
   Librarian roles are changing, requiring more research, data management, and regulatory skills. Leadership can explore changes in library organizational structures to understand the changing roles and needs of librarians.

3. **Follow the (Grant) Money**
   go.nmc.org/follow (Brian Kenney, *Publishers Weekly*, 14 October 2016.)
   Funding announcements indicate what libraries should have in the future. Digital library projects, maker activities, and community outreach programs receive funding, requiring agile organizational design.

4. **Making Matrix Organizations Actually Work**
   go.nmc.org/matrix (Herman Vantrappen and Frederic Wirtz, *Harvard Business Review*, 1 March 2016.)
   This article outlines principles of matrix-based organizational work. Although aimed at the general public, library leaders can apply these guidelines to their institutions.

5. **Organizing the Work of the Research Library**
   go.nmc.org/organi (Roger C. Schonfeld, Ithaka S+R, 18 August 2016.)
   In this research project, Ithaka S+R interviewed library directors about leadership and change management issues related to library organizational structures.

6. **Subject Matrices: An Innovative, Collaborative Approach to Serving the Agricultural Sciences**
   go.nmc.org/submat (Jenny K. Oleen et al., *Western Libraries Faculty & Staff Publications*, 8 January 2015.)
   Kansas libraries transformed from discipline-based departments to user-based departments. During the transformation, an agricultural and biological sciences matrix emerged, bringing together professional librarians

from various library departments, including content development librarians, data services librarians, and scholarly communication librarians.

4.3.2 Continuously Developing Library Integration, Interoperability, and Collaboration Projects To obtain funding, research institutions increasingly rely on partnerships with other institutions to improve their visibility and strengthen their positions. In this context, libraries face tremendous pressure to conduct high-quality research and quantify outputs. Although improvements have been made in recent years, existing publishing and dissemination infrastructure often requires researchers to work collaboratively. More academic and research libraries are striving to improve the research ecosystem, meet funder requirements, and reduce administrative burdens on researchers. In this situation, strengthening interoperability has become an urgent priority. To some extent, interoperability enables research systems to work in harmony, enabling seamless exchange of scientific knowledge and data across institutions, departments, and disciplines. The ultimate goal is to improve convenience for institutions to share research results with funders and other stakeholders.

4.3.2.1 Overview Balancing institutional performance and individual researcher needs supported by information flows, libraries must manage both research information management systems (RIMS) and digital repositories, along with their metadata. These sometimes operate independently and sometimes overlap. RIMS integrate information about institutional research activities at the institutional, national, or funder level, while digital repositories store and grant access to data and objects. With the development of open access initiatives and open-source repository platforms, libraries face the challenge of keeping pace with repository development. As a pioneering interoperability protocol for standardized information exchange between repositories, the Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) was established. Data providers expose structured repository metadata through OAI-PMH, while service providers harvest metadata through OAI-PMH service requests.

Despite progress, significant obstacles remain in integrating open access repositories to achieve interoperability with RIMS, journal publishing platforms, indexing and abstracting services, and search engines. Challenges to interoperability between repositories and repository networks come from multiple aspects, such as resources available for web development, web development speed, and negative directives for repositories and similar network facilities. Language barriers and cultural, organizational, and legal differences also create obstacles. In this diverse scenario, the ability to build a unified research materials system depends on whether repositories and other systems follow consistent interoperability standards that allow metadata and digital objects to be transferred between systems.

The University of Florida is experimenting with linking its repository to Else-

vier's online journal and e-book catalog ScienceDirect through an application programming interface (API) that can regularly search for and save metadata of articles published by the university's researchers on ScienceDirect, finding links to over 30,000 articles. Researchers' distributed network identities across various platforms lack persistent unique identifiers, exacerbating these challenges. It is particularly difficult for scholars intending to collaborate to view complete information about another scholar's work to determine whether to establish cooperation. Fortunately, ORCID has become a widely applicable research identity standard structure across fields. ORCID helps identify researchers with similar or identical names; even when researchers' work or affiliations change, it can reveal their relationships with research, funders, and publishers; automatically establishing connections with publications, funding, and patents. These functions save research management time, making it easier for institutions and funders to link funding with outputs or commercial benefits.

4.3.2.2 Implications for Policy, Leadership, or Practice Global libraries also face challenges in selecting standards and strategic support technology policies. In the U.S., *Journal of Librarianship and Scholarly Communication* surveyed 206 U.S. universities, finding that about 50% have established specialized policies for data access, indicating that libraries can play a role in developing and applying institutional guidelines for data access. Currently, funder policies emphasize sharing, dissemination, and openness, while institutional policies focus on legal issues and ownership. As institutions begin responding to changing funder and government policies, this will provide rare opportunities for libraries to lead in developing institutional data policies that align with general trends to improve data openness and accessibility. Librarians at the University of Wisconsin-Milwaukee, University of Illinois at Chicago, and Carnegie Mellon University are conducting related research to provide references for best practices in developing institutional data policies.

Strengthening integration, interoperability, and collaboration among numerous interfaces of global research institutions requires strong partnerships. Library directors of the Big Ten Academic Alliance investigated challenges to achieving better seamless user experiences from information discovery to service realization. Library directors recognized the need for deeper mutual influence, joint planning, and collective decision-making among public services, resource sharing services, and technical services units to optimize libraries' ability to develop and integrate systems and services at the service layer. The final series of reports proposed model frameworks and recommendations from information discovery to service provision. To achieve better interoperability in open access initiatives, national and regional repository networks have emerged. For example, the Digital Repository Federation is Japan's institutional repository network; the Chinese Academy of Sciences Institutional Repository Grid integrates records from 96 affiliated institutions; the European network OpenAIRE is a central portal integrating EU-funded research results.

4.3.2.3 Recommended Reading The following resources are recommended for those wishing to learn more about continuously developing library integration, interoperability, and collaboration projects:

1. **European Cloud Initiative—Building a Competitive Data and Knowledge Economy in Europe**
   go.nmc.org/eci (Eur-Lex, 19 April 2016.)
   The European Commission proposed the European Science Cloud and European data infrastructure as interoperability solutions. This document details the development of a competitive data and knowledge economy.

2. **Green OA and the Interoperability of Institutional Repositories**
   go.nmc.org/interop (John Parsons, *Library Journal*, 31 May 2016.)
   Global initiatives are being implemented to share unified strategies and technologies for improving metadata standardization to promote interoperability.

3. **Harvard Medical School Launches Digital Repository of Medical Evidence**
   go.nmc.org/libofevid (HIT Consultant, 16 September 2016.)
   A team of librarians, clinicians, and engineers developed the Harvard Evidence Repository to help practicing physicians select imaging examinations for patients based on recommendations from literature reviews.

4. **Overview of Systems Interoperability Project (PDF)**
   go.nmc.org/osipreport (Ian Lynne et al., Research Councils UK, 17 June 2015.)
   Shares research results from the Overview of Systems Interoperability Project (OSIP), reviewing complex scenarios of research interoperability. The authors propose recommendations for maximizing interoperability of research data systems used by UK Research Councils.

5. **The Research Data Alliance**
   go.nmc.org/rd-a (Research Data Alliance, accessed 21 February 2017.)
   The Research Data Alliance provides a forum for members to jointly develop and adopt infrastructure promoting data sharing and data exchange research.

6. **Status of Open Access Institutional Digital Repositories in Agricultural Sciences**
   go.nmc.org/openasia (Bijan Kumar Roy et al., *Library Philosophy and Practice*, February 2016.)
   The review analyzed 43 Asian agricultural science open access repositories, finding that 79% lack standard guidelines for researchers on self-archiving open access outputs. The authors recommend mandatory archiving strategies to improve resource accessibility and usability.

4.4 Wicked Challenges: Complex and Difficult to Define and Solve

4.4.1 Economic and Political Pressures Flat or declining university enrollment rates, rising subscription and publishing expenses, and reduced government support have increased the complexity of the environment facing academic and research libraries. Consequently, they are increasingly emphasizing technologies and digital resources that can compress service costs. The complexity of this challenge lies in that technology applications may trigger various costs. The adoption and creation of open educational resources (OER) are seen as potential solutions to reduce costs. Open access is a strategy that can not only combat rising paywalled journal subscription costs but also expand the accessibility of research results, thereby changing how libraries handle scholarly outputs. Increased functions without corresponding resource increases also bring economic and political pressures, such as providing scholar profiling systems and open data repository services for institutions. Additionally, some newly introduced administrative and management policies challenge the core principles of academic libraries in maintaining intellectual freedom and warrant attention.

4.4.1.1 Overview Since the 2008 economic recession, academic and research libraries have faced increasingly fierce competition for funding, prompting them to reconsider how to effectively allocate resources to address global budget challenges. ALA's *2016 State of America's Libraries Report* highlighted this challenge, providing clear statistics on U.S. economic pressures; nearly 50% of university leaders in 2015 believed their institutions had not yet recovered from the recession. State cuts to public universities have placed greater pressure on academic libraries. Wiley's survey shows that budget issues are considered the biggest challenge facing global academic libraries. Global impacts of exchange rate fluctuations also add financial burdens to academic libraries. South Africa's sluggish commodity market has caused its currency to depreciate, but universities typically subscribe to international journals in U.S. dollars and euros, creating significant impacts on local libraries.

Academic libraries are increasingly purchasing new forms of scholarly publications to improve accessibility and reduce costs. Many scholars and funders view open access mechanisms as the future of scholarly publications while recognizing their potential impact on face-to-face services. The development of open access resource-related research drives libraries to transform their roles, shifting from collection-centered to scholar-centered spaces, achieving a transformation from physical collection management to roles strengthening deep connections around information. Unfortunately, according to a Jisc report, the academic journal market has been dominated for years by large publishing companies that drive up costs; although open access is viewed as a solution, the currently widely implemented solution path is extremely slow and expensive.

Political actions such as policy adjustments or government administrative changes also create pressures for libraries. The Brexit vote created unexpected

impacts for UK libraries. For example, besides pound depreciation, reduced European academic cooperation means fewer co-authored articles in UK open access resources, also affecting academic libraries. UK austerity policies have threatened libraries for years, sparking political activities defending their critical role in society. In the U.S., the recent presidential election also raised concerns in the library community due to fears that President Trump might cut government agencies. Stakeholders worry that such cuts could affect innovation funding for research and cultural organizations. The new administration could also affect international trade, driving up costs for mobile devices that have promoted digital publishing development over the past decade. Additionally, U.S. libraries must defend their core values of information privacy and intellectual freedom while opposing net neutrality policies that support corporate interests over public interests, which has also raised concerns.

4.4.1.2 Implications for Policy, Leadership, or Practice As more academic libraries hope to reduce costs and expand research output availability through open access, quality control policies urgently need development. Hundreds of academic institutions have developed open access policies managing faculty and staff publications, and international funding agencies typically require open access for funded project papers. During the Obama administration, a memo guiding federal agencies stated that institutions with annual R&D expenses exceeding $100 million, such as the Department of Homeland Security and EPA, must prioritize open access to federally funded academic publications and digital data. Therefore, in 2017, over 20 federal agencies accounting for 99% of federal R&D expenditures developed a plan. Since the Trump administration plans significant budget cuts and may eliminate some federal agencies and departments like EPA, whether this policy's future impact on research and academic libraries remains unknown is uncertain.

Libraries worldwide are also seeking mutual cooperation and partnerships with external organizations to address increasing financial pressures. CARL brings together over 30 institutions to improve knowledge access, promote effectiveness and sustainability of scholarly communication, and share best practices and policies in the Canadian research community. Its white paper *Canadian Universities and Sustainable Publishing (CUSP)* explores how libraries can shift from procurement management to serving faculty and students under publisher monopolies and university budget constraints. As this transformation unfolds, library professionals experience this change process, uncertain about how to maintain their relevance. These confusions are closely related to another difficult challenge in this report—transforming organizational structures to meet future work needs. When hiring new staff and reassigning responsibilities, leadership must not only identify skills critical for today's users but also anticipate future library service development. Innovative libraries are identifying unmet user needs, implementing technologies to enhance user experience, and participating in outreach activities. Supporting and training existing staff to acquire new skills and adapt to new roles is difficult to achieve in budget contracts.

As budget pressures intensify, institutions face greater pressure to adopt virtual planning and technology to improve student success and retention. Libraries are working to align their work goals with institutional goals supporting teaching. A series of strategies are recommended: segmenting library services, establishing partnerships, and incorporating library perspectives into higher-level institutional dialogues—including library professionals joining university committees and cooperating with student services and faculty. To improve responsiveness to future needs, libraries must increase agility. Maintaining a positive atmosphere in uncertain change environments is important; many organizations are drawing on John Kotter's change management principles, including communicating urgency, developing shared vision, gaining stakeholder buy-in, and consolidating change progress.

4.4.1.3 Recommended Reading The following resources are recommended for those wishing to learn more about economic and political pressures:

1. **The Forbidden Forecast: Thinking About Open Access and Library Subscriptions**
   go.nmc.org/forbid (Rick Anderson, *The Scholarly Kitchen*, 21 February 2017.)
   As a researcher at the London Reader Conference, library opinion leaders consider whether green open access could reduce academic libraries' journal subscription fees, concluding that if GOA gains traction, costs for identifying meaningless papers would be greatly reduced.

2. **Funding Open Access Monographs**
   go.nmc.org/fund (Rupert Gatti and Marc Mierowsky, *College & Research Libraries News*, October 2016.)
   Ithaka S+R and OAPEN-NL's latest research provides reliable data on costs and revenues for academic libraries publishing open access monographs related to traditional publishing models.

3. **Gale Gets Ready to Toast to the New Year**
   go.nmc.org/toast (Gale Blog, 20 December 2016.)
   Library decision-makers share views on 2017 academic library trends, including libraries adjusting budget priorities through coordinating OER and providing more support to improve students' technology access capabilities.

4. **Has the Library Outlived its Usefulness?**
   go.nmc.org/outli (Donald A. Barclay, *University World News*, 6 May 2016.)
   U.S. academic libraries face increasing pressure to cut non-critical expenses. Recent trends such as the rise of e-books, declining book circulation rates, and space reallocation are causing libraries to continuously change budgets to maximize relevance.

5. **Research Libraries, University Presses Oppose Trump's Immi-**

gration Order
go.nmc.org/oppose (Richard Senese, *EdSurge*, 30 January 2017.)
When President Trump issued an executive order temporarily banning immigration from seven countries, U.S. ARL and the University Presses Association publicly opposed it. They stated that this order would not only immediately prevent students and academics from entering or returning to the U.S. but also undermine international academic cooperation.

6. **The Wrench in the Gears: How Independent Academic Presses Can Disrupt the Publishing Model**
go.nmc.org/wrench (Brian Gaines and David Blakesley, *Digital Rhetoric Collaborative*, 28 November 2016.)
In this interview, a Clemson University professor describes the rise of independent academic presses and their impact on academic libraries.

4.4.2 Need to Respond to Radical Change Academic and research libraries are facing continuous leadership issues affecting all aspects of their facilities and services, including updating staffing models and addressing shortages of financial resources. The emergence of mobile technology is affecting information accessibility: users can now search from their personal devices without coming to the library. As information is increasingly stored in the cloud rather than in tangible formats, libraries are rethinking collection strategies and how to best utilize physical spaces. Additionally, libraries must design new services that align with institutional priorities to meet student success needs. Librarians face the challenge of helping faculty and students understand and maximize library value and encouraging them to integrate library products into academics and teaching.

4.4.2.1 Overview Technology is enabling more libraries to focus on key issues, but they also face the challenge of staying relevant. While libraries are often considered vital, stable, historical beacons regionally and globally, they are not immune to pressures from national economics, government, consumer behavior and expectations, and changes in educational paradigms. Many library directors are responsible for implementing new work, guiding organizations toward new priorities, and may encounter staff resistance. The author advocates for empathy as an important characteristic that allows leaders to unite teams.

As technology enables more libraries to focus on key issues, they also face the challenge of staying relevant. While libraries are often considered vital, stable, historical beacons regionally and globally, they are not immune to pressures from national economics, government, consumer behavior and expectations, and changes in educational paradigms. Many library directors are responsible for implementing new work, guiding organizations toward new priorities, and may encounter staff resistance. The author advocates for empathy as an important characteristic that allows leaders to unite teams.

4.4.2.2 Implications for Policy, Leadership, or Practice Libraries are developing policies to clarify their vision and drive change. The University of Virginia's UVA Library strategic declaration *The University Library: Into the Third Century* states that its central mission is to persist in promoting new knowledge creation while acknowledging the limitations of 20th-century models based on physical collections and reference services. The document details an innovation-centered service framework. For example, staff provide face-to-face and online training for new learning technologies and develop solutions for issues such as digital copyright law.

Addressing these challenges requires visionary leaders, and professional development is also helping library staff envision new solutions and thrive in changing environments. The Harvard Graduate School of Education's annual "Library Leadership in a Digital Age" series helps participants think critically about the impact of future learning and technology and clarify opportunities for libraries to contribute to their institutions' intellectual development. Similarly, the 2017 Library Leadership Workshop at the University of Hong Kong themed "Libraries at a Crossroads: Leadership Challenges" will gather library directors from Asia in Bangkok to enhance management and leadership skills and promote innovation through practice, interactive simulations, and discussions on strategic planning, branding, and awareness building.

Library staff at the University of Western Australia cooperate with student services teams to promote learner success. In the WRITESmart Drop-in program, learning skills advisors provide face-to-face tutoring to help students improve writing skills, while librarians help improve research capabilities and provide guidance on citation formats. This cooperation provides one-stop services for learners and increases the visibility of library services. The University of Huddersfield in the UK is using Library Impact Data Project survey results to establish evidence-based marketing methods and increase student engagement. The Roving Librarian program, where library staff set up booths in densely populated campus areas to promote services and help students via iPads, maintains brand consistency with logos used in email and social media campaigns so students can associate the logo with library products. Librarians also provide door-to-door services, offering personalized services in academic staff offices to improve usage of subject-specific resources. This outreach not only builds personal relationships but also increases the likelihood of attracting students to the library through staff.

4.4.2.3 Recommended Reading The following resources are recommended for those wishing to learn more about responding to radical change:

1. **Effective Techniques for the Promotion of Library Services and Resources (PDF)**
   go.nmc.org/libpromo (Zhixian Yi, *Information Research*, March 2016.)
   A study reviewing various campus communities about the popularity and effectiveness of library service marketing techniques. Digital promotion

is considered effective, especially social media campaigns that promote interactivity and support user-generated content.

2. **Empathy as the Leader's Path to Change**
go.nmc.org/empathy (Steven Bell, *Library Journal*, 27 October 2016.)
Library directors responsible for implementing new work and guiding organizations toward new priorities may encounter staff resistance. The author advocates for empathy as an important characteristic that allows leaders to unite teams.

3. **How Libraries Are Boldly Innovating to Meet the Needs of Changing Communities**
go.nmc.org/boldlib (Anna Pratt, *Truthout*, 26 November 2016.)
Due to continuous budget challenges, academic and public libraries are working to strengthen user engagement to enhance users' sense of ownership. Librarians are also working to change public perceptions by creating pop-up events and programs that meet specific community needs.

4. **Institute-wide Task Force on the Future of Libraries**
go.nmc.org/mitfuture (MIT Ad Hoc Task Force on the Future of Libraries, 24 October 2016.)
A task force composed of faculty, staff, and students reviewed MIT Library programs and issued a series of recommendations for enabling the library to better support content creation and knowledge sharing in the global community.

5. **Leadership in Disruptive Times**
go.nmc.org/iflalead (James M. Matarazzo and Toby Pearlstein, *IFLA Journal*, 27 September 2016.)
This article compares managers focused on operational goals and daily services with leaders working for organizational sustainability through vision. Both roles must be coordinated to guide library staff in meeting current challenges.

6. **Yale Libraries Adapting in Digital Age**
go.nmc.org/yaleadapt (Ishaan Srivastava and Ryan Gittle, *Yale Daily News*, 13 October 2016.)
Yale University's "Personal Librarian Program" provides students with a single point of contact.

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5. Important Technology Developments in Academic and Research Libraries

Based on the Delphi method, after multiple rounds of research, discussion, and voting, the project expert panel selected six technology development trends for detailed introduction in this section. In the NMC Horizon Project, technology is broadly defined as tools and resources used to improve teaching, learning,

creative inquiry, research, and information management. Although many technologies were not originally developed for academic and research libraries, they have very practical applications in these fields.

The expert panel identified future technology developments driving technology planning and decision-making, which can be divided into three time horizons: short-term developments expected to be widely adopted within one year or less; mid-term developments expected to be adopted within two to three years; and long-term developments expected to become mainstream library applications within four to five years.

The expert panel divided important technology application trends based on technologies' origins and uses. They conducted a series of discussions on these technologies' potential applications, particularly in the context of global academic and research libraries. Discussion content is available at horizon.wiki.nmc.org/Horizon+Topics.

At the project start, the panel was provided with extensive background materials documenting existing technology applications in education and other fields. The project also recommended that experts study potential future technologies that may affect academic and research libraries.

A key criterion for evaluating "important technologies" in this report is their potential relevance to global academic and research libraries. Before voting, project researchers had already selected a series of technologies. After the first round of voting, the expert panel narrowed the scope to 12 technologies, with final voting limiting it to six key technologies. Technologies not selected are still frequently discussed on the project wiki at horizon.wiki.nmc.org. Some candidate technologies were not selected because experts believed they were already widely applied in reality or had been applied for more than five years. Some technologies were not selected due to insufficient reliable project examples.

Table 3 Seven Important Technology Categories

Consumer Technologies	Internet Technologies	Social Media Technologies
Instant messaging tools	Data blockchain	Aggregation tools
Wearable devices	Digital scholarship technologies	Social networks
	Library services platforms	Virtual worlds
		Emotional computing

Visualization Technologies	Enabling Technologies	Learning Technologies
Smart positioning	3D printing	Adaptive learning technologies
Makerspaces	Information visualization	Micro-learning technologies
Preservation and energy-saving technologies	Mixed reality	Mobile learning
	Virtual reality	Next-generation learning manageme

Visualization Technologies	Enabling Technologies	Learning Technologies
		Virtual and remote laboratories

These technologies, tools, and combination strategies can be divided into seven categories. However, these categories are not closed sets but attempt to provide an explanation and organize new technologies into development paths relevant to academic and research libraries. Technology categories are relatively objective and fair. Each new research cycle adds new technologies and merges or updates others. Overall, this classification is just a tool for thinking about innovation. The seven categories are:

1. **Consumer Technologies:** Can serve as assistants for learning and research and are well-suited for libraries. Although not originally developed for educational use, they were ultimately adopted by institutions because people use them at home or other places for entertainment and work needs.
2. **Digital Strategies:** Not referring to a large collection of technologies, but a series of technology usage methods through devices and software to support teaching, learning, research, and information management inside and outside libraries. Effective digital strategies can be applied in formal and informal learning, making learning interesting and inspiring users to transcend traditional thinking to create fresh, meaningful 21st-century artifacts.
3. **Enabling Technologies:** Have the potential to change perceptions of existing devices and tools. Technologies may have weak relevance to learning but are visible starting points for essential technological innovation. Enabling technologies expand the usage range of existing tools, broadening their plasticity and usefulness.
4. **Internet Technologies:** Include technologies and infrastructure that help people interact with networks more transparently, comfortably, and easily.
5. **Learning Technologies:** Include both tools and resources specifically developed for the education sector and those originally developed for other sectors but adapted for learning. These also include technologies that change formal or informal learning environments to make them more accessible and personalized.
6. **Social Media Technologies:** Could be classified under consumer technologies, but social media has become universally and widely applied in every corner of society, thus can be a separate category. As recognized new technologies, social media still rapidly develops online with new ideas and tools.
7. **Visualization Technologies:** Use simple charts for visual analysis of complex data. Mimicking brain functions, they quickly process

visual information of complex situations, identify patterns, and perceive sequences. These technologies are rapidly developing into tools for mining large datasets, exploring dynamic processes, and simplifying complex situations.

The following sections elaborate on the six key technology development trends identified by the 2017 NMC Horizon Report Library expert panel as having potential impact on academic and research libraries. Therefore, each section includes an overview of the technology, discussion of its relevance to academic and research libraries, as well as project application examples and recommended reading.

5.1 Technologies Widely Adopted Within One Year

5.1.1 Big Data Today, almost all interaction data generated from Internet and goods and services consumption is being selectively tracked, stored, and used. This has led to the concept of big data—large-scale data reflecting behaviors and actions of various populations. Data scientists and data collection platforms can now rely on computing to organize petabyte and exabyte-level data for analysis and identification of previously undiscovered patterns. The massive, diverse data sets are so complex that displaying information in understandable formats is crucial. Data visualization analysis integrates highly advanced computational methods, using complex graphics engines to illustrate patterns, structures, or the most complex visual demonstrations. Information visualization uses infographics and technical diagrams to display data for quick and easy understanding. Therefore, libraries are ideally positioned as information collectors, managers, and analysts to serve academia, government, and enterprises. Particularly, libraries can play indispensable roles as collaborators, facilitating educational institutions to make informed decisions that reflect and serve learners' real needs.

5.1.1.1 Overview Due to the proliferation of data sources such as mobile devices and social media and the rapid development of data mining technologies, big data has become a focus of attention in academia and research library communities. Although there is no standard definition for big data, it is typically understood through the "3V" framework: volume (the scale of data sets, usually calculated in terabytes and petabytes), variety (big data is unstructured and diverse in form, such as text, audio, video, and images), and velocity (the speed at which data is generated—90% of all data was generated in the past two years). SAS's definition of big data includes two additional dimensions: variability (peaks and valleys in data generation) and complexity (heterogeneity from different sources). IBM adds veracity (data uncertainty) as another characteristic of big data.

The exponential growth and accessibility of big data have led to a new scientific research paradigm—data-driven science. This research paradigm is built on three core activities: data collection, management, and analysis. Essentially,

this paradigm requires research data management support, providing libraries with opportunities to actively integrate and participate in research processes. Correspondingly, many academic libraries have established research data service departments, providing a range of consulting services including data management, developing data management processes, and identifying and selecting appropriate data collection, analysis, and visualization tools.

5.1.1.2 Relevance to Academic and Research Libraries As research facilitators and supporters, big data has significant impact and role in this process. Although data-centric research focuses on natural and social sciences, researchers and librarians have noted big data's role in digital humanities research. This field focuses on large numbers of text or video digital objects, such as Google Earth, photos, messages posted on social media, and continuously growing citation data in academic research. Collecting these data can promote new knowledge generation, allowing people to understand new knowledge in unprecedented ways through text mining and topic modeling techniques. For example, Yale University's *Robots Reading Vogue* project includes 2,700 covers, over 400,000 pages, and 6TB of data. This project has changed digital humanities librarians' analysis and quantitative research methods, expanding public services librarians' skills in interdisciplinary research (gender studies, art history, and computer science).

Additionally, libraries generate data in network resource and service provision and in using social media to promote programs and services. Libraries' purchased digital resources and campus-native text and data forms of digital scholarship resources can all be structured as big data. Analyzing this internal data can provide basis for libraries to develop personalized user service strategies. In recent years, as attention to data and analysis has continuously increased, library business in academic data has gradually become an important aspect of library services. The typical work of data librarians is to assist in analysis research and guide programming. Therefore, data librarians should have data literacy, possessing abilities to understand, analyze, transform, and display data needed for knowledge innovation. Typically, they are very familiar with various data formats and data analysis and visualization software such as SPSS and Tableaux. As information consultants and research collaborators, they also need strong communication and presentation skills.

Libraries are recruiting more and more "data"-related positions, such as research data librarians, data management specialists, and data visualization experts. To meet this need, library and information science fields are developing related courses, especially for future library professionals. For example, the University of Illinois School of Information Sciences has specifically established data management courses in its MS/LIS program. The Digital Curation Centre (DCC) in the UK provides a series of services, products, and training in research data management. DCC cooperates with the UK Open University to develop an institutional research data management framework, supporting needs collection,

training, and guideline development.

5.1.1.3 Big Data in Practice The following are examples of big data applications that have direct impact on academic and research libraries:

1. **Big Data, Small Library**
   go.nmc.org/bigsmall
   Shell Australia's technical librarians have cooperated with colleagues in geoscience, information technology, and data management to ensure effective management of the company's continuously growing geoscience data. Their support services include identifying metadata fields, developing controlled vocabularies, establishing rules, defining required search parameters, and developing workflow procedures.

2. **HathiTrust Digital Library Big Data Project**
   go.nmc.org/hathitrust
   The HathiTrust project uses data mining tools to parse large amounts of digital text without violating copyright law, applying computational analysis and metadata to collect, correlate, and visualize various data from large digital texts.

3. **Library Data Labs Project**
   go.nmc.org/libdat
   In this project, five cross-institutional teams from 23 universities, funded by Jisc, analyzed library data to obtain library-related service recommendations and presented them using appropriate data visualization tools. This addressed e-resource usage, using information dashboards to support outstanding frameworks, and library facility and space usage and impact issues.

5.1.1.4 Recommended Reading The following resources are recommended for those wishing to learn more about big data:

1. **Directions for Research Data Management in UK Universities**
   go.nmc.org/direc (Sheridan Brown et al., Jisc, March 2015.)
   This report outlines the direction of research data management in the UK for the next five years. This field includes five key topics: policy development and implementation, skills and capabilities, infrastructure and interoperability, incentivizing researchers and support, and business case and sustainability.

2. **Research Data Services in Academic Libraries: Data Intensive Roles for the Future?**
   go.nmc.org/intensive (Carol Tenopir et al., *Journal of eScience Librarianship*, 2015.)
   The article introduces the level of research data services (RDS) provided by academic libraries since 2011. The study surveyed academic institu-

tions in North America, aiming to assess the growth of RDS and future RDS pathways and challenges.

5.1.2 Digital Scholarship Technologies Digital scholarship technologies refer to the collection of digital and computational tools currently used in higher education to improve academic research levels. The Chartered Institute of Library and Information Professionals (CILIP) defines digital scholarship as applying technology to support knowledge acquisition, retrieval, and application. Digital scholarship products include digital media, websites, scholarly information archives, and digital displays. Although including digital humanities, digital scholarship is an interdisciplinary field with participants from various disciplinary backgrounds, including programmers and researchers who collaborate on scientific research. The focus of university libraries is helping scholars understand new research processes because they support scholarly research production, requiring them to use different workflows, tools, and content.

5.1.2.1 Overview The concept of digital scholarship originated in the UK in the late 1990s. Before the umbrella term digital scholarship emerged, it was initially called e-science, using new technology thinking and data analysis tools for academic research, also called cyberinfrastructure and e-scholarship. Digital scholarship includes a series of information technologies such as high-performance computing, visualization technology, database technology, and high-performance networks, creating a new research paradigm—data-intensive science. Academic libraries are quickly positioning themselves as incubators for this paradigm shift. Through cooperation, libraries provide virtual and physical spaces for academic research. Early cases can be seen in the University of Richmond's American Historical Geography Map Portal and the Center for Conservation Biology portal of William & Mary and Virginia Commonwealth University.

As new technologies for academic research are implemented, many libraries are building digital scholarship centers on campus. The characteristic of the Coalition for Networked Information (CNI) is locating these spaces in libraries rather than other institutions, focusing on digital humanities and having interdisciplinary attributes. One example of such a new environment is the Leiden University Centre for Digital Scholarship built by Dutch university libraries. The center's main goal is to cooperate with other research institutions and national or international organizations to support and promote the institution's research projects. The center's main work includes digital collection creation and management, long-term preservation, metadata, and other tasks. *College & Research Libraries News* listed digital scholarship as a hot topic in 2016, believing that academic libraries are expanding traditional research methods and adopting new technologies such as GIS data, information visualization, and big data. In addition to training scholars in new technology use, libraries also provide other services such as digital asset management, digital preservation, and consulting and resources.

People are paying increasing attention to using data-centric technologies for academic research, introducing new positions to libraries. Currently common positions include research data librarians and data visualization coordinators, which were unheard of 20 years ago. For librarians, acquiring necessary skills for various disciplines and methods is not easy. Therefore, academic libraries are training these skills internally to better serve the academic community. For example, at the Library Data Carpentry workshop in Australia, data mining librarians studied digital scholarship practices and data science lifecycles, using libraries' existing data extraction, analysis, and visualization skills training as research objects.

5.1.2.2 Relevance to Academic and Research Libraries Emerging digital scholarship technologies benefit libraries in more effectively preserving and mining collections and expanding new academic research fields. In the visualization room of the Chinese University of Hong Kong Library's Digital Scholarship Lab, there is a digital display wall and an 80-inch interactive touch screen composed of 12 55-inch high-resolution LED monitors with resolution exceeding 24 million pixels, enabling more complete interaction with data and digital objects. Carnegie Mellon University is building a new digital scholarship center and plans to recruit a two-year postdoctoral fellow in data visualization and management. The postdoc should advance data visualization research and its sustainable development through cooperation with the library and statistics department.

5.1.2.3 Digital Scholarship Technologies in Practice The following are examples of digital scholarship technology applications that have direct impact on academic and research libraries:

1. **The Digital Humanities as an Emerging Field in China**
   go.nmc.org/dhchina
   China's first digital humanities center was established at Wuhan University in 2011, and several universities have subsequently built related projects. For example, Peking University cooperates with Harvard University and Taiwan's Academia Sinica to build the China Biographical Database. The first batch of data includes 370,000 historical figures from the 7th to 19th centuries.

2. **The DiRT Directory**
   go.nmc.org/dirt
   The Bamboo project developed this website. The Digital Research Tools Directory aggregates information about digital scholarship technologies, making it easier for scholars to find and compare resources.

3. **Oxford University Bodleian Libraries' Centre for Digital Scholarship**
   go.nmc.org/oxds
   The center's collaborators span the campus, including the Bodleian Libraries, medical sciences, social sciences, and humanities, conducting mul-

tidisciplinary research, hosting researcher training, and focusing on integrating physical and digital library resources from other departments.

More and more digital humanities scholars use new tools to assist their work. In Australia, researchers can use library APIs to build personalized library catalog and collection interfaces. For example, through QueryPic, they can browse, search, and understand digital newspapers from Australia and New Zealand according to time, map trends, and research patterns. Similarly, the Archives Viewer of the National Archives of Australia is an experimental portal for reading digital files from the National Archives of Australia's RecordSearch database. With the popularity of new communication methods such as social media, researchers can use text analysis software like Umigon to understand public opinion. These tools can aggregate and classify information on Twitter as negative, positive, or neutral. The online text mining tool Voyant can help scholars generate charts of high-frequency words in their work, compare multiple texts, and sort by geographic location. A researcher at Rice University used this tool to study the entire corpus of runaway slave advertisements in the library's collection and shared results on GitHub.

5.1.2.4 Recommended Reading The following resources are recommended for those wishing to learn more about digital scholarship technologies:

1. **Digital Scholarship Week Explores Ways of Adapting New Technologies to Research**
   go.nmc.org/digschol (Bert Gambini, *University at Buffalo News*, 25 February 2016.)
   The University at Buffalo's College of Arts and Sciences and the Committee on Digital Scholarship and Culture held a series of projects on how digital technology impacts academic research, including digital reconstruction of St. George's Bermuda Islands and the oldest American English texts.

2. **Laying the Foundation: Digital Humanities in Academic Libraries**
   go.nmc.org/layfo (John White and Heather Gilbert, Purdue University Press, 15 March 2016.)
   This series of papers discusses core themes of digital scholarship at the University of Charleston, including library digital humanities cases, infrastructure construction, and cooperation.

3. **Libraries as Content Producers**
   go.nmc.org/libasco (Daniel Tracy, *College & Research Libraries*, accessed 10 February 2017.)
   As more libraries engage in multimedia and digital humanities projects, user experience is receiving increasing attention. This research provides information on "library publishing service user research and obstacles."

5.2 Technologies Widely Adopted Within 2-3 Years

5.2.1 Library Services Platforms Libraries are at a critical node for automation and resource management. Future library systems will become increasingly complex. Users expect to access resources from various devices, and library resource management must consider materials in various formats. Therefore, libraries need to play new roles in data management and analysis. On the other hand, traditional library management systems developed in the 20th century for paper resource management can no longer meet the needs of the knowledge era. Library Services Platforms (LSP) represent a new direction for library automation, meeting current network-centric intensive system requirements, providing extensive management functions for print and electronic resources, and keeping pace with business needs in changing library environments. Fundamentally, LSP provides libraries with opportunities to address complex issues of content, workflow, and resource discovery, helping libraries better integrate with users.

5.2.1.1 Overview Library Services Platforms are a type of library automation system that emerged in recent years. In 2011, Marshall Breeding, founder and editor of *Library Technology Guides*, proposed this concept to define products that help libraries handle growing digital content-related businesses. The diversification of resources and formats poses challenges to library management, and LSP provides direct solutions. At the same time, libraries are building institutional repositories to preserve and manage all materials owned, licensed, and natively produced within their institutions. Library collections are broader in scope, including journal articles, dissertations, e-books, reports, and digital assets, all of which need to be preserved, organized, and provided access to. The diversity of formats and materials poses new requirements for content collection and management. Existing Integrated Library Systems (ILS) specifically developed for print materials cannot meet these requirements.

LSP differs from ILS in many ways. Conceptually, LSP originates from the Software as a Service (SaaS) concept, delivering software applications through the Internet. Software providers host applications, including their management, acquisition, updates, security, and performance. In contrast, ILS uses internal management methods, installed on individual workstations, requiring internal maintenance and software operation on each computer. ILS core functions are implemented through separate functional modules such as cataloging, acquisition, circulation, and public service interfaces. Other functions missing from ILS, such as link resolvers, electronic resource management systems, and digital asset management systems, require libraries to purchase additionally. In comparison, LSP adopts an inclusive architecture, deploying a network platform that integrates resource management and operational tasks into a unified system based on built-in knowledge bases and simplified processes, thus eliminating the trouble of installing multiple software and maintaining staff computers.

The transition from ILS to LSP mainly occurs in large academic universities in the U.S., Australia, New Zealand, and Western Europe. However, international

vendors like Ex Libris also promote them to other regions. For example, Beijing Normal University switched from Ex Libris' Aleph ILS to Alma to establish unified business processes for print, electronic, and digital resources. On the other hand, in developing countries, print resources still account for a large proportion compared to electronic subscription resources. These countries are limited by commercial system procurement and prices and have special requirements such as localized system interface languages, thus more often choosing ILS, especially open-source applications like Koha, rather than LSP.

5.2.1.2 Relevance to Academic and Research Libraries Library services platforms have many advantages that traditional library systems do not have, including time efficiency, cost efficiency, new functions, and transformation opportunities. The University of Wales Trinity Saint David library system adopted Ex Libris' Alma and Primo, improving service efficiency by providing unified library management and discovery service systems for all faculty and students. The HELIN Library Consortium needed a cloud library management system to facilitate resource sharing among members and save costs. Since OCLC's WorldShare Management Services (WMS) provided both functions on the same platform, the consortium chose this service. Another benefit of using this service is the opportunity to communicate with other WMS users through OCLC's community center to discover best practices and keep timely updates on latest products.

The time and funds libraries save by investing in LSP can be used to implement new initiatives that improve operational efficiency. For example, Saddleback College Library conducted its first complete inventory of all collections in 40 years because WMS LSP could streamline routine business workflows. Saddleback librarians had time to clean shelves, find, and repair damaged collections, thereby improving physical collection quality. In other examples, libraries improved visibility and strengthened external connections through LSP applications. As an early adopter of BLUEcloud Visibility, the Army's Engineer Research and Development Center shares academic achievements with more users through its digital institutional repository, which can be found using search engines like Google and Yahoo. Another BLUEcloud Visibility user, Garland County Library, also expanded its user base through this system. Although LSP is still an emerging technology, it has the potential to bring significant benefits to libraries, as proven by the Houston Area Library Automated Network (HALAN). As a consortium serving the Houston and east-central Texas region, HALAN has seen exponential growth in network access since adopting BLUEcloud Visibility in early 2016.

LSP products not only have advanced data collection and analysis functions but also data parsing and measurement functions. For example, the University of Leeds uses Innovative Interfaces' Sierra LSP to create custom queries for users and other data to provide reading recommendations, accelerate on-demand ordering speeds, and identify suspicious activities like hacking threats. Radboud

University in the Netherlands uses OCLC's WMS, which supports the library in sharing data with other libraries globally to advance best practices, discover innovations, and improve overall library service experiences. It also supports integrating library data into institutional big data, enabling libraries to play greater roles in serving academia.

5.2.1.3 Library Services Platforms in Practice The following are examples of library services platform applications that have direct impact on academic and research libraries:

1. **Stellenbosch University—First South African Customer to Choose Ex Libris Alma for Optimizing Library Services**
   go.nmc.org/stellen
   Purchasing Ex Libris Alma was a strategic decision for Stellenbosch University. The university plans to use the advantages of a unified library management system to better manage print and electronic resources, improve user experience, and maintain its status as a top academic institution.

2. **Swiss Library Services Platform (SLSP)**
   go.nmc.org/slsp
   Through building a centralized service platform integrating technical solutions, standards, and library network services, the cooperative project SLSP helps Swiss academic libraries use resources more efficiently.

3. **Three Universities Choose SirsiDynix Solution for Unique Collaboration**
   go.nmc.org/sirsi
   Canterbury Christ Church University, the University of Greenwich, and the University of Kent share a unified library management system on the BLUEcloud platform to improve student services and strengthen cooperation.

5.2.1.4 Recommended Reading The following resources are recommended for those wishing to learn more about library services platforms:

1. **Approaching Discovery as Part of a Library Service Platform**
   go.nmc.org/approa (Nathan Hosburgh, *Rollins College Rollins Scholarship Online*, 2016.)
   The author explains how Rollins College's Olin Library transitioned to the Ex Libris Alma platform, describing motivations for the system change, evaluation and selection processes, and providing an evaluation framework.

2. **How to Conduct a Library Platform Services Review and Selection**
   go.nmc.org/lspreview (Matt Gallagher, *Information Today*, October 2016.)

This article provides a practical guide for critically evaluating and selecting library services platforms. The author recommends that libraries select platforms based on the background of the entire institution's technical infrastructure.

3. **Implementing Kuali OLE at SOAS Library**
go.nmc.org/kuali (Simon Barron, ARIADNE, 29 June 2015.)
The School of Oriental and African Studies Library was the first European library to use the open library services platform. The report describes Kuali OLE system functions and technical details.

5.2.2 Online Identity Online identity, also known as digital identity, refers to the set of inherent or variable data and attributes that people or entities in networks possess, which can serve as unique bases for identifying them. Online identity is related to privacy and includes a wide range of contextual relationships and technical identifiers in ontological classifications. We should understand these characteristics in mutually agreed contexts, such as providing names and addresses for transactions. From a more technical perspective, characteristics describe relationships between entities and objects in cyberspace. Another aspect of this theme is shaping personal identity through online profiles and avatars. The importance of this development for libraries is escalating for two reasons: Online identity is part of broad digital literacy; Authors can disseminate their works more widely through networks, revealing relationships between their works and other academic content.

5.2.2.1 Overview The development of networks and social media has given rise to the concept of digital footprints. Due to the existence of online identity, people can access discussion content they participated in, purchasing behaviors, and almost all network behaviors can be traced. Through full-time tracing, people's behaviors, viewpoints, relationships, and habits can be described. In the era of personal branding, information a person shares online can help others identify their identity. This concept carries considerable weight in academia because the content that faculty, students, and researchers disseminate online is determined by their identity. Therefore, online identity has become an important component of the increasingly expanding connotation of digital literacy. More and more universities incorporate digital footprint management into their programs and resources, such as the University of Edinburgh and the University of Illinois School of Information Sciences.

Researchers at India's Savitribai Phule Pune University describe digital footprints as "data about data that is searched or used on the web." Digital footprint data can be collected passively, where users are unaware their data is being collected (such as browsing websites), or actively collected, where users intentionally publish personal data (such as creating a LinkedIn profile). Institutions with massive user information and interaction behavior data have developed related systems to clarify relationships between data. Facebook's Open Graph can

support any webpage becoming a "rich media object" in social websites based on metadata sets. In turn, companies can customize content and advertisements provided to each user. Many people feel uncomfortable that their every move is monitored, so privacy issues gradually emerge. Pew Research Center reports show that 86% of U.S. internet users have taken measures to hide their digital footprints, such as clearing cookies or avoiding using real names on social networks.

As primary positions for advancing digital literacy, academic and research libraries have advantages in guiding the creation and understanding of online identity. The UK Open University Library has developed a digital information and literacy framework that includes content collaboration and sharing as essential elements. They believe participating in online communities or professional groups is a requirement for digital literacy. Online identity is also related to the connection between user-created research outputs, their content, and other online content. For example, research by a student or researcher on climate change can be linked to papers on the same topic, pointing out clearer research directions for research teams and inspiring and verifying key discoveries. Libraries also play important roles in creating knowledge organization standards and achieving their discovery through the semantic web and linked data.

5.2.2.2 Relevance to Academic and Research Libraries Libraries are playing indispensable roles in helping students understand how to create and manage online identity. In ACRL's *Framework for Information Literacy for Higher Education*, competency standards include the ability to "fully recognize privacy issues and personal information commodification in online behavior and make informed choices." Queensland University of Technology Library in Australia focuses on the productive use of social media and its role in online identity. Their website includes a social media skills portal allowing students to view their digital behaviors through tools that monitor their digital footprints, then learn how to compare themselves with peers. Their goal is to help students become more competitive job seekers and understand their social media rights and responsibilities.

University faculty also need library help to create and maintain their academic digital footprints. Texas A&M University Library has published relevant guidelines—*Managing Your Brand*—to help faculty and researchers create reliable online identity, create citation profiles on Google Scholar, and make their academic outputs more linked and tracked online. Online self-publishing and research sharing platforms including ResearchGate, Academia.edu, Mendeley, and SSRN continue to grow. These tools facilitate faculty and researchers in disseminating their research results to peers through links with library repositories. The University of North Florida's Thomas G. Carpenter Library helps faculty make advantageous decisions when selecting online publishing and peer review platforms, providing comparisons of different systems. Washington University in St. Louis's Bernard Becker Medical Library website helps scholars

establish profiles across multiple platforms and integrates medicine-specific social networking sites.

Additionally, libraries must help faculty and researchers connect their names with growing research institutions and academic work. The non-profit organization ORCID (Open Researcher and Contributor ID) provides a permanent digital identifier that distinguishes different researchers or authors. Previously, it was difficult to track all works published by a specific person due to non-unique names or inconsistent descriptions. Now, researchers' outputs are bound to themselves, supporting their continuous building of output collections and linking ORCID records with LinkedIn or other professional accounts. This system has gained popularity worldwide. In the Netherlands, ORCID has replaced the Dutch digital author identification system SURF. Leiden University Library recently hosted a conference to teach academic communities about persistent identifiers and providers. Last year, the University of Pretoria signed an agreement with ORCID, becoming the 11th South African institutional member using ORCID.

5.2.2.3 Online Identity in Practice The following are examples of online identity applications that have direct impact on academic and research libraries:

1. **Digital Identity: Making Your Mark**
   go.nmc.org/latrobel
   A team composed of academic staff, instructional designers, and librarians used Smart Sparrow's Learning Design Studio to develop an adaptive, personalized online module helping students understand how social media creates digital identity functions. The course includes changing privacy policies and career risks.

2. **Employability Skills and Resources**
   go.nmc.org/manchester
   Manchester Metropolitan University Library in the UK provides students with social media resources to help them find jobs and build relationships, as well as effectively manage their digital behaviors.

3. **Managing Your Online Reputation**
   go.nmc.org/reput
   The Claremont Colleges Library provides open access resources for faculty, librarians, and students to help them improve their online reputation. They provide videos related to this topic and practical guidance on tracking related academic research and publishing.

5.2.2.4 Recommended Reading The following resources are recommended for those wishing to learn more about online identity:

1. **Digital Identity Development**
   go.nmc.org/gful (Robin Ashford, *Digital Commons @ George Fox University Libraries*, June 2015.)

Analyzes the concept of digital identity, describing the high stakes of establishing a reliable online identity to ensure employment.

2. **Digital Literacy, Identity and a Domain of One's Own**
go.nmc.org/domainof (Doug Belshaw, DMLCentral, 15 September 2016.)
As more people build their personal and professional websites and documents through borrowed domains, the author believes online identity is risky; recommends owning one's domain, like renting an apartment short-term to build personalized rooms.

3. **Exploring Researchers' Participation in Online Research Identity Management Systems (PDF)**
go.nmc.org/explorerim (Shuheng Wu et al., ASIST, October 2016.)
This study proposes nine motivations for using research identity management systems, including connecting with peers and keeping academic outputs updated. It also finds that users of research identity management systems can be divided into three groups: readers, personal record managers, and community members, with personal record managers being the majority.

5.3 Technologies Widely Adopted Within 4-5 Years

5.3.1 Artificial Intelligence In the field of artificial intelligence (AI), computer science is used to create intelligent machines that functionally imitate humans. This technology includes a large amount of knowledge, including classification, attributes, and relationships between various information sets, built on the foundation of knowledge engineering, enabling computers to imitate human consciousness, learning, and decision-making thinking. Machine learning is a subset of AI that uses algorithms for computer programming to practice in different learning datasets, then automatically processes new input content without precise programming. As academic and research libraries begin exploring using AI to improve user services, research processes, and learning outcomes, it is necessary to develop guidelines through research to ensure the regulated use of student data.

5.3.1.1 Overview In recent years, AI development has blurred the boundary between artificial synthesis and human intelligence. Like humans, AI enables machines and applications to learn over time. When completing tasks, these machines can simultaneously collect data, store information, and use this information to respond to future situations. Although the concept of AI is not new, it has had a major impact on the consumer field in recent years. From Google's heavy investment in researching driverless cars to Amazon developing the voice-recognition Echo, AI has penetrated daily life. A recent milestone in the AI field was a computer defeating the world's best Texas Hold'em poker players in a 20-day "Brains vs. AI" poker tournament, winning by over $1 million in poker chips.

Futurists in academic and research libraries have begun actively envisioning using AI to promote learner success. AI provides libraries with more complex databases. Machines can customize content to meet learner needs, replacing the method of individuals locking in relevant content through extensive reading. AI improves the ability to learn and absorb experiences from numerous users, prompting changes in academic research processes. In fact, strategic implementation of AI can promote more interdisciplinary academic research, assisting scholars in locating larger-scale data and allowing them to access more viewpoints that may have been previously overlooked. As users' technology learning capabilities grow and personalized demands increase, this trend is most obvious in the retail industry. Online stores have begun using machine learning to deeply understand users' consumption habits and make purchase suggestions based on behavioral observations. These trends prompt libraries to apply new technologies to support learner success.

As technology is increasingly applied in learning interactions, learners are beginning to pay attention to the management and regulation of personal data use and analysis, which are currently lacking. The novelty of AI and its growth trend in multiple fields have prompted industry leaders to establish alliances dedicated to studying the proper use of AI. Google, Facebook, Amazon, IBM, and Microsoft recently joined forces to establish the Partnership on AI to benefit people and society. The organization is committed to exploring AI best practices through research and open publication. Similarly, the AI Ethics and Governance Organization allocated $27 million to technology decision-makers and institutions including Harvard University and MIT to advance AI development from the public interest perspective. As AI is applied in academic and research libraries, libraries also need to invest resources to protect student data and guide the proper and regulated use of AI.

5.3.1.2 Relevance to Academic and Research Libraries Academic and research libraries are still working to understand different aspects of AI to promote its integration with library systems, and current applications will inevitably bring potential breakthroughs. The academic search engine Semantic Scholar, born in 2016, is an academic application. Compared with applications that only highlight the most critical information in search results, Semantic Scholar uses data mining and natural language processing to compare large numbers of articles to determine which content better matches researchers' needs. This AI search engine has powerful summarization capabilities, able to process methods, citations, and related data for each paper. It contains over 10 million research items.

The increasing amount of data generated by networks has led futurists and technology companies to begin seeking to use this data to advance AI development. For example, Yahoo is preparing to release the largest online database (13.5TB of data), hoping to stimulate academic innovation. The company has obtained opportunities for academic cooperation with institutions such as the

University of California, San Diego, to jointly advance current emerging technology research plans, including machine learning and AI. Google Translate has also actively engaged in academic research, releasing Google Neural Machine Translation, which can translate research papers into any language. This development has proven invaluable because researchers now have opportunities to access global papers through this application, which were previously difficult to obtain due to language barriers or lack of funds and time for translation.

5.3.1.3 Artificial Intelligence in Practice The following are examples of AI applications that have direct impact on academic and research libraries:

1. **Artificial Intelligence Laboratory at the University of Michigan**
   go.nmc.org/umail
   A focus of the University of Michigan AI Laboratory is researching and developing assistive technologies for people with physical and cognitive disabilities, such as developing automatically adjusted computer interfaces to meet the needs of visually impaired people. This is a convincing invention that libraries can use to strengthen resource accessibility.

2. **IBM and Eight Universities Train Watson for Cybersecurity Sleuthing**
   go.nmc.org/watson
   IBM cooperated with some North American universities for a year-long collaboration on cybersecurity issues. An AI technology-based Watson was applied on eight campuses to improve student data security. This is precisely the challenge libraries face in the open network publishing environment.

3. **Robot Librarian Designed by Aberystwyth University Students**
   go.nmc.org/hugh
   Students at Aberystwyth University designed the intelligent robot "Hugh," which can access electronic catalog information and help users locate collection information through virtual consultation. Library staff cooperate with students to test the robot's positioning awareness and navigation functions.

5.3.1.4 Recommended Reading The following resources are recommended for those wishing to learn more about artificial intelligence:

1. **Artificial Intelligence: Computer Says YES (But is it Right?)**
   go.nmc.org/policy (Louise Walsh, University of Cambridge, 20 October 2016.)
   Driverless cars and medical applications allow AI systems to make choices affecting human life. To build user trust, researchers emphasize improving transparency of data driving AI decisions.

2. **Libraries in an Artificially Intelligent World**
   go.nmc.org/focus (Kristin Whitehair, Public Library Association, 11

February 2016.)
AI narrows the gap between users and massive information access, allowing libraries to streamline some business processes and shift focus to resources that deeply interact with learners.

3. **Reinforcement Learning as a Framework for Ethical Decision Making (PDF)**
go.nmc.org/reinforce (David Abel et al., Association for the Advancement of Artificial Intelligence, 2016.)
Reinforcement learning functions improve the normative issues of using AI for decision-making, proposing future challenges and questions in this field.

5.3.2 Internet of Things The Internet of Things (IoT) consists of objects with powerful computing capabilities that can transmit information across networks through processors or embedded sensors. These connections enable remote management, status monitoring, tracking, and alerts. Municipal governments are leveraging IoT functions to use data to streamline workflows and improve sustainable development issues in public affairs, such as saving public resources through energy-saving smart LED lights and solving traffic management problems through intelligent traffic sensors and mobile traffic applications. Library directors are discussing how to benefit from IoT environmental monitoring capabilities of network devices to optimize energy use and track items such as audio or video resources and books. IoT providers may also begin seeking cooperation with libraries to include libraries in their reference layers, connecting resources and objects based on application scenarios.

5.3.2.1 Overview Gartner predicts that by 2020, nearly 21 billion IoT objects will be put into use. Due to RFID technology application, many libraries are already familiar with the concept of network-connected objects. RFID technology gives books and other objects unique identifiers, enabling efficient borrowing, preservation, and theft prevention. Recently, beacons are another IoT iteration adopted by libraries. These small wireless devices continuously transmit small data packets when devices approach beacon transmitters, activated by related applications. The University of Oklahoma's Bizzell Library installed Aruba Bluetooth low-energy beacons to associate digital resources with physical locations, guiding users to resources through personalized navigation applications and expanding user experiences based on location information, tutorials, and videos.

However, as connected objects grow, privacy and security issues emerge one after another. A study by HP Enterprise Security Research revealed that the average number of vulnerable IoT devices is very high: 70% use unencrypted network services; 60% provide user interfaces vulnerable to attacks; 80% use weak passwords. In 2016, millions of weak-security network-connected devices (such as DVRs) and routers were hacked and infected with malware, and Dyn,

a major internet infrastructure provider, suffered a distributed denial-of-service attack. Major network services including Netflix, Twitter, Spotify, and Reddit were disrupted, drawing public attention to the impact of future large-scale security vulnerabilities. Academic libraries must both ensure transparency in data collection and protect user privacy, while informing users of risks in online access and measures to protect privacy. ALA privacy guidelines can help library leaders develop or update privacy policies to protect them and their users from security threats.

Additionally, there are risks in libraries' open access information, requiring protection of user interests and locating optimal resources for users to advance IoT best practices. Decentralized systems are particularly helpful in promoting the free flow of information. Because IoT is essentially decentralized, libraries need to consider security issues when generating and analyzing data from connected data and devices. One possible solution is blockchain technology, which can record digital interaction information, ensuring security, transparency, and resistance to disruption and censorship. Blockchain does not exist in any single location, enabling open distributed accounts to shield against malicious operations. This concept can expand IoT scale, allowing billions of devices to share the same network without needing additional cloud or centralized network authorization.

5.3.2.2 Relevance to Academic and Research Libraries Through IoT, libraries can directly push recommendations, information, and services to user devices, so IoT can enhance students' and faculty's awareness of accessing library resources. Munich University of Technology students and their computer science professors cooperated with the Bavarian State Library to develop a library application that can stimulate relevant supplementary information and other user interest points when users explore art collection spaces. At the same time, Western Michigan University's campus partner network combined with location services supports beacon and LED sensor systems to interact with users' smartphones. This activity is part of the university's multi-year IoT prototyping and deployment plan to build the Waldo Smart Library infrastructure.

Smart devices obtaining more data benefit libraries in better understanding users to develop strategies meeting changing user needs. Smart devices and beacons have become increasingly easy to collect library usage information, so libraries can view visitor traffic patterns to see how much time visitors spend on various services. Additionally, smart devices may alert staff and providers about equipment service needs before problems occur. The German smartLAB project is a typical future laboratory based on IoT, connecting all parts of the laboratory and automating operations, including automatic laboratory cleaning and using smart safety goggles displaying safety information based on virtual reality technology. Libraries can use similar settings to manage tasks such as maintaining constant temperature and humidity in book stacks or maintaining makerspaces and other library equipment.

Academic libraries have cooperated with enterprises to provide users with training on IoT technology so that users have relevant experience to deal with real-world problems. Pennsylvania State University and New York startup littlebits jointly created a new studio in the Pattee Library Knowledge Commons where students can use IoT to collect and exchange data for original innovation. North Carolina State University Library created a plan to create service spaces for female researchers in STEM, and an interactive seminar room created by D.H. Hill Makerspace on IoT is part of this plan. Students in the seminar room designed an IoT product to assist vegetable cultivation-related processes, including local distribution and transportation.

5.3.2.3 Internet of Things in Practice The following are examples of IoT applications that have direct impact on academic and research libraries:

1. **Carnegie Mellon to Lead Internet of Things Expedition**
   go.nmc.org/carmell
   Carnegie Mellon University, Cornell, and the University of Illinois at Urbana-Champaign are cooperating with Google to develop an open infrastructure called GIoTTO, providing a simple entry point for campus users to test various IoT application cases.

2. **Internet of Things Lab Fosters Student Innovation, Adds Industrial Partners**
   go.nmc.org/iotwisc
   By using IoT to identify areas that can improve manufacturing efficiency, the University of Wisconsin-Madison provides examples of potential university-enterprise cooperation, promoting innovation and advancing enterprise and economic development.

3. **UT Starts Living Smart Campus**
   go.nmc.org/utsmart
   The University of Twente's Living Smart Campus project provides resources and funding for a series of pilot projects where students use the campus as a test platform to experiment with IoT concepts and tools related to efficiency and sustainability.

5.3.2.4 Recommended Reading The following resources are recommended for those wishing to learn more about the Internet of Things:

1. **Internet of Things Applications in Academic Libraries**
   go.nmc.org/iotapp (Ashwini Nag, *Research India Publications*, 2016.)
   This article explores IoT concepts such as magic mirror technology, pressure sensor mats, and wireless sensor networks that can enhance academic library services and resource utilization and management.

2. **The Internet of Things: Seizing the Benefit and Addressing the Challenges**
   go.nmc.org/seiz (OECD, 2016.)

The OECD encourages governments to implement policies and fund IoT and open data framework projects, hoping IoT and resulting aggregated data can drive innovation and optimize services, prompting more solutions to address national problems.

3. **Understanding the Opportunities and Risks of the Internet of Things Environment on Campus**
go.nmc.org/opprisk (Chuck Benson, *The evollution*, 27 January 2017.)
IoT transforms institutional personnel management models, improves campus security system capabilities, and provides better research environments for faculty and students. However, institutions must make substantial and complex management preparations before investing.

Methodology

The research and formation process of the *NMC Horizon Report: 2017 Library Edition* is entirely based on the research methodology commonly used by the NMC Horizon Report project. All versions of the NMC Horizon Report are based on primary and secondary sources. Each report may contain dozens of meaningful trends, challenges, and important technology developments.

Each report is based on the exquisite professional knowledge of international expert panel members who first consider broad themes, then conduct detailed analysis of each theme, gradually reduce them, and finally form a final list of 18 themes. This process is conducted online, with data captured in the NMC Horizon Project workspace. The workspace aims to become a completely transparent window into project development, not only providing real-time understanding of work status but also containing process records for each version published since 2006. The workspace for the *NMC Horizon Report: 2017 Library Edition* can be accessed at horizon.wiki.nmc.org.

This year's expert panel consists of 75 education and technology experts from 14 countries across five continents; their names and institutions are listed at the end of the report. Although they have different backgrounds and experiences, they all agree that each theme elaborated in the report will have significant impact on global academic and research library practices within the next five years.

The theme selection process is based on a modified Delphi method. The expert panel has used this method for 15 years since its establishment, continuously improving it to produce a series of NMC Horizon Reports. The panel represents a wide range of knowledge backgrounds, nationalities, and research interests, with each member having expertise in relevant research fields. Over the decade of NMC Horizon Project research, more than 2,000 internationally renowned practitioners and experts have participated in this field's research; each year, one-third of panel members are new, ensuring new research perspectives annually.

More candidates are welcome to join the expert panel; see go.nmc.org/panel.

Once the expert panel is established, experts begin systematically reviewing literature related to new technologies (including newspaper news, reports, papers, and other materials). The project provides the panel with extensive background materials, then asks them to comment and select content worth retaining. The group discusses existing applications of emerging technologies and brainstorms new ones. Whether a technology application theme can be included in the 2017 version depends on its potential relevance to academic and research library services and practices. As the project progresses, a carefully selected set of articles from hundreds of relevant documents is retained, continuously stimulating panel members' ideas.

After literature review, the panel's research shifts to the project's key content—the NMC Horizon Project's core research questions. These questions are designed to guide experts in comprehensively listing technologies, challenges, and trends of interest:

1. In the next five years, which trends do you hope will drive new technology application and development in global academic and research libraries?
2. In the next five years, which significant challenges do you believe will hinder new technology application and development in global academic and research libraries?
3. In the next five years, which major developments in which technology areas will have the most profound impact on global academic and research libraries?
4. Which major developments in technology areas are missing from our list? Please consider: Which technology developments currently used in academic and research libraries should be widely used? Which technology applications with solid user bases in consumer, entertainment, or other industries should academic and research libraries actively adopt? Which major technology developments should academic and research libraries pay attention to in the next five years?

The first step of the research is to compile answers to the above research questions, then each expert uses a multiple-choice voting system for selection with weighting and classification allowed. After these selected answers are compiled and ranked, the answers receiving the most agreement become clear at a glance.

From the initial list of considered trends, challenges, and technology developments, the top-ranked themes in each area receive further research and expansion. Once these preliminary results are determined, the panel begins discussing how these themes affect learning and research in academic and research libraries. After spending substantial time researching each theme's practical and potential applications, the preliminary results' rankings are readjusted to form new rankings. These rankings are continuously adjusted until finally determined by the panel, and corresponding themes are elaborated in the *NMC Horizon Report: 2017 Library Edition*.

Translator Contributions

- **Zhao Yan:** Full text proofreading and final editing
- **Wei Rui:** Translated the "Key Trends Driving Technology Adoption" section; proofread the "Important Challenges" section
- **Gao Chunling:** Translated the "Overview, Introduction, and Methodology" section; proofread the "Important Technology Developments" section
- **Wang Dandan:** Translated the "Important Challenges" section; proofread the "Key Trends Driving Technology Adoption" section
- **Yang Zhigang:** Translated the "Important Technology Developments" section; proofread the "Overview, Introduction, and Methodology" section

Call for Papers: *Knowledge Management Forum*

Knowledge Management Forum (ISSN 2095-5472, CN 11-6036/C) has obtained official online publication qualifications from the State Administration of Press, Publication, Radio, Film and Television, and was completely redesigned in 2016. This journal focuses on research results related to knowledge production, creation, organization, integration, mining, sharing, analysis, utilization, and innovation. All matters related to knowledge management, knowledge services, and knowledge innovation are within the scope of this journal, including theories, methods, tools, technologies, applications, policies, solutions, and best practices for knowledge management issues in government, enterprises, universities, libraries, and other physical and virtual organizations. This journal implements article-by-article publication. Once manuscripts are accepted, they enter a rapid publication process and achieve immediate and complete open access.

2017 Focus Areas: Internet + Knowledge Management, Big Data and Knowledge Organization, Communities of Practice and Knowledge Operations, Content Management and Knowledge Sharing, Knowledge Creation and Open Innovation, Data Mining and Knowledge Discovery.

Submission Guidelines: 1. Manuscript themes should be knowledge-related, discussing knowledge management, knowledge services, knowledge innovation, and related issues. Articles can focus on theory or application, technology, methods, models, and best practices. 2. Articles must have substance, integrate theory with practice, have clear research purposes, appropriate research methods, original academic insights, and have reference or guiding value for theory or practice. 3. All submissions must undergo similarity detection, peer expert review, and the editorial department's preliminary review, re-review, and final review. 4. Article length is not limited, but generally 4,000-20,000 words are appropriate. 5. Submission results will be communicated within one month. 6. Please submit manuscripts at www.lis.ac.cn, noting "Knowledge Management

Forum Submission."

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Note: Figure translations are in progress. See original paper for figures.