NMC **Horizon Report** > 2016 Museum Edition

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Foreword

The Balboa Park Online Collaborative is proud to support the publication of the *NMC Horizon Report: 2016 Museum Edition* for a second year. Founded in 2008 to serve 17 organizations in Balboa Park, San Diego, BPOC collaborates and leverages the economy of scale to help museums, art, science, and cultural organizations make cost-effective, sustainable, and strategic technology decisions with a range of technical and support services, including digital production, website and in-gallery development, and digital strategy. While BPOC supports the broader museum community, it has a focus on the cultural organizations within the Park where their physical proximity and collaborative efforts present a solid foundation for all forms of cooperation, digital or otherwise.

For a second year, *Cross-Institution Collaboration* has made its way to the final selection of trends accelerating technology adoption. BPOC was founded on this principle and continues to seek collaborative opportunities with single institutions as well as park-wide partnerships at every opportunity. The realities of successful collaboration continue to be complex, but the benefits of aggregating technology tools, bulk purchasing, shared resources, shared services, and political capital continue to gain traction and breed success. Further, as we partner more deeply with other representative organizations within Balboa Park such as the Cultural Partnership (an organization formed from every Park institution and a board comprised of their executive directors), the Balboa Park Conservancy, and the Friends of Balboa Park, our ability to secure contributed income and mount successful advocacy initiatives increases. Strength of numbers in its many forms is a clear strategy for the non-profit sector.

This operational foundation and political partnering is crucial to BPOC's ability to pursue its domain strategies and enact many of the findings in this report. While our core services continue to serve the park institutions and visitors with day-to-day operational technology, a key area of focus is a unified *Digital Strategy*, one that places the visitor at the center of our cultural experience. For Balboa Park, this "solvable" challenge is made all the more complex by requiring us to solve it for individual institutions, in support of their individual missions and goals, and also solve it for the aggregate, to provide an experience that, from the visitor's perspective, is both institutionally agnostic and institutionally specific.

Our approach is one of layering and simplification. Based on the assumption that a rising tide lifts all boats, BPOC pursues *Improving Digital Literacy* at every opportunity with a combination of informal gatherings such as the San Diego chapter of #drinkingaboutmuseums and ad hoc brown bags, and formal training through our partnership with the Balboa Park Leadership Institute for campus-wide training or targeted sessions for discipline-specific groups such as social media and education. For us, improved digital literacy will provide a more fertile ground to implement a unified digital strategy.

By way of illustration, an inventory of all Balboa Park social media identified over 100 separate channels across the five major social media platforms of Facebook, Twitter, Instagram, Pinterest, and YouTube. Given the many niche organizations, and discipline-specific interests, there is some sense to this, but for the majority of our visitors and potential audiences, this seems too diluted of a presence to be meaningful and effective. The opportunity to raise the social profile and reach of smaller institutions in meaningful partnerships with the larger ones seems compelling; however, being the disappearing entity in a social media merger will likely not sit well with an institution's board, which is where a solid operational or political base from which to negotiate, comes into play. Nevertheless, before that can happen, we need to build broader literacy around social media to create an understanding of why such a strategy would make sense, so we share tips, tricks, and successful insights with all of our partner institutions until a time when unifying channels, thoughtfully and appropriately, becomes obvious. Our initiative here follows Malcolm Gladwell's observation in *Tipping Point*, that in order to effect an epidemic, you sometime have to create many small epidemics.

Our *Digital Literacy* initiatives are in pursuit of a broader goal to define a unified digital strategy for the Park, which while solvable, will be complex. Our approach here is to create a groundswell of support for "a big idea," a simple vision for a unifying end result, under which many smaller projects, initiatives, and discrete

institutional goals can live. Big ideas that excite and bring institutions together are a de facto digital strategy requirement. Museums, museum professionals, and sponsors all want to be part of a big idea and even the dull requirements of information management tools and infrastructure hardware all become anointed with the glamour and excitement of a visionary idea.

BPOC's big idea is called *Lost in Balboa Park*, an initiative to help audiences discover hidden treasures of people, places, and things that will create curiosity and inspire them to visit the Park. Our strategy calls for a unified and connected virtual experience that facilitates both serendipitous and meaningful connections between objects, their makers, themes, and meaning, and for our audiences that is both *Personalized* and *Participatory*. Looking outside one's industry often provides the most compelling metaphors and clear examples of how to solve our challenges, so BPOC looked to Spotify as a model.

Spotify provides one of the most elegant and comprehensive frameworks within which to discover music, musicians, and performance. One can engage as a knowledgeable user searching by song title, artist, genre, or ethnicity, or as somewhat of a novice through playlists representing emotions *(Confidence Boost* or *Breakup Songs)* or situations *(Workout* or *Sleep)*. Additionally, Spotify learns one's tastes and presents suggestions, but the key is the playlist concept itself, promoting discovery through meaningful connections based on a personal preference in taste or by following someone of similar tastes, which may be an educational discovery or sharing opportunity.

Imagine the arts and cultural equivalent of Spotify as a platform to foster discovery of art, performance, science, natural history, and culture for all: search by object, genre, subject, or maker, but then make discoveries based on a myriad of progressive playlist concepts that might be situational, emotional, or celebratory, or any type of curated lens – essentially anything that establishes a personal connection with our audience that might be niche or broadly applicable. The possibilities are endless and boundless and our goal is to create an experience that helps visitors lose themselves through serendipitous discovery – the essence of the web.

But there is method in our madness. There is no question that digital is crucial to the future of a cultural experience, but simply putting content online does not guarantee success or ensure relevance. Massive disruptions in the PR and marketing industries show us that content marketing is our future; it is no longer

enough to tell people what to expect, we have to SHOW them. *Lost in Balboa Park* is the try-before-you-buy, "freemium" version of a park visit, because while we want to create the most compelling, serendipitous online experience that we can, driving visitation is our goal, as it is for all museums. And while our audiences can consume this experience purely virtually, if they visit the park, these playlists become wayfinding *Mobile* tours delivered throughout the park, museums, and galleries.

BPOC has already started this initiative by soft launching a number of curated playlists which will form the heart of this experience. For St. Valentine's Day, we created a *Date Day*[1] playlist, which features a tour of some romantic hidden gardens, stealing a kiss by the kissing booth featured in one of the landscapes at the San Diego Model Railroad museum, and ending with a shared gelato from the House of Italy, an international cottage in Balboa Park promoting Italian culture. For our younger audiences, we created a *Fairy Tales*[2] playlist, where the iconic California Tower is where Rapunzel is trapped by the evil witch, and where the San Diego Museum of Man's display of cacao beans used by the ancient Mayans to make chocolate looks identical to the magic beans Jack planted to climb to the giant's castle. How much more interested would a child be to tour the Park through a fairy tale voyage of discovery?

The end game of *Lost in Balboa Park* is to meet audiences where they are by creating a unique personalized experience that will be realized from scale when a myriad of content will support niche and mass appeal and we are able to leverage our assets with trending memes, news, and media stories and science, cultural, and social events at a moment's notice. A more important outcome is to change thinking in the park around what it means to be a cultural destination, with a digital strategy that realizes the holy grail of museums in the 21st century, that digital content and a cultural visit are a marriage: not a divorce. The encyclopedic experience offered by the diversity of museums, galleries, gardens, and performances, and their physical proximity makes Balboa Park, without doubt, one of the few places where such a concept can be achieved, and many of the trends, challenges, and interpretive technologies detailed in the *NMC Horizon Report: 2016 Museum Edition* come to bear in delivering this big idea.

Nik Honeysett, CEO
Balboa Park Online Collaborative

May 17, 2016

The *NMC Horizon Report: 2016 Museum Edition*
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Kat Schmitt

Inside Cover: December Nights/Park at Night
Richard Benton

Back cover: Self/Reflection, Museum of Photographic Arts
Chad Weinard, BPOC

Executive Summary

What is on the five-year horizon for museums? Which trends and technologies will drive changes to museum education and interpretation? What are the challenges that we consider as solvable or difficult to overcome, and how can we strategize effective solutions? These questions and similar inquiries regarding technology adoption and educational change steered the collaborative research and discussions of a body of 45 experts to produce the *NMC Horizon Report: 2016 Museum Edition*, in partnership with the Balboa Park Online Collaborative (BPOC). The *NMC Horizon Report* series charts the five-year horizon for the impact of emerging technologies on education and interpretation in museums across the globe. With more than 14 years of research and publications, it can be regarded as the world's longest-running exploration of emerging technology trends and uptake in education.

The experts agreed on two mid-term trends: increasing focus on personalizing experiences in museums, as well as focusing on the power of data analytics to inform museum operations. These are just two of the 18 topics analyzed in the *NMC Horizon Report: 2016 Museum Edition*, indicating the key trends, significant challenges, and important technological developments that are very likely to impact changes in museums across the world over the next five years.

Regarding the challenges for museums, developing effective digital strategies is considered one of the solvable challenges. It is already being addressed by actions at individual museums. At the Andy Warhol Museum, they placed their key planning documents in the GitHub repository hosting service in order for files to be easily shared, revised, and repurposed.[3] On the other hand, the experts identified privacy concerns as a wicked challenge — one that they consider complex to define, let alone solve. Compounding this challenge is that technologies are evolving at such a rapid rate, it is difficult for museums to keep pace of cybercriminals.

With more than 14 years of research and publications, the NMC Horizon Project can be regarded as the world's longest-running exploration of emerging technology trends and uptake in education.

In view of the trends and challenges observed, the panel also signaled the technological developments that could support these drivers of innovation and change. Digital humanities technologies and makerspaces are expected to be increasingly adopted by museums in one year's time or less to make use of new tools for expanding scholarship and engagement. The time-to-adoption for location intelligence and virtual reality are estimated within two to three years, while networked objects and information visualization are expected to be mainstream in museums within four to five years.

The three key sections of this report constitute a reference and straightforward technology planning guide for a full range of museum professionals, including staff, leaders, board members, and policymakers. It is our hope that this research will help to inform the choices that institutions are making about technology to improve, support, or extend education and interpretation in museums across the globe. Museum and education leaders worldwide look to the NMC Horizon Project and both its global and regional reports as key strategic technology planning references, and it is for that purpose that the *NMC Horizon Report: 2016 Museum Edition* is presented.

Topics from the *NMC Horizon Report > 2016 Museum Edition*

TRENDS, CHALLENGES, AND DEVELOPMENTS IN TECHNOLOGY FOR MUSEUMS

TRENDS

SHORT-TERM
> **Mobile Content and Delivery**
> **Participatory Experiences**

MID-TERM
> **Data Analytics for Museum Operations**
> **Personalization**

LONG-TERM
> **Cross-Institution Collaboration**
> **New Roles for Museum Professionals**

2016   2017   2018   2019   2020

CHALLENGES

SOLVABLE
> **Developing Effective Digital Strategies**
> **Improving Digital Literacy of Museum Professionals**

DIFFICULT
> **Improving Accessibility for Disabled Populations**
> **Measuring the Impact of New Technologies**

WICKED
> **Managing Knowledge Obsolescence**
> **Privacy Concerns**
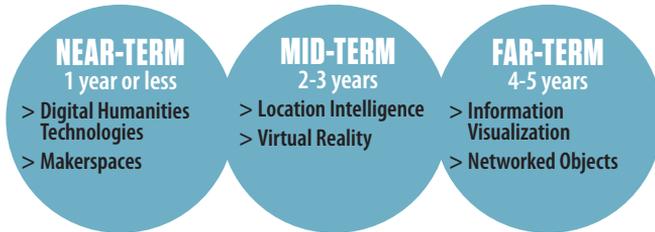
NEAR-TERM
1 year or less
> **Digital Humanities Technologies**
> **Makerspaces**

MID-TERM
2-3 years
> **Location Intelligence**
> **Virtual Reality**

FAR-TERM
4-5 years
> **Information Visualization**
> **Networked Objects**

DEVELOPMENTS IN TECHNOLOGY

Introduction

I n the pages that follow, 18 topics carefully selected by the 2016 Horizon Project Museum Expert Panel related to the educational applications of technology are examined, all of them areas very likely to impact technology planning and decision-making over the next five years (2016-2020). Six key trends, six significant challenges, and six important developments in educational and interpretive technology are placed directly in the context of their likely impact on the core missions of museums, and detailed in succinct, non-technical, and unbiased presentations. Each has been tied to essential questions of relevance, policy, leadership, and practice.

The *NMC Horizon Report: 2016 Museum Edition*, the 6th in the annual museum series of reports, was produced by the NMC in collaboration with the Balboa Park Online Collaborative. The internationally recognized *NMC Horizon Report* series and regional *NMC Technology Outlooks* are part of the NMC Horizon Project, a comprehensive effort established in 2002 by the NMC that identifies and describes emerging technologies likely to have a large impact over the coming five years in education around the globe.

Key trends, challenges, and technological developments that are detailed here will directly inform policy, leadership, and practice at all levels within the museum environment. This report aims to help museums, museum boards, and education leaders to strategically approach the further evolution of museum education and interpretation. Each topic has been carefully researched and framed in the context of its potential impact on global museum education and interpretation.

The report's first two sections focus on an analysis of trends driving technology decision-making and planning, and the challenges likely to impede the adoption of new technologies, respectively. Each includes an explicit discussion of the trend or challenge's implications for policy, leadership, and practice in museums, along with examples and relevant readings.

The third section, in which six important developments in technology are described, is ultimately framed by these trends and challenges. The adoption or abandonment of these technologies by museums will be very much determined by the responses taken across the globe to these drivers of and obstacles to innovation and change.

Each of the four global editions of the *NMC Horizon Report* — higher education, primary and secondary education (K-12), museum, and library — highlights six emerging technologies or practices that are likely to enter mainstream use within their focus sectors over the next five years. Key trends and challenges that will affect current practice over the same period frame these discussions. The discussions of trends and technologies have been organized into three time-related categories; challenges are discussed within a similar three-part framework related to the scope of the challenge.

Key trends, challenges, and technological developments that are detailed here will directly inform policy, leadership, and practice at all levels within the museum environment.

Each topic closes with an annotated list of suggested readings and additional examples that expand on the discussion in the report. All the background materials for the *NMC Horizon Report: 2016 Museum Edition*, including the research data, the preliminary selections, and this publication, can be downloaded for free on iTunes U and in the project wiki at museum.wiki.nmc.org.

The process used to research and create the *NMC Horizon Report: 2016 Museum Edition* is rooted in the methods used across all the research conducted within the NMC Horizon Project. All editions of the *NMC Horizon Report* are informed by both primary and secondary research. Dozens of meaningful trends, challenges, and emerging technologies are examined for possible inclusion in the report for each edition.

Every report draws on the considerable expertise of an international panel that first considers a broad

set of important trends, challenges, and emerging technologies, and then examines each of them in progressively more detail, reducing the set until the final listing of trends, challenges, and technologies is selected. This process takes place online, where it is captured in the NMC Horizon Project wiki. The wiki is intended to be a completely transparent window into the work of the project, one that not only provides a real-time view of the work as it happens, but also contains the entire record of the process for each of the various editions published since 2006. The wiki used for the *NMC Horizon Report: 2016 Museum Edition* can be found at museum.wiki.nmc.org.

The panel was composed of 45 technology experts from 9 countries on four continents this year; their names and affiliations are listed at the end of this report. Despite their diversity of backgrounds and experience, they share a consensus view that each of the profiled technologies will have a significant relevance to museum education and interpretation around the globe over the next five years. The key trends driving interest in their adoption, and the significant challenges museums will need to address if they are to reach their potential, also represent their perspective.

The procedure for selecting the topics in the report is based on a modified Delphi process refined over the now 14 years of producing the *NMC Horizon Report* series, and began with the assembly of the panel. The panel represents a wide range of backgrounds, nationalities, and interests, yet each member brings a relevant expertise. Over the years of NMC Horizon Project research, more than 1,500 internationally recognized practitioners and experts have participated on the panels; in any given year, a third of panel members are new, ensuring a flow of fresh perspectives each year. Nominations to serve on the expert panel are encouraged; see go.nmc.org/horizon-nominate.

Once the panel for a particular edition is constituted, their work begins with a systematic review of the literature — press clippings, reports, essays, and other materials — that pertains to emerging technology. Members are provided with an extensive set of background materials when the project begins, and are then asked to comment on them, identify those that seem especially worthwhile, and add to the set. The group discusses existing applications of emerging technology and brainstorms new ones. A key criterion for the inclusion of a topic in this edition is its potential relevance to education and interpretation in museums. A carefully selected set of RSS feeds from hundreds of relevant publications ensures that background resources stay current as the project progresses. They are used to inform the thinking of the participants.

Following the review of the literature, the expert panel engages in the central focus of the research — the research questions that are at the core of the NMC Horizon Project. These questions were designed to elicit a comprehensive listing of interesting technologies, challenges, and trends from the panel:

1 Which of the key technologies catalogued in the NMC Horizon Project Listing will be most important to museum education and interpretation within the next five years?

2 What key technologies are missing from our list? Consider these related questions:

> **What would you list among the established technologies that some museums are using today that arguably all museums should be using broadly to support education and interpretation?**

> **What technologies that have a solid user base in consumer, entertainment, or other industries should museums be actively looking for ways to apply?**

> **What are the key emerging technologies you see developing to the point that museums should begin to take notice during the next four to five years?**

3 What trends do you expect to have a significant impact on the ways in which museums approach their core missions of education and interpretation?

4 What do you see as the key challenges related to education and interpretation that museums will face during the next five years?

In the first step of this approach, the responses to the research questions are systematically ranked and placed into adoption horizons by each expert panel member using a multi-vote system that allows members to weight and categorize their selections. These are compiled into a collective ranking, and inevitably, the ones around which there is the most agreement are quickly apparent.

From the comprehensive list of trends, challenges, and technologies originally considered for any report, the group explores the ways in which these topics impact education and interpretation in museums. A significant amount of time is spent researching real and potential applications for each of the topics that would be of interest to practitioners. For every edition, when that work is done, each topic is written up in the format of the *NMC Horizon Report*. With the benefit of the full

picture of how the topic will look in the report, the topics in the interim results are then ranked yet again. The final topics selected by the expert panel are those detailed here in the *NMC Horizon Report: 2016 Museum Edition*.

Key Trends Accelerating Technology Adoption in Museums

The six trends described in the following pages were selected by the project's expert panel in a series of Delphi-based voting cycles, each accompanied by rounds of desktop research, discussions, and further refinements of the topics. These trends, which the members of the expert panel agreed are very likely to drive technology planning and decision-making over the next five years, are sorted into three impact-related categories — long-term trends that typically have already been impacting decision-making, and will continue to be important for more than five years; mid-term trends that will likely continue to be a factor in decision-making for the next three to five years; and short-term trends that are driving technology adoption in museums now, but will likely remain important for only one to two years, becoming commonplace or fading away in that time.

While long-term trends have already been the topic of many museum education leaders' discussions and extensive research, short-term trends often do not have an abundance of concrete evidence pointing to their effectiveness and future directions. All of the trends listed here were explored for their implications for museums in a series of online discussions that can be viewed at museum.wiki.nmc.org/Trends.

The NMC Horizon Project model derived three meta-dimensions that were used to focus the discussions of each trend and challenge: policy, leadership, and practice. Policy, in this context, refers to the formal laws, regulations, rules, and guidelines that govern museums; leadership is the product of experts' visions of the future of learning, based on research and deep consideration; and practice is where new ideas take action, in museums and related settings.

Policy. While all of the identified trends had policy implications, two trends in particular are expected to have a strong impact on policy decisions in the next five years. Cross-institution collaboration has emerged as a major topic of interest to national governments and museums, as strategic funding decisions often hinge on collaborative approaches to problem-solving. The IMLS-funded Museums United Project is working to strengthen the network of state museum associations in the US through leveraging technology for management,

communications, and the sharing of best practices and resources.[4]

Likewise, prioritization of mobile content and delivery, currently on the rise in museums, will reach its maximum impact in the next one to two years, calling for the development of more institutional policies. As the selfie phenomenon sweeps across the world, museums such as the Smithsonian are developing policies to prohibit the use of selfie sticks in order to protect objects and patrons.[5]

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Leadership. There are leadership implications for all the identified trends that are discussed in the following pages, but two trends stand out as unique opportunities for vision and leadership. The growing interest in customizing services unique to each visitor requires museum leaders to pilot initiatives, such as the CHIP Project at the Rijksmuseum Amsterdam which seeks to gain a greater understanding of how individual knowledge and interests drive preferences for artworks.[6]

Another mid-term trend that is being emphasized in leadership discussions is how museums can improve analysis of visitor interactions to make better informed decisions. This movement reflects the growing notion that museums should explore more effective means for collecting, analyzing, and reporting data. Culture

Metrics is a UK partnership that has developed a platform to support the day-to-day use of metrics across 20 arts and cultural organizations.[7]

Practice. Each of the six trends identified by the expert panel has numerous implications for museum education and interpretation, and current examples are easy to find. Rethinking the roles of museum professionals, highlighted as one of two developing long-term trends in the following pages, is materializing in workshops that focus on building a greater sense of inclusivity with diverse audiences. The Chrysler Museum, for example, recently ran a training to help staff and volunteers understand how to provide safe and respected spaces for patrons of various sexual orientations and gender identities.[8]

All over the world, museums are leveraging social networks to augment their reach and create more opportunities for participation. The Columbus Museum of Art's #MobilePhotoNow crowdsourced exhibit using Instagram received nearly 50,000 photo entries from across 89 countries. It is one of several projects that recognize patrons who make the effort to share their unique perspectives and interpretations.[9]

The following pages provide a discussion of each of the trends highlighted by this year's expert panel that includes an overview of the trend, its implications, and a set of curated recommendations for further reading on the topic.

Cross-Institution Collaboration
Long-Term Trend: Driving Ed Tech adoption in museums for five or more years

ollective action among museums is growing in importance to drive best practices in technology use across the sector. More and more, museums are joining consortia or alliances — associations of two or more organizations[10] — to combine resources or to align themselves strategically with innovative initiatives. Today's global environment is allowing museums to unite across international borders and work toward common goals concerning technology use, and the sharing and co-creation of collections and exhibitions. Support behind technology-enabled learning in museums has reinforced the trend toward museum communities and consortia, as leaders in the space recognize collective action as a sustainable method of supporting upgrades in museums' technological infrastructures and digital offerings.

Overview
In order to remain relevant in a world where information can be accessed anytime and anywhere, museums are gradually evolving away from solely being collectors and catalogers of information to becoming disseminators and enablers of technological innovation, which often entails working collaboratively with other institutions.[11] Additionally, political, social, and economic pressures are forcing museums to leverage each other's resources to broaden their expertise and solve problems that can help improve practice at the institutional and system-wide levels, enabling smaller museums to reap the benefits from large foundation and federally-funded projects.[12] The UK group JISC, which provides digital solutions for education and research, believes that many contemporary research challenges are too large in scale for one institution to address, and digital technologies can help international teams share data, computing power, or software through the Internet.[13] The 2016 Museum Edition Expert Panel believes that new technologies are not only making cross-institution collaboration easier, but are also imperative for the sustainability of organizations.

Social media is one area accelerating this trend, allowing museums to build their knowledge base and expertise around new technologies. The collaborative project #MuseumInstaSwap, for example, involved ten London museums sharing their Instagram accounts with each other for one week, providing fresh perspectives of each museum's collection.[14] The project unearthed

unexpected cross-disciplinary relationships, such as the swap between the Natural History Museum and Victoria and Albert Museum, where a photograph of an ostrich in motion had both scientific and artistic significance.[15] Conversely, the private Facebook group, "International Museum Social Media Managers," is helping to improve social media practice. The group is a community of social media leaders that share ideas, upcoming projects, and campaigns,[16] and it currently counts more than 1,000 members from museums large and small.[17]

An important aspect of this trend is the spirit of openness between museums, and increasingly third parties are working to help facilitate collaborations. The American Art Collaborative (AAC) is one consortium bringing together museums to expand access to cultural holdings, deepen research connections, and create public interfaces for museum stakeholders. AAC members achieve this by sharing best practices, guidelines, and lessons learned about linked open data with each other and the broader art museum community.[18] Led by the Open Knowledge Foundation, OpenGLAM is another initiative that convenes galleries, libraries, archives, and museums around the mission of open access; they provide workshops and resources for cultural organizations wanting to provide greater accessibility to their data and content.[19] The network behind OpenGLAM includes the Wikimedia Foundation, Creative Commons, and Europeana, among others.[20]

Implications for Policy, Leadership, or Practice
Governments have long been concerned with developing policies that stimulate relationships among cultural institutions. The Network of European Museum Organizations (NEMO) is a partnership that facilitates networking opportunities along with the sharing of best practices among museums across the continent, enabling them to collaborate on multilateral and international projects.[21] One of their focuses is disseminating relevant information on EU policy to museums.[22] Under NEMO, the think tank Creative Museum has been monitoring and mapping successful collaborations between museums and creative industries in Latvia. One of their goals is to prove the benefits of these types of partnerships for policymakers.[23] Reputable government organizations such as IMLS have emphasized the need to strengthen networks of museum associations with technology. The IMLS-funded Museums United project,

for example, aims to develop resources to strengthen state museum associations through the creation of an association management system, an online platform for communication and collaboration, and the development of a toolkit to share best practices and resources.[24]

Advancing cross-institution collaboration requires leaders to design programs that convene museums and other information-centered organizations, such as archives and libraries, around technology-centric purposes. Linked Open Data in Libraries Archives and Museums (LODLAM) is a network of technicians and professionals who are working with linked data in the field. LODLAM's website is a hub for the sharing of resources and collaboration between participants.[25] Members of the group recently held a two-day workshop in Toronto where they demonstrated real-world examples of linked open data in use, taught open source tools, and provided hands-on instruction.[26] LYRASIS is another leader in the field that is bringing together cultural heritage organizations from 48 states to create, access, and manage digital content.[27] One of their principles is to leverage the member-base to negotiate savings on e-resources and services, such as the LYRASIS Mass Digitization Collaborative.[28]

These collaborations can also have a profound effect on research, especially when museums and scientific organizations from around the world work together to tackle environmental issues. The Australian Museum, in collaboration with the Atlas of Living Australia, has created DigiVol — an online crowdsourcing platform that encourages the digitization of data from disparate scientific sources, such as museum object labels, field notebooks, recording sheets, and photographs. By capturing this data digitally, it is helping scientists and planners better understand, use, manage, and conserve biodiversity.[29] Similarly, the National Resource for Advancing Digitization's Integrated Digitized Biocollections[30] website hosts over 60 million digital specimen records that university researchers, citizen scientists, and museums are using to estimate levels of biodiversity in a particular location to project the impact of global change on species distribution.[31]

For Further Reading
The following resources are recommended for those who wish to learn more about cross-institution collaboration:

Exploring a Cross-Sector Residency Program for Professionals in Libraries, Archives, and Museums (PDF)
go.nmc.org/crossres
(Raynna Bowlby et al., Association of Research Libraries, February 2016.) This paper defines frameworks for cross-sector professional development opportunities and discusses the potential impacts on learning outcomes, skill-building, and collaborative efforts. **>** *Policy*

Learning Research Agenda
go.nmc.org/learnhist
(Natural History Museum, 2015.) Two institutions joined forces with the UK's Natural History Museum to develop a collaborative learning research agenda. Through a seminar series, academic researchers and museum professionals discussed research, practice, and theory to shape the future of the field. **>** *Leadership*

Museums: What Are They Good For?
go.nmc.org/acme
(Mindy Wilson, The University of Utah @theU Blog, 7 March 2016.) In collaboration with the Salt Lake City Public Library, the Utah Museum of Fine Arts has launched ACME, a series of roundtable gatherings dedicated to rethinking museums' public roles and exploring new models of community engagement. **>** *Leadership*

The McCoy Project
go.nmc.org/mccoy
(The University of Melbourne, 2015.) The University of Melbourne and Museum Victoria have partnered for the McCoy Project, a series of cooperative endeavors to stimulate scholarship based on museum assets and other impactful joint projects. **>** *Leadership*

Fossil Database to Create Cross-Discipline Collaboration
go.nmc.org/fossil
(The Field Museum, 2016.) Chicago's Field Museum has worked with a global team of scientists and computer programmers to launch the open-access Fossil Calibration Database, which links fossil records to DNA sequences to advance understandings of plant and animal origins. **>** *Practice*

Rethinking the Senses
go.nmc.org/rethink
(Tate Blog, 12 August 2015.) Rethinking Research: Experimental Approaches and Methods in the Art Museum is a cross-disciplinary event in which a diverse group including scientists, museum professionals, and artists examine measurement of art engagement in the museum context. **>** *Practice*

New Roles for Museum Professionals
Long-Term Trend: Driving Ed Tech adoption in museums for five or more years

Access to educational materials of all kinds has never been as open or easy as it is today, and this trend is only increasing. The model of the museum curator who stands in front of an object and interprets the meaning for a passive audience is no longer relevant. As a result, the role of museum professionals is changing to reflect the need to guide visitors in finding, interpreting, and making their own connections with collections and ideas. Today museum staff are also more willing to see themselves as learners, taking advantage of user-generated content to enhance the overall understanding of collections.[32] Further, museum leaders are being urged to address their disconnect with society-at-large by hiring individuals that bring expertise in areas outside of a museum's traditional purview.[33]

Overview
The current evolution of museum practices is being driven by the changing roles of museums in the 21st century. A yearlong international research study conducted by Gensler Research on the relationship between museums and their constituencies revealed that museum experiences in the future will be more interactive and self-directed, more community-focused, and more public, welcoming, and flexible in the area of museum design.[34] Traditionally, museums have nurtured a paternalistic relationship with their audiences, serving as content authorities disseminating information to the public. Although museum visitors still value expertise, there is an emerging trend towards shared authority, where multiple perspectives are highlighted and community involvement in programming and exhibitions is welcomed, impacting how museum staff approach their jobs.[35] Conversely, audiences expect museum staff to provide new ways to make the museum experience more interactive, primarily through the creation of digital projects.[36]

These changing roles will continue to have a profound effect on the type of skills the museum professional of the future will need. Some museums are already breaking new ground, moving beyond the familiar territory of preserving and interpreting objects in their collections to exploring their potential as social change agents. By creating programs that raise awareness of topics such as poverty, war, and discrimination, museums hope to increase their relevance and societal impact.[37]

A webinar hosted by the Association of American Art Museum Curators recently presented how social justice is shaping contemporary curatorial practice. Through the analysis of case studies involving pressing social issues including marriage equality and racism, they demonstrated how partnering with the community not only builds new audiences, but uncovers new forms of primary research.[38] These new strategies involving more user-generated and user-informed programming will increasingly require museum staff outside of digital departments to embrace digital as mission critical.

The growth of digital initiatives requires the continuous development of digital literacy — a topic covered in more detail later in the report. Some leaders in the field argue that in addition to assessing the needs of the community and training staff, museums need to employ a service design approach when creating transformative, visitor-centered digital initiatives. This shift involves staff becoming more aware of the museum's collection of systems, cultures, values, and processes holistically in order to move an organization beyond silo-based, project-oriented thinking.[39] Further, the work being done now has the potential to prepare museum professionals for what is being referred to as the "post-digital" world. At the Metropolitan Museum of Art, they are developing digital skills across the various departments and decentralizing certain tasks, such as digital content development, in order to make technology a mainstream rather than a special form of business activity.[40]

Implications for Policy, Leadership, or Practice
While there are no formal policies in place regarding the evolving roles of museum professionals, agencies and foundations are beginning to prioritize funding for museums that serve as both community anchors and catalysts for change. The Institute of Museum and Library Services, for example, has listed a number of areas of growth within museums that have direct impact on staffing roles—they include embracing data-informed decision making, providing greater access to collections and content, and forging cross-sector collaboration.[41] Similarly, the Paul Hamlyn Foundation in the UK funds museum and cultural projects that help individuals overcome disadvantage and lack of opportunity.[42] A recent grant to the Atrium Studio trains staff to develop arts and crafts activities and support for those with mental health issues or learning disabilities.[43]

For this trend to take hold, museum leadership must re-assess how they plan and manage change in their organizations. A recent post on CODE | Words, a blog on technology and theory in the museum, focused on this specific issue. The author explains that museums are lagging behind TV, print media, and the music and publishing industries in terms of how technological advances are changing the way museums engage with their audiences. Further, when topics regarding the need for adaptation arise in conferences, museum directors tend to be underrepresented. She argues that museum leaders need to embrace new thinking from all parts of the organization as well as involve users as part of the process that fosters cultural change.[44] Although still too uncommon, some organizations are taking steps to adopt new leadership strategies, such as the Minneapolis Institute of Art (Mia). At Mia, they have adopted agile methods that align staff better with strategy, deliver services faster, and allow for greater flexibility and adaptability.[45]

In practice, innovative museums are taking steps to openly rethink their roles through workshops and symposia. At the Tate Modern, staff have developed a course called Towards Tomorrow's Museum, which assesses the Tate within 21st century global, social, and cultural dynamics. The formats for sessions include short lectures, participant presentations, visits to the collections, and group discussion involving multiple departments including curatorial, learning, development, and research.[46] Chrysler Museum is another organization focused on their evolving role through inclusivity training that is teaching staff how to respond and engage with diverse audience groups. A recent workshop held for museum staff and volunteers offered insight into how to provide a safe and respected space for visitors of various sexual orientations and gender identities. Part of the training was to provide museum workers with correct terminology to use when addressing guests.[47]

For Further Reading

The following resources are recommended for those who wish to learn more about new roles for museum professionals:

In Search of Museum Professional Knowledge Base: Mapping the Professional Knowledge Debate onto Museum Work
go.nmc.org/museumprof
(Anwar Tlili, Taylor & Francis Online, 26 November 2015.) As a historically unexplored profession, researchers are working to distinguish the distinctive expectations and responsibilities held by museum professionals. **>** *Policy*

Celebrating 50 Years: Advancing Transformation & Innovation in Museums
go.nmc.org/MCN1
(Loic Tallon, MCN, January 2016.) As a leader in the digital transformation of the museum sector, the Museum Computer Network recently launched a new strategic plan for 2016-2018 that reflects their mission of continued growth and opportunities to connect museum professionals to each other and new technological trends on the forefront of shaping the profession. **>** *Leadership*

#MuseTech: How Has Technology Changed Your Work in the Museum Sector?
go.nmc.org/internetwk
(Sean Rameswaram, InternetWeek, 25 June 2015.) In this short clip, four museum professionals discuss how their role has evolved throughout the years to keep up with the integration of technology into the museum sector, including social media engagement and presentations of online exhibits. **>** *Leadership*

Do It Together: The Effect of Curators, Designers, and Technologists Sharing the Making of New Interactive Visitors' Experiences
go.nmc.org/MW2016
(Daniela Petrelli et al., MW2016: Museums and the Web 2016, 5 February 2016.) Technology versus content is no longer the debate among museum professionals; instead, research illustrates how one empowers the other. Tasked with developing exhibitions, curators must now combine technology and content seamlessly to create an experience that immerses the visitor within the storyline. **>** *Leadership*

The Impact of Technology on Museum Work by Function
go.nmc.org/mustech
(Canadian Heritage Information Network, 12 January 2016.) While there is no consensus among museum professionals on the extent to which technology has impacted museums, many agree it has fundamentally changed the landscape of museum work both behind the scenes and in interactions with the public. **>** *Practice*

Questions Brought to the Surface: On Curating Art and Technology with Ceci Moss
go.nmc.org/moss
(Emily Holmes, *Art Practical*, 8 September 2015.) This interview offers a deeper insight into how curators are finding new ways to leverage digital technology to connect their audiences with the message behind their art. **>** *Practice*

Data Analytics for Museum Operations
Mid-Term Trend: Driving Ed Tech adoption in museums for three to five years

Between 2013 and 2015, the global internet population[48] grew 18.5%, reaching 3.2 billion people – nearly half the world's population – and by the end of 2016, the world will have reached an annual data transfer rate of one zettabyte.[49] In recent years, companies such as Macy's, Netflix, and Walmart have been analyzing data to boost their sales and track customer behavior. Traditionally, museums conducted behavioral analysis of visitors primarily through attendance statistics and staff-administered surveys. Museums are now employing similar strategies as businesses for deciphering visitor information to generate more revenue and improve the efficiency of their operations in areas such as food service, marketing, retail, development, and program and exhibition design. The benefits are becoming clearer as museums mine data to learn more about their visitors, resulting in offering more focused information on the collections as well as a greater understanding of an audience's interests and needs.

Overview

Technologies applied in museums such as point-of-sale systems, social media, websites, and Bluetooth beacons are generating significant amounts of data that require organization and analysis to glean insights that can inform positive changes in museum operations and services.[50] This development is requiring a new expertise on museum staffs; in 2016, the role of data scientist was named the best job in America, supporting the importance of big data as a driver for organizational success.[51] A report predicts a shortage of 100,000 data scientist jobs by 2020[52] and global demand will exceed the number of data scientists by more than 50% by 2018.[53] While museums are increasingly hiring for these coveted positions, emerging technologies such as machine learning, artificial intelligence, and natural learning processing applications that interpret human voice commands are helping to supplement the shortage of candidates.[54]

After Apple introduced iBeacon, a technology that utilizes Bluetooth Low Energy (LE) to transfer signals between devices,[55] many museums across the world began leveraging it to track visitor interactions and personalize their experiences.[56] One challenge associated with iBeacon platforms is the dependency on users having an Apple iOS device, leaving out 80% of global mobile device users. Recently Google announced an open, cross-platform beacon platform termed Eddystone.[57] Like iBeacon, it benefits from Bluetooth LE to send and receive data from smartphones and other supported devices. Existing providers are already incorporating Eddystone into their products, benefitting users on both iOS and Android platforms,[58] and the Hong Kong Museum K11 has adopted the technology to deliver museum information and content to their patrons.[59]

Beacon technology is not the only means for tracking interactions and gathering visitor data. Museums are becoming savvier in designing guiding tools with built-in data-tracking capabilities. The Cooper Hewitt, Smithsonian Design Museum collaborated with interactive design agency Local Projects to develop an Internet-connected pen for patrons to use during their visit. Patrons collect objects from the museum by touching the pen to the object's label and produce designs inspired by items in the collection. In addition to the pen encouraging more visitor interactions, the ability for it to collect data will ultimately help inform and improve museum operations. Initial data has indicated that 94% of the visitors accepted the pen, 20% of those returned to the museum's website to view the items they had collected, and four of the six most collected objects are models of staircases.[60, 61]

Implications for Policy, Leadership, or Practice

Privacy is at the forefront of visitor data conversations. With museums constantly tracking information about how people engage with their websites and onsite exhibits and collections, there is a need for them to clearly communicate how they are using and sharing the data. In the UK, Brighton Museums uphold the Data Protection Act, which entails them never providing patron data to any other companies; any third-party vendors hired to provide museum services are also contractually obligated to uphold the same policies.[62] The Irish Museums Association has also publicized its data security protocols, emphasizing that the information collected and analyzed is explored through a big picture lens, meaning that data patterns are used to inform museum decisions — not individual visitor data. In this analysis, patrons' personal identifiers such as name and email address are not part of the process.[63]

Leaders in the field are exploring affordable and efficient models for collecting, analyzing, and reporting data. Culture Metrics, a UK partnership among 20 arts and cultural organizations, aims to evaluate the efficacy of a co-produced data collection system designed to measure performance and experience. The project includes a platform developed to support everyday use of the data and provide an easy-to-use survey feature. Potential benefits of the standardized approach could help institutions with self-awareness and improvement, and the ease of data portability for sharing and comparison could open up a new paradigm for collaboration. While the tools are available for organizations to analyze and make data-informed decisions, initial research has indicated that a major cultural shift would be necessary to drive future adoption, as many organizations today do not have a consistent strategy for the collection and analysis of data.[64]

In practice, museums are turning to emerging technologies that blend in with exhibits to gather new kinds of data. England's Durham Light Infantry Museum, for example, is embarking on a facial recognition effort as part of their digital strategy to reposition themselves for modern audiences. By mapping depth and movement, infrared HD cameras placed throughout the museum monitor each visitor's experience, and recognition cameras at the entrance provide staff with information into the patron's recent visits, to guide them to areas and exhibits that may be new or interesting. The data will be leveraged to gain insight into visitor's navigational patterns, where exhibits should be positioned, and what is most successful.[65] Similarly, Nasher Museum of Art employed eye-tracking glasses to gather data from viewer interactions. Researchers at Duke University created a heat map identifying areas of the objects that were viewed the most to understand how faces influence perceptions of art.[66]

For Further Reading
The following resources are recommended for those who wish to learn more about data analytics for museum operations:

Art Museums Find Going Free Comes with a Cost
go.nmc.org/gofree
(Amy Langfield, *Fortune*, 1 June 2015.) While some museums struggle with a free-admission model as federal funding and private philanthropy grow increasingly scarce, others have seen attendance growth and are harnessing the opportunity to learn more about their visitor base through audience engagement and incentive models. **>** *Policy*

Data Culture and Organisational Practice
go.nmc.org/datac
(Kostas Arvanitis et al., *MW2016: Museums and the Web 2016*, 20 March 2016.) This paper describes results of the Culture Metrics project, which aimed to create a framework for quantifying experiential, opinion-based data gathered in museums and galleries. The authors also derive insights on the future of data analysis in the cultural sector. **>** *Policy*

Predicting Our Cultural Future: Is 2016 the Year of Musedata?
go.nmc.org/musedata
(Center for the Future of Museums, 8 December 2015.) Three museum professionals describe how data are impacting institutional practices including audience engagement, future exhibition planning, and redefined departmental roles. **>** *Leadership*

Facts and Figures
go.nmc.org/factfig
(Museum of Contemporary Art Chicago, 2015.) The Museum of Contemporary Art Chicago's "Facts and Figures" page presents graphic visualizations of data on its works and community to help visitors better understand their cultural experience. **>** *Practice*

The Digital Metrics Dashboard
go.nmc.org/digdash
(Drew McDermott, Carnegie Museums Studio, 4 November 2015.) The Innovation Studio at the Carnegie Museums of Pittsburgh has developed the "Digital Metrics Dashboard" to help museum leaders access and interpret website data. The dashboard's format presents an easily digestible summary and timeline to support data-informed decisions. **>** *Practice*

Personalization
Mid-Term Trend: Driving Ed Tech adoption in museums for three to five years

*I*n *an era where information is being delivered to individuals based on their needs and behaviors, personalization is becoming an important feature of educational experiences. For the past several years, Google, Amazon, and Netflix have been leading the charge in building algorithms that take into account users' online activities and discern which content to display or recommend to them.[67] For example, a user who has watched a dinosaur documentary and purchased dinosaur paraphernalia online would subsequently see posts and advertisements for a Triassic period exhibit when surfing the web or logged on to social media. The personalization of marketing has set the precedent for other everyday activities to follow suit. AAM's 2015 Trendswatch report describes this advancement as playing out in three key areas: the creation of personalized goods, the filtering of personalized content, and the creation of personalized experiences.[68] As scientific, data-informed approaches to effectively facilitate personalization gain traction, museums are refining how they tailor communications, content, and offerings to their audiences.*

Overview

Personalization is not an entirely new trend for museums for face-to-face engagement. Onsite experiences often entail personal facilitated experiences — one-on-one or one-to-few interactions that occur between a museum representative and the visitor(s).[69] This could take the form of a docent intervening in a crowded tour to answer the questions of a small subset of people about a particular object. IMPACTS data reveals that these opportunities promote patron satisfaction better than non-personalized exchanges, demonstrating higher levels of admission and educational value, staff courtesy, and entertainment.[70] Standardized group tours for any venue have become less desirable as people crave tailored experiences; an IMPACTS study reveals that on a scale from 1-100, with 100 being the most amount of fun, museum tours declined nearly 10 points between 2008 and 2015.[71] Subsequently, iconic museums such as the Tate are rethinking the way they approach museum visits, designing them more as customizable experiences and less as transactional knowledge transfers.[72]

The possibilities for personalization have expanded with the evolving definition of museums, which now encompasses their digital presence.[73] Individuals

frequently use social media to reach out to museums with feedback and receive real-time responses. Further, the use of social media is bridging the gap between the physical and online realms as museums are increasingly encouraging patrons to share their personal experiences live with their networks.[74] As evidenced in the Data Analytics for Museum Operations section that precedes this one, museums are also becoming more adept at continuously collecting information about each patron and housing it in central data repositories that fuel all of their resource allocations and communications. Museums are now able to customize emails with recommendations and news based on a user's specified interests and exhibit viewing history, creating a deeper relationship with each patron.

The popular online publication *Hyperallergic* characterizes the 21st century personalized museum as acknowledging visitors' capacity to make their own interpretations; discerning what they want out of their experiences; and mobilizing museum resources to fulfill their needs.[75] Progressive institutions are embodying these attributes through crowdsourcing and co-curation strategies. Museum of Fine Arts in Boston, Museum of London, and the Victoria and Albert Museum are among the growing number of museums that have selected artworks and objects to feature in their exhibits based on votes from their communities. A January 2016 announcement from Modern Museum of Art specifically outlined their vision as providing visitors with opportunities to discover personal meaning, reconceiving their gallery spaces to nurture more organic linkages between the past and the present.[76]

Implications for Policy, Leadership, or Practice

Advancing personalization requires significant data collection, prompting museums to create policies that educate their communities on usage. The United States Holocaust Memorial Museum (USHMM), for example, distinguishes anonymous information from personal, explaining on their website two different pathways for gathering and sharing information. The former pertains to a user's website visit, including what materials they read or download. USHMM only uses that data to enhance their website offerings and does not share user information. The latter entails people voluntarily submitting information about themselves in the form of profiles, gift contributions, email subscriptions, and

other formal interactions. USHMM leverages these details to communicate with their patrons and provide them with tailored content they believe would be beneficial.[77] It is also the responsibility of museums to be upfront about their intentions. When the Museum of Brisbane collects data about patrons, they preface each request by expressly stating their purpose and how they plan to follow up.[78]

In terms of applying the data to personalize experiences, Rijksmuseum Amsterdam's work has been seminal. They created a process of using semantic metadata of cultural heritage to improve personalized access through patrons' devices. The pilot, CHIP Project, allowed users to build profiles and associate them with their art preferences and related activities, and Rijksmuseum Amsterdam responded by personalizing virtual and face-to-face tours.[79] Further, the museum was able to more accurately generate personas for novice and expert patrons by gaining a better understanding of how background knowledge and interests drive their art preferences; this helped them transform into a highly adaptive institution, continuously guided by patron needs.[80]

More museums are relying on apps to personalize art discovery. Graduate students in MIT's School of Humanities, Arts, and Social Sciences created "Artbot" to help people connect their passions with the Boston art scene. Users specify their interests and the app mines information from a wide variety of local museums to find artists, movements, and themes that link events to each other and then tailors recommendations accordingly.[81] Through funding from the European Commission, Acropolis Museum in Greece and the Cité de l'espace in France have deployed the CHESS web app (Cultural Heritage Experiences through Socio-personal interactions and Storytelling), which uses personalized information from survey data to generate customized stories that guide visitors through the galleries with augmented reality and gamification features. After visits, patrons have the opportunity to share artifacts they created within the stories on the museum websites.[82]

For Further Reading
The following resources are recommended for those who wish to learn more about personalization:

Improving Museum Visiting: Personalization
go.nmc.org/muslearn
(Yidi Zhang, Georgetown University, 21 December 2015.) As the role of the traditional museum has expanded into a space for cultural learning, digital technology is being leveraged to optimize the individual experience. This research focuses on two methods of personalization: through an online recommender system based on individual profiles and location-based programming that maps an individual's movement to provide suggestions for future visits. **> Leadership**

Museums and Personalized Learning
go.nmc.org/musfuture
(Ashley Weinard, Center for the Future of Museums, 22 March 2016.) As museums increasingly become centers for educational learning, they must adopt designs that fit individual needs as opposed to using generalized information. Combining the ability to predict learner variability and respond to learners' demands are ways in which experts believe museums can begin to personalize these unique learning experiences. **> Leadership**

An Interactive User Interface Prototype Design for Enhancing On-Site Museum and Art Gallery Experience Through Digital Technology
go.nmc.org/aust
(Richard Lia and Alan Liew, Griffith University, 29 January 2015.) An Australian museum is tapping into the interests of its visitors to create a more personalized experience by developing an application that leverages mobile devices to interact with the individual, therefore gathering information about their visiting behavior to deliver real-time personalized tour trajectories. **> Practice**

Deep Personalization: A Case Study of Systems Thinking Within an Art Museum
go.nmc.org/deep
(Paul Fishwick, MW 2016: Museums and the Web 2016, 12 January 2016.) Deep personalization strikes a balance in the combination of customization and personalization, where the former is the ability of the customer to select what is desired and the latter uses prior behaviors to provide suggestions. Topic learning hopes to find this balance by encouraging visitors to select specific topics of interest that can then guide their visit accordingly. **> Practice**

ICER Innovation Center: Using Biometrics to Welcome Museum Visitors
go.nmc.org/icer
(Museum and Heritage, 17 December 2015.) A museum in the Netherlands is using biometric recognition software to personalize the museum experience. The process includes a pre-visit registration, using biometrics to welcome the visitor, and 15 checkpoints that allow for individualized interaction between the visitor and the information. **> Practice**

Muzeums Prototype App
go.nmc.org/muz
(Muzeums Prototype App, YouTube, 18 March 2015.) Launched onto the market recently, this mobile phone application centers the museum experience around the individual by developing a profile based on their interests. The application then compiles a list of appropriate museum destinations, therefore allowing visitors to focus solely on exhibits that match their interests and learning style. **> Practice**

Mobile Content and Delivery
Short-Term Trend: Driving Ed Tech adoption in museums for the next one to two years

The pervasiveness of mobile devices is changing the way humans interact with information and their surroundings. Smart devices, including phones, tablets, and watches, are now capable of acting as miniaturized computers; their storage space and processing power has increased dramatically with each subsequent release, and they continue to gain advantages by including a number of tools like barometers, photometers, and gyroscopes that laptop or desktop computers do not offer. In 2015, global mobile data traffic grew by 74%, and mobile connection speeds increased by 20%.[83] In concert with the expanding use and advancing functions of these devices, museum patrons expect not only to learn about information, services, and content anywhere and anytime, but also to create and share their personal museum experiences.[84] Museums benefit in becoming more discoverable and serviceable by embedding themselves in this digital culture, which has led half of them worldwide to enhance their visitor experience via mobile services.[85]

Overview
Smartphones have quickly become essential tools for information access. Research from GSMA Intelligence reveals that the world gains more than 750,000 new mobile users every day,[86] and GlobalWebIndex found that mobiles capture 50% of daily online time for 16- to 24-year-olds.[87] Pew Research Center has identified that some smartphone owners, particularly young adults, minorities, and lower-income populations, depend solely on their smartphones for Internet access.[88] With Google adding mobile performance to its quality indicators, favoring mobile-friendly pages in its search rankings, museums that do not optimize their websites for mobile risk reduced discoverability.[89] The frequency with which visitors reach for their mobile devices also requires updated WiFi infrastructure and clear guidelines that encourage creative personal device use while minimizing distractions.

Museums are increasingly employing responsive design, which has allowed many to optimize their websites and online content to fit a variety of screen sizes, with deeper implementations including responding to contextual information about visitors such as location, time of day, and how they have interacted with content previously.[90] Prioritizing mobiles also includes recognizing the devices visitors bring with them to the museum and

strategizing how they can meet those visitors in their comfort zones to not only fulfill information needs, but also encourage enhanced exploration, interpretation, and sharing. The Broad Museum in Los Angeles offers a mobile app with a variety of self-guided tours, including one aimed at reaching younger audiences that is narrated by the host of "Reading Rainbow," and another entitled "Artists-on-Artists," with artists commenting on the work of fellow artists featured in the museum.[91]

Museum-produced apps can further heighten visitor experiences by providing more comprehensive materials, including multiple critical interpretations, stories, and contextual information. In Australia, the National Portrait Gallery's "Portrait Stories App" provides access to 1,700 portraits from their collection, with accompanying articles, artist interviews, and enhanced search functions; whether visitors are in the gallery, at school, or out for coffee, they can continue their learning and exploration of the portraits.[92] During a museum visit, tools such as hyperzoom allow patrons to more deeply engage with the museum content they are unable to physically handle, while interactive features including gamification, location-based services, augmented reality, and social networking integration can encourage more personalized and shareable experiences. Museo del Prado's "Second Canvas," for example, lets visitors zoom into 14 masterpieces in ultra-HD, view X-rays to reveal sketches beneath the works, and share details and ideas on images through social media.[93]

Implications for Policy, Leadership, or Practice
While several years ago it was not uncommon for museums to ban cameras, today smartphones with built-in cameras have become so ubiquitous that the bans are difficult to enforce. Many museums now embrace visitor devices, allowing them to snap photos and engage with apps. However, a new smartphone accessory, the selfie stick, has made its way to many museums' list of banned items. The selfie stick is akin to a tripod, as it extends the camera beyond arm's length and has potential to invade others' personal space, possibly compromising the safety of visitors and artwork. The goal in developing policies for personal devices is to allow them to enhance the physical experience of exploring the museum space for visitors, while minimizing their capabilities to distract visitors

or overwhelm the space.[94] The Smithsonian recently updated their policy to prohibit selfie sticks to protect visitors and objects. They included a statement beneath their ban that they encourage visitors to still take photos and share their experiences, but without the use of selfie sticks.[95]

The newly expanded San Francisco Museum of Modern Art has prioritized mobile technology in their digital strategy with the goal of enabling visitors to engage more intently with the art and less with their screens. They built their app experience around location-aware audio navigation, providing visitors the opportunity to listen to unique perspectives and reflections, while exploring the museum with their heads up and eyes on the physical content. Another part of their plan incorporates mobile devices into participatory learning environments. For example, their Pritzker Center for Photography houses the Photography Interpretive Gallery, which invites visitors to closely examine the kinds of images they take and post them in relation to the history of photography, which has advanced to its current pervasiveness in our daily lives.[96]

Mobile devices are playing a major role in facilitating more inclusive learning experiences rather than limiting visitors to experience the art through a single, top-down interpretation.[97] With increased screen real estate and battery life, many museums have found tablets to be well-suited for interactive and creative exploration of the physical space and objects, and are investing in a supply to keep on hand. The Louis Vuitton Foundation in Paris, a Frank Gehry-designed building, inspires visitors to explore architectural techniques with rubber-cased iPads that they use to take photos of specific locations in the museum, culminating in an activity to design their own Gehry-inspired structures. Successful museum apps invite engagement and movement within the physical space in a way that does not detract from the in-person experience.[98]

For Further Reading
The following resources are recommended for those who wish to learn more about mobile content and delivery:

Adopting an Agile Approach to Mobile App Delivery
go.nmc.org/agileapp
(Selena Bretton, Create Hub, 11 May 2015.) The Natural History Museum, London is leveraging their mobile app usage feedback to reconsider initial assumptions on visitor behavior, and inform a mobile app delivery framework they can use for coherence across future projects. They have found their visitors want simple, core information to initiate their visits, but are less likely to refer to their phone as they explore the building.
> *Policy*

Wireless Access Point Tip Sheet for Museums
go.nmc.org/tipsheet
(Government of Canada, 22 October 2015.) This tip sheet covers some of the most common issues that arise in offering public wireless access points as well as recommendations for drafting a simple user policy.
> *Policy*

'Digital Sketchbooks': Using iPads to Support School Visits to the Ashmolean Museum
go.nmc.org/digsketch
(Sarah Wilkin, University of Oxford, 16 March 2016.) The Education Department at the Ashmolean Museum welcomes thousands of students each year, and in response their staff has developed a series of workshops for student visitors as part of their "Digital Sketchbooks" project, leveraging iPads loaded with three free applications. After implementation and feedback, they have designed an online handbook with tutorials and resources to help others translate the learning activities that include annotating, photographing, drawing, editing, and research to other museum and cultural heritage contexts. **>** *Leadership*

Museums in Israel
go.nmc.org/isr
(Museums in Israel National Portal, accessed 23 May 2016.) The Museums in Israel National Portal brings together dozens of Israel's museum collections into one interface that allows any visitor worldwide to easily and freely access visual collections and artifacts of Israel's museums from any computer, tablet, or smartphone. Tools for inquiry, retrieval, comparison, and saving meet the needs of researchers, students, educators, and anyone interested in exploring Israel's heritage. **>** *Leadership*

Mobile: From Responsive to Mobile Moments
go.nmc.org/mobmom
(Catherine Devine, MW2016.) This article dives into the adoption and evolution of mobile strategies within museums and asserts that the current iteration is based upon the idea of designing visitor experiences around "mobile moments," the day-to-day information needs and questions visitors have that cause them to reach for their mobile devices. **>** *Practice*

Storyteller – World War One: Love and Sorrow: A Hybrid Exhibition Mobile Experience
go.nmc.org/meld
(Timothy Hart, Johnny Brownbill, MW2015, 19 February 2015.) The Museum Victoria developed the mobile experience for its "WWI: Love and Sorrow" exhibition to guide visitors through the story of war as told through personal experiences of eight characters and their families. The app can serve as a complementary guide to support a visitor's journey through the physical exhibition, while off-site mode provides a virtual journey before, after, or in lieu of visiting the museum.
> *Practice*

Participatory Experiences
Short-Term Trend: Driving Ed Tech adoption in museums for the next one to two years

Expectations for civic and social engagement are *profoundly changing museums' scope, reach, and relationships. The 2010 publication of* The Participatory Museum *online book was a major step to formalize the movement, which has since gained significant traction with the broader museum community.[99] Museums are integrating emerging technologies and approaches such as social media, open content, and crowdsourcing as a means of engaging their communities both internally and externally on a continuum of participation.[100] Leadership and staff are embracing innovations that include mobile and network technology, which enable their institutions to provide patrons with more immersive opportunities that integrate visitor knowledge into exhibits and objects.[101] Additionally, museums recognize that niche visitor groups and individuals can provide museums with insights that enrich collections and enhance the interpretive value of an exhibit. Participatory experiences are becoming the norm, both onsite and online, and museums are increasingly finding new ways to encourage and incorporate community contributions.*

Overview

The move toward participatory experiences in museums mirrors the changing tide of the learning sector as a whole. Both of the latest higher education-[102] and K-12[103]-focused editions of the *NMC Horizon Report* series featured the trend of stimulating more active, hands-on opportunities to foster deeper knowledge acquisition.[104] *The New York Times* points to challenges in engaging a rising key demographic for museums — millennials — citing that static galleries are ineffective.[105] *Fast Company* asserts that millennial audiences are "dedicated to a radically participatory ethic," craving experiences that incorporate fun, discovery, and community.[106] Museums are well-positioned as leaders in this space as they have experience designing exhibits and collections that encourage interaction. In recent years, the proliferation of communications technologies has enhanced the social implications of a visit, creating a bridge from a physical experience to the virtual realm. As soon as patrons step foot into the building, they can check in via social media and document their experience with photos and personal perspectives, instantly inviting their networks to be a part of their visit.

A flurry of social media activity has also drawn more crowds and revenue for museums.[107] Since the Los Angeles County Museum of Art (LACMA) opened their highly social "Rain Room" exhibit,[108] visits have increased by 24%. Museums in China, such as the Songzhuang Art Museum and Ullens Center for Contemporary Art, are driving more foot traffic by leveraging discussion-oriented platforms like Weibo.[109] Visitor participation has also translated to effective marketing for exhibits. The Hammer Museum's #Spunday campaign encourages people to post and tag photos of themselves spinning in featured artist Thomas Heatherwick's chairs.[110] Museums that have historically discouraged photography have been capitalizing on the participation cultivated by social media to captivate their audiences. Rather than snapping pictures with their smartphones, visitors of the Rijksmuseum in Amsterdam are asked to share their own interpretations by sketching drawings of the objects and uploading them to social media networks using the hashtag #Startdrawing.[111]

For smaller museums that face serious financial constraints, audience participation is increasingly taking the form of crowdsourcing and crowdfunding. The growth of platforms such as Kickstarter and GoFundMe are enabling institutions to rally people around their projects, educating them on the importance of artistic and cultural heritage displays and then inviting them to share ownership through co-development. Non-monetary contributions are also on the rise as museums collect data, ideas, and content from users, empowering people to contribute and share accountability for the ongoing expansion of the research and media ecosystem.[112] The British Museum and UCL Institute of Archaeology's MicroPasts initiative invites the public to collaborate on research about archaeology, history, and heritage by designing new projects or funding existing ones within the community.[113]

Implications for Policy, Leadership, or Practice

The momentum behind the participatory movement is causing many museum leaders to consider formulating policies that foster digital interaction inside museum walls. Historically, the National Gallery of Denmark limited patrons from sharing photos and other tokens of their visit; however, after a one-month experiment to support visitor photo-sharing led to a 2,500% increase in Instagram followers, they formally relaxed their social media guidelines.[114] As more museums embrace social media, all staff must have a clear understanding

of related policies so they are empowered as digital interaction facilitators. Western Australia Museum's guidelines expressly state time limits for video footage uploads and emphasize that posts should contain a call-to-action for readers to get involved.[115] With a rise in crowdsourcing initiatives, museum leaders caution that there are not concrete standards or professional codes in place for online contributors, making it critical for museums to carefully consider their strategies and create clear accompanying policies.[116]

Just as in implementing any innovative approach, fostering participatory experiences requires leadership and financial support. Bloomberg Philanthrophies awarded $17 million to six New York museums to expand its Bloomberg Connects program — an initiative developed to make museum visits more interactive.[117] The National Endowment for the Humanities recently launched Community Conversation grants to stimulate museum-led public discussion projects that invite people to address pressing challenges through the lens of humanities.[118] Focused on cultivating deeper onsite exchanges, the Dallas Museum of Art built the 12,000-square-foot Center for Creative Connections (C3) to underscore the importance of learning by doing. C3 encompasses an interactive gallery where visitors can engage in activities such as sketching famous sculptures, along with a technology lab where community members respond to artworks through creative, technology-enhanced expression.[119]

Part of progressing the participatory movement is actively recognizing visitors who take the time to share their unique interpretations. The Chicago History Museum launched an Instagram contest asking people to share their favorite part of an exhibit, and the winner was announced on their social media and received a special catalogue.[120] Columbus Museum of Art (CMA) has taken user contributions to a new level, featuring participants' smartphone photos in the "#MobilePhotoNow" exhibit. After CMA issued a contest for people to upload shots to Instagram inspired by the Photo League collection, more than 45,000 photos were submitted across 89 countries. The resulting exhibit showcased the work of 240 photographers, making it the largest mobile photography exhibit in any museum. Additional social media sharing strategies helped the exhibit reach more than 270 million people worldwide.[121]

For Further Reading
The following resources are recommended for those who wish to learn more about participatory experiences:

Museums and Participatory Governance (PDF)
go.nmc.org/musepub
(Catherine C. Cole and Lon Dubinsky, Alberta Museums Association, May 2015.) Museums' public roles have evolved from displaying objects to engaging with communities and fostering dialog on social issues. The authors recommend resource sharing among museums, inclusive practices to help groups tell their stories, and acknowledgment of the political nature of exhibition choices. **>** *Policy*

The Future of Museums Is Reaching Way Beyond Their Walls
go.nmc.org/learnopp
(Jessica Leber, *Fast Company*, 17 April 2015.) The American Museum of Natural History is expanding patrons' learning opportunities and encouraging deeper exploration of exhibition topics through free online courses, public seminars, and mobile apps. **>** *Leadership*

Air and Space Museum Hits Refresh Button with Hands-On Exhibit
go.nmc.org/kidsfly
(Marylou Tousignant, *Washington Post*, 17 August 2015.) At the Air and Space Museum, visiting children can fly jets, pilot drones, and more through the museum's tactile simulations in their "Above and Beyond" exhibit. The museum plans to use patrons' reactions to the interactive elements to guide future exhibition design. **>** *Practice*

Crowdsourcing for Academic, Library and Museum Environments
go.nmc.org/crowddig
(University of Oxford, 2015.) The University of Oxford's Digital Humanities at Oxford program offered a workshop for museum and library professionals to discover the potential of the Panoptes crowdsourcing site to foster large-scale data extraction from collections that cannot otherwise easily be digitized. Analysis and visualization tools were also explored. **>** *Practice*

Get Up Close and Personal: Please DO Touch!
go.nmc.org/touchart
(Museum of Inuit Art Blog, 21 August 2015.) The Museum of Inuit Art's Educational Collection offers "Get Up Close and Personal" sessions; visitors can touch exhibit pieces to learn more about the objects' roles in Inuit culture and gain additional contextual understanding of other sculptures in the museum's collection. **>** *Practice*

Norsk Teknisk Museum wins 2015 Ecsite Creativity Award
go.nmc.org/ting
(Ecsite, 11 June 2015.) Oslo's Norsk Teknisk Museum has created the TING exhibit, an interactive experience that creates social dialog by inviting patrons to answer questions about impacts of technologies on democracy and society; the response data generates visualization graphics to illustrate the debate. The museum was awarded the 2015 Ecsite Creativity Award for this unique installation. **>** *Practice*

Significant Challenges Impeding Technology Adoption in Museums

The six challenges described on the following pages were selected by the project's expert panel in a series of Delphi-based cycles of discussion, refinement, and voting; the expert panel was in consensus that each is very likely to impede the adoption of one or more new technologies if unresolved. A complete record of the discussions and related materials were captured in the online work site used by the expert panel and archived at museum.wiki. nmc.org/Challenges.

Because not all challenges are of the same scope, the discussions here are sorted into three categories defined by the nature of the challenge. The Horizon Project defines solvable challenges as those that we both understand and know how to solve; difficult challenges are ones that are more or less well-understood but for which solutions remain elusive; and wicked challenges, the most difficult, are categorized as complex to even define, and thus require additional data and insights before solutions will even be possible. Once the list of challenges was identified they were examined through three meta-expressions: their implications for policy, leadership, and practice for museums.

Policy. While all of the identified challenges had policy implications, two specific challenges are driving policy decisions at many museums at the moment. The easiest one to address is developing effective digital strategies. Governments and museum organizations are already making ample headway. Europeana is focused on the digitization and networking of cultural heritage to further the Digital Agenda for Europe's 2020 initiative. They have convened a special team for the development of policy standards that support new business models.[122]

A more challenging policy area is the complexity involving data privacy, and international organizations are currently drafting policies to ensure privacy protection. European data protection reform has implications for museums using data collecting technologies—a compliant museum app must provide the explicit option to erase some or all data collected on an app.[123]

Leadership. Again, while all the identified challenges have leadership implications that are discussed in the following pages, two pose roadblocks to employing effective visions. There is a major need for museums to develop benchmarks and standards before integrating new technologies, and some museum leaders are already making progress. The European project LEM has created a report titled "Measuring Museum Impacts" that helps museums gauge the social return on technology investments. The report focuses on areas such as audience development through the use of ICT to create lasting relationships.[124]

Managing knowledge obsolescence is considered by the panel to be a wicked challenge requiring effective leadership. Some organizations are stepping up to train future museum visionaries, such as the Getty Leadership Institute at Claremont Graduate University. They avoid discrete training on specific technologies in favor of instilling deep philosophical approaches to using digital strategies in museums to increase the value of museums to society at large.[125]

> **Because not all challenges are of the same scope, the discussions here are sorted into three categories defined by the nature of the challenge.**

Practice. Each of the six challenges identified by the expert panel presents numerous impediments for advancing museum education and interpretation, but two in particular are presenting unique obstacles. The expert panel perceives improving access for disabled populations to be a difficult challenge. The Canadian Museum for Human Rights is working to improve the experience for blind and low-vision museum-goers through new imaging technologies. Using 3D PhotoWorks, the museum is converting 2D images into 3D objects to provide a new way of experiencing previously inaccessible artworks.[126]

Improving the digital literacy of museum professionals is still an ongoing although solvable challenge for museums, especially as technology advances at an accelerating rate. The Metropolitan Museum of Art is addressing this through peer-to-peer coaching sessions they refer to as "Digitalpaloozas." Held twice a year, they offer staff the opportunity to get hands-on with new digital projects and tools such as the Oculus Rift.[127]

The following pages provide a discussion of each of the challenges highlighted by this year's expert panel that includes an overview of the challenge, its implications, and a set of curated recommendations for further reading on the topic.

Developing Effective Digital Strategies
Solvable Challenge: Those that we understand and know how to solve

The ubiquity of technology use in society has impacted how museums develop strategic plans and digital strategies. Such documents include deploying the proper hardware, software, and networks, as well as critical tasks such as digitization. More importantly, these plans help museums expand the meaning of digital to involve the adoption of values such as agility, flexibility, and usability to keep pace with rapidly evolving societal changes that are increasingly inseparable from technology.[128] Digital strategies are more than the development of a website; they are the multiple channels of technologies that provide unique opportunities for audience engagement.[129] A museum's online activities include not only a website, but also social media, mobile tools and apps, electronic fundraising, and much more. Additionally, it is clear that a museum cannot simply plan a web presence in the same manner as a brochure or catalog; they require the development of new workflows and staffing adjustments.

Overview

As mirrors of contemporary society, which is increasingly networked, mobile, and open, museums are in the midst of a digital paradigm that is impacting all areas of a museum's operations. At the center of this challenge is the notion of museums needing to be more aware and responsive to their audiences' evolving behaviors to stay relevant. The "Digital Strategies for Audience Engagement" study recently conducted by Axiell and Museums and the Web surveyed 71 international senior museum leaders, strategy consultants, and museum professionals about the status of their digital strategy and revealed that there is still much progress to be made in developing these documents, especially in the realm of engagement. They found that while 24% of a museum's digital strategy is integrated into their institutional strategy, 60% responded that it was still in development, and 13% responded that it was not a priority for the institution at all.[130]

Compounding this challenge is that some digital strategies are built around legacy tools, such as interactive websites, customer relationship management systems, and fundraising databases, which lock professionals into a way of working that may ignore opportunities for greater innovation and efficiencies.[131] The creation of effective planning documents in many ways requires a digital transformation of an organization. The MIT Sloan Management Review's 2015 global study of digital business can help inform museums as they plan for the future. They found that mature organizations leverage social, mobile, analytics, and cloud technologies to transform how their businesses work while less mature organizations focused on solving discrete problems with specific technologies.[132] Further, some believe that technology must be an integrated part of the visitor experience and that museums should avoid master plans where technology feels forced or where it is just a technology layer superimposed over the museum.[133]

Although the Museum of Victoria has noted that writing effective planning documents is intensive, demanding, and challenging, progress is being made to overcome obstacles.[134] The South West Museum Development Programme in the UK helps regional museums achieve sustainable improvements in order to maximize benefits to audiences.[135] They produced a guide to writing a digital strategy that featured two different approaches: the first approach, inspired by the Tate Museum's policy paper, "Digital as a Dimension of Everything,"[136] embeds digital activity into current strategies or reframes objectives from forward planning goals with a technological focus. Depending on the culture of the museum, developing a standalone digital strategy may be helpful for providing clarity and focus, or reviewing an existing planning document may be more appropriate. More importantly, museums need to ensure that digital is woven seamlessly into whatever solution is chosen.[137]

Implications for Policy, Leadership, or Practice

As governments coordinate efforts to develop arts and culture policies, some are focusing on technology initiatives that are impacting museum planning. In Australia, all federal and state arts jurisdictions have developed an Arts Accord, an agreement between federal, state, and territory governments to strengthen support for arts and culture and set principles for ongoing cooperation.[138] As part of the Arts Accord, a comprehensive national, cross-domain survey was conducted in May 2015 to establish a baseline of activity, practice, and achievement in the use of technologies. Policy recommendations from the report include encouraging all cultural institutions to develop and report on their formal digital strategy and plan.[139]

Similarly, Europeana, part of the Digital Agenda for Europe's 2020 initiative, seeks to further the digitization and networking of museum cultural heritage.[140] In cooperation with Europeana Network partners, they have convened a policy, research, knowledge, and program management team that will set policy standards to support new business models.[141]

Strong commitment and visionary leadership are required for an organization to understand how to effectively transform the way they think about digital to deliver on their missions. The Balboa Park Online Collaborative (BPOC) fosters a culture of innovation and collaboration amongst the museums in Balboa Park, San Diego and part of its role is helping its community with creating effective planning documents.[142] BPOC's digital strategy is grounded in the idea that institutional cultures, operations, philosophies, and skillsets should shift to embrace digital to improve or enhance the work of the museum.[143] Organizational leaders can also turn to an emerging body of special interest groups (SIG), such as the Museum Computer Network's Strategy SIG. The group focuses on key high-level, senior management issues around new forms of interpretation, asset management, and content sharing.[144]

On the implementation level, key organizations are making great strides to not only develop comprehensive planning documents, but to share them openly as they are created to the greater cultural and scientific sectors. The Andy Warhol Museum, for example, has taken a bold move to draft and publish their digital strategy in GitHub. They see their efforts as a living resource designed to navigate the continuously evolving nature of the digital landscape, and the repository hosting service allows for files to be easily shared, revised, and repurposed.[145] In the science realm, the Natural History Museum in the UK recently published the report "Strategy to 2020," outlining four key areas for improving their impact using technology: creating innovative ways to interact with collections, supporting citizen science programs, tackling major scientific challenges, and improving the museum's infrastructure to improve the visitor's experience.[146]

For Further Reading

The following resources are recommended for those who wish to learn more about developing effective digital strategies:

Museums Galleries Scotland Promoting Digitization Across the Country
go.nmc.org/gallerscot
(Eithne Ní Chonghaile, *Museums + Heritage Advisor*, 26 June 2015.) The National Development Body for Scotland's museums and galleries, Museums Galleries Scotland, supports museums in implementing digital practices to make collections more accessible

and inspire new forms of audience engagement, research, and interpretation through its National Skills Development Programme, MGS Digital Transformation Network, and its investment program. **>** *Policy*

Collections without Borders: Sustaining Digital Content at Cultural Institutions
go.nmc.org/sustdig
(Sarah Pickle and Nancy L. Maron, Government of Canada, 22 April 2016.) This case study describes how the Museum of Anthropology at the University of British Columbia developed their strategy to digitize permanent collections with a durable database infrastructure. It offers lessons for other institutions looking to develop their own digital capacities and features a Health Check Tool for Digital Content Creators in Cultural Heritage Institutions, developed with JISC and Ithaca S+R. **>** *Policy*

Digital Learning Network
go.nmc.org/diglear
(Digital Learning Network, accessed 9 May 2016.) The Digital Learning Network supports museums, libraries, and archives in using digital technology for learning by holding regular events to connect people and sharing information about new developments, free resources, and best practices. **>** *Leadership*

TuoMuseo
go.nmc.org/positioning
(TuoMuseo, accessed 9 May 2016.) TuoMuseo is working to create a single platform to host Italian cultural sites and their works digitally that can be accessed from computers and mobile devices, in Italian and English. They aim to make the online experience personal, emotional, interactive, and participatory, while leveraging analytics tools to inform museums and crowdfunding techniques to allow spontaneous donations from visitors. **>** *Leadership*

Making Digital Work
go.nmc.org/r&d
(The Digital R&D Fund for the Arts, June 2015.) The Digital R&D Fund for the Arts explores how valuable museum content and energy is being translated to the digital world through new business models, making more of data, accessibility, and experiences designed for mobile. **>** *Practice*

Science Museum Group Digital Strategy
go.nmc.org/scimusgro
(John Stack, Science Museum, 5 May 2016.) The Science Museum Group has published its digital strategy, outlining a three-year digital program for its four museums that facilitates deeper exploration of objects and how they operate through interactive installations; comment threads and social media; reuse of the museum's digital content for creative and research endeavors; and collaborative digital initiatives such as citizen science projects. **>** *Practice*

Improving Digital Literacy of Museum Professionals
Solvable Challenge: Those that we understand and know how to solve

With the proliferation of the Internet, mobile devices, and other technologies, the traditional view of museum professionals possessing the ability to develop exhibitions and educate patrons has expanded to encompass the understanding of a variety of digital tools. This category of competence is affecting how quickly museums evolve and the skills they expect in new hires. Some thought leaders believe there are not enough best practices guidelines for technology training for current and pre-service museum staff,[147] and the most progressive examples are taking place informally. Professional development around how emerging technologies can be leveraged to further museums' interpretation goals and enhance their visitor experiences is needed at all levels of museum education. This issue is not isolated to museum education departments and is essential to improving technical infrastructure and workflows. Digital literacy needs to be achieved across the board, especially in the context of museum leadership.[148]

Overview

While museum professionals are more accustomed to using emerging technologies in their work, the 2016 Museum Edition Expert Panel believes that improving digital literacy is an ongoing challenge because of the evolving nature of digital tools and processes, as well as constrained budgets to support the development of new skill sets. Although museums leverage technology to communicate with and generate content for their growing onsite and online audiences, reductions in funding from government and other traditional sources are impeding progress in this area.[149] In Europe, for example, the Museums Association Cuts Survey 2015 paints a grim forecast; some of the museums they surveyed experienced budget cuts of 69% between 2010 and 2017.[150] Despite these concerns, the panel views this challenge as being solvable because increasing access to low-cost resources and emerging frameworks is helping museum professionals keep pace with digital advancements.

As the need for digital literacy has been continuously acknowledged by museums, students in museum studies programs, such as at Rochester Institute of Technology, are working directly with museums on collaborative projects that are designed to cultivate their digital and multi-modal literacies, including

crowdsourcing, cataloguing, and developing mobile content.[151] While these opportunities are available for pre-service professionals, current staff without sufficient technology training — and the time or funds to enroll in formal training — still face challenges. According to the UK's Warwick Commission "Report on the Future of Cultural Value," many cultural organizations believe significant barriers to digital aspirations still exist. 70% of the 900 surveyed in England claimed lack of funding and time as the biggest hurdles in developing digital literacy.[152] Similarly, when smaller museums face budget constraints, professional development opportunities are often the first to be cut.[153]

Another facet of this challenge is the need to develop a shared vision for digital literacy across the museum sector. The Baltimore Principles, launched at the Museums and the Web 2014 conference and revisited in 2016, highlights some of the obstacles museums need to overcome to address digital training. This framework called for emphasizing digital literacies, rather than specific digital skill development; professional development tied to strategy, rather than reactive training; a more discursive, rather than didactic approach to training; and most importantly, evolving collective expertise across museum departments, rather than within a select few.[154] The European Commission (EC) is rethinking how museum professionals approach digital in their work environment. A recent post on the EC's Electronic Platform for Adult Learning in Europe advises that devising effective digital strategies "involve transforming the context, content, and nature of a visit, but also the ways in which people behave, communicate, and learn."[155]

Implications for Policy, Leadership, or Practice

At a governmental level, no specific policies exist on the stewardship of technology training for museum staff. However, government organizations such as the Institute of Museum and Library Services are helping to better define 21st century skills in museums. They include learning and innovation skills, such as critical thinking and problem solving; information, media, and technology skills, such as applying technology effectively; 21st century themes, including global awareness; and life and career skills, such as flexibility and adaptability.[156] Conversely, researchers in Denmark are also exploring digital literacy in heritage

organizations and urging institutions to develop sustainable policies for guiding digital work practice. This includes the critical task of setting aside funding for strategic planning and the hiring and training of staff.[157]

Advancing digital literacy across museums requires effective leadership, and often that guidance and incentive comes from external organizations. Increasingly, international organizations such as the Museum Computer Network (MCN) are stepping in to fill the gaps. MCN special interest groups (SIGs) convene people around technology-focused areas, such as the Educational and Interpretative Media SIG, encouraging ongoing peer-to-peer learning and open dialogs in monthly Google Hangouts that are free for participants.[158] The Library of Congress also offers resources on their Digital Preservation Outreach & Education (DPOE) website. DPOE is made up of Library of Congress staff, a trainer network, and a working group of subject-matter experts that provide training events on digital curation, digital preservation tools, and more.[159] Internally, leading museums are dedicating new staffing positions that help stimulate culture shifts, such as the Los Angeles County Museum of Art's new digital literacy specialist that will work with staff to assess their current state of literacy and develop ways to help them become more efficient in their work.[160]

In practice, digital literacy is frequently being approached in informal settings — "#drinkingaboutmuseums," for example, brings together museum professionals in various cities across the US.[161] Small groups convene in a bar or restaurant to share best practices and experiences, generally around the use of emerging technology. Leveraging social media, the group has recently expanded beyond the US to include meet-ups in Italy, Russia, and Latin America.[162] While social media has stimulated discussions amongst peers around the world, there is still a need for museum staff to work internally with their colleagues to ensure they stay up-to-date with the latest technologies. The Metropolitan Museum of Art hosts small-group coaching sessions bi-annually called "Digitalpaloozas" where museum professionals learn about digital projects and gain hands-on experience with new tools such as Oculus Rift.[163]

For Further Reading
The following resources are recommended for those who wish to learn more about improving digital literacy of museum professionals:

eCult Skills Training Guidelines
go.nmc.org/ecult
(E-Jobs Observatory, 2015.) With support from the European Commission, the Training Guidelines offers extensive guidance to cultural institutions'

implementation of digital technology curriculum, including: multiple role profiles, methodology and assessment of training, and case studies that provide start to finish execution of the training procedures.
> *Policy*

Museums and Museology in Modern Society: New Challenges, New Relationships
go.nmc.org/musetech
(Kostas Arvanitis, *Arts and Technology*, 29 June 2015.) This article addresses the need for museum professionals to begin the process of adapting technology to fit their content – which would reverse the conventional process of modifying their content to fit technological constraints—and place more responsibility on the organization's staff to develop these "museology technologies." **>** *Policy*

Museomix CH
go.nmc.org/museomix
(Museomix, 2015.) An international community of museum technology enthusiasts, Museomix is set to host a three-day conference in Fall 2016 that aims to convene a variety of museum experts to exchange ideas and designs that will further implement innovative digital technologies into the museum sector.
> *Leadership*

How to be a Digital Leader and Advocate: The Changing Role of the Digital Department
go.nmc.org/digrole
(Dafydd James and Carolyn Royston, *MW2015: Museums and the Web 2015*, 30 January 2015.) This paper shares insights from recent experiences of the digital team at National Museum Wales and provides guidance for museums transitioning digital technologies to the forefront, including best practices for social media policies and professional development. **>** *Practice*

Third International Training Course in Bucharest - Digital Storytelling
go.nmc.org/nemo
(Silvaggi, Antonia & Braga, Patrizia, Network of European Museum Organisations, November 2015.) The Romanian Museums Association hosted a 21-hour training course designed to educate museum professionals on digital storytelling, including its methodology, the most effective uses, and development strategies. **>** *Practice*

Improving Accessibility for Disabled Populations
Difficult Challenge: Those that we understand but for which solutions are elusive

Accessibility is a key user experience concern in the museum sector. With more than 50 million people in America alone with disabilities, museums need to continuously improve the accessibility of facilities, exhibitions, and programs for this important population. While museums built before the advent of disability equality laws such as the Americans with Disabilities Act (ADA) face challenges in retrofitting their buildings to meet modern standards, many institutions are investing more thought into the way educational programs and didactic materials meet the needs of diverse audiences. Museums leading the field are integrating responsiveness training across all departments and consulting with communities of disabled people to identify core needs and values.[164] Technology can aid in enabling more inclusive experiences. As museums address this challenge, they are positioned to become cultural leaders by creating solutions that can be adopted outside the sector.

Overview

Approximately 650 million people — one in ten worldwide — live with disabilities,[165] including 12.2 million in the UK[166] and 56.7 million in the US.[167] Developments in technology have potential to increase access and enable opportunities for disabled persons. AT&T and New York University's Ability Lab's recent Connect Ability Challenge spurred innovations including Kinesic Mouse, software that enables users with mobility disabilities to control PCs with facial expressions and head movements.[168] Virtual reality,[169] wearables,[170] and augmentative and alternative communication (AAC) apps[171] are being explored to assist persons with autism spectrum disorders. 2015 marked the 25th anniversary of the passage of the Americans with Disabilities Act, a landmark piece of US legislation designed to eliminate discrimination against disabled populations in public spaces, including museums.[172] This milestone has prompted reflection within the museum community about how to improve facilities and programming to be more accessible and inclusive.[173]

While physical accessibility of spaces is a paramount concern, there is an increased understanding that museums carry an ethical responsibility to create exhibits geared toward the needs of disabled persons to better serve all audiences.[174] One common scenario

compounding this challenge is museum staff and volunteers who do not have experience interacting with and serving disabled populations, lacking knowledge of best practices. Disability responsiveness training and professional development can bridge these gaps. Additional barriers include financial constraints and a lack of resources to design and implement new programming.[175] Museums are challenged to prioritize inclusive efforts as they address other changes in the sector discussed in this report, but these efforts can benefit all patrons: incorporation of universal design principles has been shown to enrich the user experience for all ability levels.[176]

It is also vital for museums to foster partnerships with the disabled community and advocacy organizations to improve offerings and lead the field by example; this is a key method to obtain feedback to measure impact and identify areas for improvement. For instance, the German Federation of the Blind and Partially Sighted (DBSV) has launched a working group of blind and low-vision persons and museum professionals to solve navigation challenges and implement tactile exhibitions at the Berlinische Galerie.[177] Museums can encourage participation and engagement of disabled populations by promoting their accessibility and inclusive programming online. The Australian Museum has posted a "Disability Action Plan" on their website, publicizing their commitment to eliminating barriers, increasing use of accessible formats, and building community.[178] These measures can move the museum sector beyond legal compliance toward the goal of universal accessibility.

Implications for Policy, Leadership, or Practice

Several protocols and standards documents are available to guide museums in meeting this accessibility challenge. The United Nations' Convention on the Rights of Persons with Disabilities, an international human rights treaty, became effective in 2008. Article 30 lays out the duties of countries to enable cultural participation by disabled persons, including accessible museums.[179] Though only binding on consenting states, the treaty serves as an important framework for legislation and policy that advances rights of disabled populations. In the United States, the Department of Justice published "Expanding Your Market: Maintaining Accessibility in Museums," a 2009 document intended

to help museums with ADA compliance. It describes accessibility standards for entrances and exhibition routes as well as inclusive programming.[180] Additionally, the Smithsonian Institution published "Smithsonian Guidelines for Accessible Exhibition Design," which museums can use for design tools for creating accessibility programming.[181]

A number of nonprofit organizations, coalitions, and institutions are leading the field in raising awareness of this challenge and proliferating best practices. The Garage Museum of Contemporary Art in Moscow's Department of Inclusive Programs has offered "Experiencing the Museum" training for Russian museum professionals. This three-day seminar features speakers from the disabled education community with a focus on overcoming physical and educational barriers and creating mission-aligned accessible programming.[182] The US advocacy organization Art Beyond Sight's website contains extensive free online training for museum staff and docents. Disability awareness materials include communication strategies and tools to increase participation opportunities.[183] As part of the Prime Minister's Challenge on Dementia initiative, the UK's Alzheimer's Society has produced "Becoming a Dementia-Friendly Arts Venue." This guide describes considerations for designing dementia-inclusive programming and facilitating community partnerships.[184]

Many innovative and inclusive ideas have been incorporated within the sector. The Milwaukee Public Museum's "Crossroads of Civilization" hands-on exhibit features a Braille exhibit guide, subtitled videos, and interactive screens placed low to accommodate wheelchairs. The museum has invited local disabled students to test exhibit accessibility and offer feedback.[185] Technology has also increased cultural access for disabled populations. Suitable Technologies created the Beam, a motorized mobile telepresence system that allows users to navigate distant places remotely. The company has partnered with eight US museums to offer virtual tours so disabled patrons can discover exhibits from their homes or hospital rooms.[186] 3D PhotoWorks has developed a process for converting images into 3D printed objects, enabling blind museum patrons to experience previously inaccessible works of art. In late 2016, the Canadian Museum for Human Rights will exhibit 3D printed versions of photographs taken by blind photographers that utilize this technology.[187]

For Further Reading
The following resources are recommended for those who wish to learn more about improving accessibility for disabled populations:

Inclusive Design: From Approach to Execution
go.nmc.org/cmhr
(Bruce Wyman et al., MW 2016: Museums and the Web 2016, 24 February 2016.) Within the last decade, the Canadian Museum for Human Rights has been at the forefront of implementing inclusive designs that target changing the museum environment to accommodate visitors with special needs. Quantifying the success of the project's ability to provide an accessible experience for all remains a challenge. **>** *Policy*

Inclusive Museum and Its Impact on Learning of Special Needs Children
go.nmc.org/inclusive
(Liya Deng, Wiley Online Library, 24 February 2016.) The research done at the Columbia Museum of Art demonstrates the ability for museums to provide unique informal learning spaces for children diagnosed on the Autism Spectrum Disorder, underscoring the need for more collaboration between special needs communities and museums in the future. **>** *Leadership*

Museums Plan Range of Events to Mark Disabled Access Day
go.nmc.org/day
(Geraldine Kendall, *Museum Association*, 10 March 2016.) In the UK, over 55 museums participated in Disabled Access Day 2016, an annual event and awareness campaign to encourage discovery of new accessible experiences and increase visibility of disabled populations in the museum space. **>** *Leadership*

Hands On! Multisensory Tours for People with Alzheimer's and Low Vision
go.nmc.org/multisensory
(Association of Art Museum Directors, 2015.) The Art Institute of Chicago is leveraging 3D printing technology to create multi-sensory tours for adults with Alzheimer's and low vision. By creating 3D replicas of objects, visitors with these disabilities are able to interact with the exhibits beyond sight, including sound and touch to stimulate their senses. **>** *Practice*

How Museums Are Helping People with Memory Loss
go.nmc.org/disabled
(Erin Blackmore, *Smithsonian*, 11 January 2016.) Ten museums throughout the Midwest have developed programs that combine health care and museum exhibits to help people with memory loss engage with the arts in meaningful ways. **>** *Practice*

Opening the World of Museums and Libraries to Visually Impaired Visitors
go.nmc.org/impair
(Institute of Museum and Library Services, 15 July 2015.) The North Carolina Museum of Natural Sciences has received funding from IMLS to create a mobile app that helps blind and low-vision visitors navigate the space and learn more about exhibits. **>** *Practice*

Measuring the Impact of New Technologies
Difficult Challenge: Those that we understand but for which solutions are elusive

Museums are increasingly leveraging emerging technologies such as mobile apps, social media, natural user interfaces, and augmented reality to add interactive elements to their exhibits and collections.[188] With the growing emphasis on the digital realm, some thought leaders fear that use of these tools is superseding the development of sufficient technology evaluation frameworks.[189] While many museums are astute at assessing their traditional programs,[190] they have yet to cultivate standard protocol for measuring the success of the technologies they deploy. Exacerbating this challenge is the notion that evaluation should occur both before and after technologies are implemented; staff must have a thorough understanding of how the tools correspond with the museum's mission and goals prior to being embraced at scale. Unfortunately, there are not always concrete precedents for the use of new technologies in the cultural heritage sector, and museums that are early adopters often must forge new paths when implementing and evaluating projects. The hope is that as museums become more adept at measuring the impact of these technologies and share the results with other institutions, they will significantly mitigate the risks.

Overview

As museums continue to integrate new digital tools and processes, the need to adequately measure their impact is a multi-faceted challenge. On one hand, some tools and platforms evolve so quickly that establishing reliable standards can be elusive;[191] on the other, museums often do not effectively articulate specific objectives or outcomes for their digital initiatives.[192] The impact of a museum's mobile app, for example, may not be solely reflected in the sheer number of people using it, but also in the quality of their interactions with it. Quality, however, is inherently more subjective to measure than quantity. Demonstrating the impact museums have on learning is also challenging because evaluation instruments do not always acknowledge the full value of an innovative project. For example, a recent study on the Walls of Nicosia at the Leventis Municipal Museum of Nicosia in Cyprus compared a virtual group using a 3D multi-touch table to a traditional group on a guided tour and found that there were no statistical differences in learning performance between both groups, but

that the user experience, an important factor, was rated significantly higher by the virtual group.[193]

Many museums have already turned to social networks to bolster interactions with followers and track their engagement, but challenges remain for using and evaluating social media. Marketing experts have noted that both the multitude of social analytics tools available and the sheer volume of real-time data generated makes social media both the easiest and most difficult tool to measure.[194] A study released at the Museums and the Web 2016 conference examined the challenges, methods, and strategies for social media in museums; researchers found that 25% of respondents cited setting targets and objectives as challenging, while 33% cited defining appropriate metrics as problematic. Researchers conclude that there is still a clear need for an evaluation framework for helping organizations use social media better.[195]

The difficulty in evaluating new technologies and initiatives affects multiple aspects of the museum. Those working in the cultural sector to make collections more accessible through open data and open content are challenged to measure the impact of the open movement. With the exception of the Open Culture Data network's exploratory project on GLAMetrics — measurements for gallery, library, archive, and museum collections — there is currently no comprehensive method to track open data usage across collections.[196] For those pursuing more participatory experiences in the museum, a trend featured earlier in this report, developing metrics for this work is still underway. Obstacles to progress in this area include the varying nature of what constitutes participatory work and aggregating them into an easy-to-analyze "box of metrics."[197]

Implications for Policy, Leadership, or Practice

This challenge is notably difficult for museums due to a lack of formal policies available to govern the evaluation of technology impact. Museums can, however, look to standards and protocol from relevant fields and adapt them to their environments. Both the gaming and film communities have each banded together to develop methods for contemplating the impact of their products and services. The report "Impact with Games: A Fragmented Field" is the first in a series

that hopes to improve the coherence of the field by recognizing obstacles. The authors' recommendations include defining impact more broadly, developing flexible evaluation methods, and avoiding politicized terminology.[198] In the field of filmmaking, Britdoc's "The Impact Field Guide and Toolkit" is a five-step guide to increase impact. Topics include the importance of vision and strategy as well as making evaluation plans.[199]

It is vital for museum leaders to work cooperatively on developing new assessment metrics. Material EncounterS with Cultural Heritage (MeSch) is a four-year initiative of 12 partners across Europe with the goal of designing, developing, and deploying tools for creating interactive experiences in the cultural sector. Their project is grounded on principles of co-design, where each partner equally contributes to both the creation and evaluation, providing methods of assessment that are scalable. Similarly, the European Union-funded Project LEM generated a report titled "Measuring Museum Impacts" that focused on museum visitors and audience development, the use of multimedia technologies, and the role of ICT in strengthening lasting relationships with audiences. It contains ways to measure and assess economic impact, social return on investment, and methods to evaluate the social impacts of museum activities.[200]

Some museums and museum organizations, such as Museotechniki,[201] believe that early and open communication of new ideas and digital tools enables the museum community to better evaluate their cultural impact. When the Brooklyn Museum implemented the ASK mobile app, a tool that allows onsite museum visitors to ask questions or start conversations with staff, they created a series of blog posts that focused on the importance of anecdotal evidence in evaluation. In the post "Measuring Success," the team describes what they learned about engagement goals and use rates, as well as institutional knowledge gained from data. While they are pleased with the overall depth of engagement, they see a need to increase the use of the mobile app and are still waiting to quantify the impact on institutional knowledge.[202]

For Further Reading
The following resources are recommended for those who wish to learn more about measuring the impact of new technologies:

Learning in Museums and Young People (PDF)
go.nmc.org/findingnemo
(NEMO - LEM Working Group, March 2015.) This European Commission-funded report discusses initiatives related to the smart growth of innovation in museums and how R&D can be better supported, with the need to frankly evaluate the efficacy of emerging technologies for young audiences. **>** *Policy*

Social Impact of the Arts Project
go.nmc.org/siap
(University of Pennsylvania, accessed 12 May 2016.) The University of Pennsylvania's Social Impact of the Arts Project (SIAP) was founded on the mission that cultural, art, and heritage institutions are critical to urban vitality and social well-being. SIAP emphasizes the use of linked open data to reveal patterns in positive community responses to museums. **>** *Leadership*

Sustainability Health Check Tool for Digital Content Projects
go.nmc.org/healthcheck
(JISC and Ithaka S+R, 2014.) While museums are increasingly embracing digital strategies and content, they do not always factor in the resources needed to ensure long-term viability. JISC and Ithaka S+R partnered to create a guide for any cultural heritage institutions to measure and ensure sustainability. **>** *Leadership*

Evaluating Tangible and Multisensory Museum Visiting Experiences
go.nmc.org/evalmul
(Areti Damala et al., Museums and the Web, 2016.) In a paper that was presented at the 2016 Museums and the Web Conference, a group of museum leaders share lessons learned from a project called MeSch in which technology was applied to create more interactive and multisensory experiences for patrons. Video interviews and meaning mapping were two of many methods used for evaluation. **>** *Practice*

Metrics, Metrics Everywhere! Which Are The Right Ones For Museums' Social Media And Websites?
go.nmc.org/sve
(Svegliamuseo On Air, 11 December 2014.) This Svegliamuseo On Air panel with Brian Alpert, Web Analytics & Search Engine Marketing (SEM) Analyst for the Smithsonian Institution in Washington DC, and Elena Villaespesa, Digital Analyst at the Tate in London explores using web analytics to measure an organization's online performance on specific social media platforms. **>** *Practice*

Transforming Audiences, Transforming Museums
go.nmc.org/transfor
(Suse Cairns, *Museum Geek*, 27 January 2016.) The author explores how digital tools enhance museums' evaluation of audience impact. Tracking technologies measure visitor behavior, providing staff with more insight into how exhibits are generating engagement. In this sense, part of assessing the efficacy of technology is being able to make a clear connection between a tool and its ability to illuminate deeper meaning in audience perception. **>** *Practice*

Managing Knowledge Obsolescence
Wicked Challenge: Those that are complex to even define, much less address

Staying organized and current presents a challenge to museums in a world where information, tools, and devices advance at a strenuous rate.[203] New developments in technology are presenting exciting opportunities for museums with the potential for improving the quality of operations and engaging experiences. It can be overwhelming, however, for staff to keep up with the ever-changing landscape; just as they are able to master one technology, a new version launches. Compounding this challenge is the notion that products may have a short lifespan, and it is difficult to predict those cases. Museums may invest in a particular tool that a company ultimately discontinues, causing staffs to scramble to devise another solution while factoring in the thorough training needed to implement it. There is a need for effective processes and resources that help museums anticipate these changes and build capacity for deploying new strategies. Additionally, societal changes and financial pressures are transforming the work of museum professionals, requiring greater agility and a constant pursuit of absorbing new skills.[204]

Overview
While museums have made great strides in integrating emerging technologies into their offerings,[205] this wicked challenge reflects a larger shift in how technology is continuously changing people's environments and lives. Today, for example, many living rooms and dens are configured around a single piece of technology — the television; couches and tables are oriented so that everyone can view it. The advent of flexible[206] and even holographic displays,[207] however, is changing the need to place a cumbersome piece of equipment and then design a space around it. As museums similarly move away from relying on heavy kiosks to adding technology that fosters more flexible interactions, they are tasked with continuously evolving their content delivery formats to maximize convenience for visitors while remaining relevant in a world where educational resources are abundant.

In order to fulfill patron expectations in this landscape, museums must have both the infrastructure and expertise on staff or in their networks to adapt creatively and efficiently — all while curtailing associated risks and costs. Unfortunately, they frequently lack adequate leadership in this area as technologists are underrepresented in senior management roles.[208] Additionally, the increasing emphasis on incorporating user-generated content[209] in both virtual and physical displays means that staff must sift through a mountain of contributed information. While museums may recognize that technologies such as artificial intelligence and linked data could increase the discoverability and organization of their content, as well as provide greater levels of automation,[210] these tools are still not ready to be operationalized in daily workflows.

Exacerbating this challenge is the notion that even when museums successfully leverage a technology, they may face the repercussions of a product's short lifecycle. Using the Google Maps Engine to help develop an app, the Royal Ontario Museum in Canada enabled museum studies' students to display research on the history of social work placements in Toronto in their galleries.[211] However, in January 2016, Google announced that it was no longer supporting this technology.[212] With the future of technology being uncertain, museums grapple with determining which changes to make to prepare for new advancements. The Head of Learning and Engagement at Imperial War Museums in the UK asserted, "the future is yet to settle to a coherent consensus — forced change prevails as the norm."[213] As museum leadership continue to train staffs on the new tools they deem important, it is difficult to assess whether what they are learning today will become obsolete in the next five years. For museums without the capacity to nurture specialist skills on staff, some believe it is necessary to forge partnerships within and outside of the sector for resource sharing.

Implications for Policy, Leadership, or Practice
While policy solutions to this challenge are elusive, museums are taking steps on the long-term development of their staff. The Western Australian government funds a number of local museums and has published a staff training policy that is general enough to be applicable to any uncharted territory, with the express goal of enabling community museums to continuously upgrade their services and technology. Their guidelines state that in addition to creating professional development programs with direction from boards of trustees, museums must seek input from their employees to consider a wide range of

perspectives on emergent skills. Among the top areas for training consideration are digitizing collections and exhibition design.[214] The Smithsonian's Office of Policy and Analysis offers the Museum Capacity Building program for museum professionals in East Asia, Central Asia and the Caucasus, Europe, and Latin America to stay abreast of best practices for policy formulation.[215]

Establishing future-focused training programs requires visionary leadership. The Getty Leadership Institute (GLI) at Claremont Graduate University provides millennials working in museums with a development pathway towards managerial roles. GLI's model is to equip participants not with specific technical skills, but instead to instill in them valuable philosophical underpinnings that are germane to any sea changes their museums may face. They are positioned as trailblazers who are responsible for improvements in the museum and increasing their value in society at-large.[216] By placing museums in the larger context of their role in advancing humanity, GLI exposes young museum professionals to the deeper meanings and consequences behind implementing new approaches and technology developments. This kind of knowledge is transferrable to many scenarios.

Part of the solution to this challenge is devising strategies and practices to keep historic and cultural sites relevant in a world where entertainment and educational opportunities abound.[217] Many museums are becoming more adept in gamification and digital storytelling to attract and more deeply engage audiences. The "Wonderkamers" exhibit at the Netherland's Gemeentemuseum Den Haag, for example, is a role-playing game and interactive art installation that introduces young patrons to fine art. Visitors become curators as they explore a variety of art forms, and ultimately create their own art exhibits with the gallery.[218] The exhibit was honored with the Themed Entertainment Association's THEA Award because of how effectively it blends art, storytelling, and game design, joining both physical and virtual elements. What is especially noteworthy is the team behind the execution — educators, media specialists, game designers, and thought leaders from a variety of disciplines shared their expertise and learned from each other to cultivate an engaging experience.

For Further Reading

The following resources are recommended for those who wish to learn more about managing knowledge obsolescence:

Does Your Business Need a Drone Policy?
go.nmc.org/byodrone
(Anne Fisher, *Fortune*, 29 December 2015.) Drones are the latest technology to enter discussions on personal device usage. While they may not be on the museum sector's current radar, it is important for staff to stay ahead of these developments and consider devising future-focused policies. This article examines the uncertain policy landscape of managing drones. **>** *Policy*

Meditations on Relevance
go.nmc.org/medit
(Nina Simon, *Museum 2.0*, 28 July 2015.) Thought leader Nina Simon provides suggestions to guide museums' policies and help them remain relevant. She reminds readers that not every technology or trend is worth accommodating; museums must critically evaluate what developments to prioritize. **>** *Policy*

Dealing with Digital Change
go.nmc.org/weare
(WeAreCulture24, accessed 12 May 2016.) A UK-based arts and culture organization curates resources to help museum professionals stay abreast of developments in technology and new tools. Content includes best practices in Google Analytics and search engine optimization. **>** *Leadership*

How Digital Tech Can Bridge Gaps Between Museums and Audiences
http://go.nmc.org/elgxh
(Mia Ridge and Danny Birchall, *The Guardian*, 23 October 2015.) To keep pace with the expanding technological needs of audiences, many museums are turning to partnerships to fill voids in their capabilities and skillsets. Additionally, the authors share how open education opportunities can make professional development more accessible to staff. **>** *Leadership*

How Do We Keep Museums Vital in Today's World?
go.nmc.org/howkeep
(Sebastian Smee, *Boston Globe*, 16 October 2015.) The author shares how art museums struggle to be perceived as important fixtures in their communities in a world where so much learning and engagement happens elsewhere. He argues that the connection between the artist and object wanes when museums use technology to control how it is interpreted. **>** *Practice*

How Museums are Adapting to 'Selfie Culture'
go.nmc.org/mselfie
(Jessica Gelt, *Los Angeles Times*, 23 October 2015.) Patron expectations for technology use are mirroring trends in society, and museums must follow suit or risk irrelevance. As a result, Los Angeles sites including the Autry National Center and the Botanical Gardens are updating their engagement strategies to enable visitors to use beacons, apps, and other tools to connect with their content. **>** *Practice*

Privacy Concerns
Wicked Challenge: Those that are complex to even define, much less address

D*ata security is a persistent challenge as more activities take place on the web. The recent Apple and FBI encryption dispute has drawn attention to the novelty and complexity of today's interconnected world; opinions are divided on how to delineate limits of privacy, such as the debate on allowing warrant-proof spaces that cannot be accessed by law enforcement or technology companies.[219] Privacy has different meanings, and many people are uncomfortable with their current level of control over their own personal information.[220] To participate in online information exchanges, users must trust third-party platforms with sensitive information, creating more opportunities for it to be compromised. A recent European Commission survey revealed that eight out of ten respondents feel they do not have control over the data they provide online, while in America, a similar survey conducted by TRUSTe and the National Cyber Security Alliance found that 46% of Americans note a lack of control of their data. 38% of the Americans who worry about their privacy also believe companies providing clear procedures for removing personal information would build more trust.[221, 222] Privacy policies in the museum sector are continually being refined, but they cannot keep pace with the rapid acceleration of new data-centered technologies and the capabilities of cybercriminals.*

Overview

As the collection of data for consumer insights increases, so does the risk for data breaches. The Identity Theft Resource Center has found that there have already been 18% more data breaches reported in 2016 than the number for the same period last year.[223] Research from the Ponemon Institute revealed that even though more companies now have data breach response plans, many are still not confident in their ability to manage a significant incident.[224] Apple recently had to remove several apps after a major attack on the app store because developers had been tricked into using a modified version of Apple's official software for creating apps, Xcode, which stole passwords from users. Xcode even passed through Apple's standard review process.[225] Companies and organizations continue to be targets for cybercriminal activity, even with safeguards in place.

The advent of context-aware devices and applications is allowing institutions to leverage user data for convenience in wayfinding, communication, digital transactions, media storage, and more. The concepts of being online versus offline are becoming more blurred into an existence where interactions and transactions are more transparent, unified, and immediate. With the continuing reliance on digital transactions, museums must evolve their digital strategies and response procedures accordingly. Museums are inherently open public spaces, making it a difficult balance to be inviting, while also ensuring the safety of their visitors, museum collections, and the associated sensitive information.[226]

A number of museums are already using location data and beacons to enhance visitors' museum experiences — a practice that is further expanded upon in the Location Intelligence section of this report. However, it is vital that they implement a responsible and legally compliant development process in the creation of such apps that make use of visitor information. For example, an app designed to initially alert users of exactly what types of data it uses with an opt-in screen immediately provides users necessary security information and the ability to opt out of sharing any personal data. Building in varying levels of engagement that each require permission to activate is one way to provide users more control over exactly what they want to share.[227]

Implications for Policy, Leadership, or Practice

Museums are tasked with keeping pace with changes in legislation affecting data usage, such as the recent European data protection reform, which has updated individual rights to include a right to erase any personal data and "to be forgotten."[228] A compliant museum app, for example, would provide an explicit option to delete any or all records at any time from the app. Museums have long been publishing their policy statements on their websites with language about opting in to communications, information that is tracked, use of web beacons, and cookies. Now, as museums experiment with new interactive digital engagement strategies, privacy policies must account for new forms of data transactions. The Cooper Hewitt Smithsonian Design Museum has developed digital pens that connect to near field communication tags in object labels, allowing visitors to save objects and preferences for later viewing. By storing a timestamp and ID of each object label collected and connecting the information with the visitor's ticket, they can save and later access their notes and drawings online anonymously.[229]

There are a number of resources to guide museums in adopting practices that protect the security of their visitors. The Future of Privacy Forum Application Developer Responsible Data Use Project has aggregated tools and resources to implement responsible information collection and use practices such as privacy policy generators and templates.[230] Additionally, the open-source movement is culminating in a consistent exchange of privacy and security solutions to complement emerging technologies, such as the Eddystone platforms recently announced by Google for their open and extensible Bluetooth Low Energy beacon format. Ephemeral ID's for Eddystone are now available on GitHub to aid developers in creating a secure exchange of information using beacons, and to enable safety features such as proximity awareness, device authentication, and data encryption on packet transmission.[231]

Museums and cultural organizations often work with third-party companies and vendors to provide necessary services, giving them control of data security. Service Systems Associates, a company that designs and runs gift shops for cultural institutions, recently suffered an attack from malware that scooped up customer credit card information from 10 zoos and science centers across the US.[232] Museums have an increasing responsibility to communicate and initiate public dialog on the issues that surround privacy, empowering people to make educated decisions about the digital tools they leverage. An exhibit called "Covert Operations: Investigating the Known at the Unknowns" that was featured in both San Jose Museum of Art and Scottsdale Museum of Contemporary Art invited viewers to consider a number of challenging issues related to life in the digital age, including privacy, surveillance, data collection and storage, and the complicated relationship between liberty and security.[233]

For Further Reading
The following resources are recommended for those who wish to learn more about privacy concerns:

Data Policy 101: What Businesses And Consumers Need to Know About Privacy
go.nmc.org/datpol
(H.O. Maycotte, *Forbes*, 30 June 2015.) This article outlines what to prioritize when writing a privacy policy and the importance of understanding local, national, and international law or including a lawyer or expert in the area when writing a data policy; laws governing what companies and organizations can do with data differ from country to country and quickly evolve as emerging technologies challenge existing legislation.
> *Policy*

The Federal Trade Commission
go.nmc.org/ftcgov
(Federal Trade Commission, accessed 7 May 2016.) The Federal Trade Commission provides information about current laws and legislation under consideration relating to protecting consumer privacy in the U.S. This is vital information for museums to adhere to in creating their privacy policies. > *Policy*

Data Transparency Lab
go.nmc.org/dtl
(Data Transparency Lab, accessed 6 May 2016.) The Data Transparency Lab is a collaboration between Mozilla, Telefonica, and MIT to create a global community of technologists, researchers, policymakers, and industry representatives working to advance online personal data transparency through scientific research and design. Some of their current projects include developing tools and programs that empower individual users to control their personal data and providing best practice recommendations on personal data transparency.
> *Leadership*

Electronic Frontier Foundation
go.nmc.org/eff
(EFF, accessed 6 May 2016.) The Electronic Frontier Foundation is a nonprofit built around defending civil liberties in the digital world; it publishes reports and resources related to user privacy, free expression, and innovation through impact litigation, policy analysis, grassroots activism, and technology development.
> *Leadership*

Harvard, Northeastern's Privacy Tools Flag Apps that Leak Personal Data
go.nmc.org/recon
(Nidhi Subbaraman, *The Boston Globe*, 16 November 2015.) Researchers at Northeastern University and Harvard University are working to empower smartphone owners by releasing information after an analysis of how the 100 most popular apps for iOS and Android devices treat sensitive user data. They have created an in-phone tool called ReCon that serves as a watchdog to flag leaky apps and recognize when sensitive information such as passwords are being transmitted. > *Leadership*

Privacy and Data Protection
go.nmc.org/datprot
(Brighton Museums, accessed 7 May 2016.) The Royal Pavilion and Museums' Data Protection and Security Policy provides a good model of using clear language to transparently explain how and why they collect visitor data and what they do with it. > *Practice*

Important Developments in Educational Technology for Museum Education and Interpretation

Each of the six developments in educational technology detailed in this section were selected by the project's expert panel using the Horizon Project's Delphi-based process of iterative rounds of study, discussion, and voting. In the NMC Horizon Project, educational technology is defined in a broad sense as tools and resources that are used to improve teaching, learning, and creative inquiry. While many of the technologies considered were not developed for the sole purpose of education and interpretation, they have clear applications in the field.

The technologies, which the members of the expert panel agreed are very likely to drive technology planning and decision-making over the next five years, are sorted into three time-related categories — near-term technologies that are expected to achieve widespread adoption in one year or less; mid-term technologies that will take two to three years; and far-term technologies which are forecasted to enter the mainstream of museum education and interpretation within four to five years. Each technology topic opens with an overview of the topic.

The initial list of topics considered by the expert panel was arranged into categories that were based on the primary origin and use of the technology. The potential applications of the technologies featured, specifically in the context of global museums, were considered in a series of online discussions that can be viewed at museum.wiki.nmc.org/Horizon+Topics.

The expert panel was provided with an extensive set of background materials when the project began that identified and documented a range of existing technologies used in both education and beyond. The panel was also encouraged to consider emerging technologies whose applications for museums may still be distant. A key criterion for the inclusion of a new technology in this edition was its potential relevance to education and interpretation in museums.

In the first round of voting, the expert group reduced the master set, shown on the following page, to 12 technologies that were then researched in much greater depth by the NMC staff. Technologies that do not make the final report are often thoroughly discussed on the project wiki at museum.wiki.nmc. org. Sometimes a candidate technology does not get voted in because the expert panel believes it is already in widespread use in museums, or, in other cases, they believe the technology is more than five years away from widespread adoption. Some technologies, while intriguing, do not have enough credible project examples to substantiate them.

There are currently seven categories of technologies, tools, and strategies for their use that the NMC monitors continuously. These are not a closed set, but rather are intended to provide a way to illustrate and organize emerging technologies into pathways of development that are or may be relevant to education and interpretation. The list of seven categories has proven fairly consistent, but new technologies are added within these categories in almost every research cycle; others are merged or updated. Collectively, the categories serve as lenses for thinking about innovation; each is defined below.

> **Consumer technologies** are tools created for recreational and professional purposes and were not designed, at least initially, for educational use — though they may serve well as learning aids and be quite adaptable for use in museums. These technologies find their ways into institutions because people are using them at home or in other settings.

> **Digital strategies** are not so much technologies as they are ways of using devices and software to enrich education and interpretation, whether inside or outside of the museum. Effective digital strategies can be used in both formal and informal learning; what makes them interesting is that they transcend conventional ideas to create something that feels new, meaningful, and 21st century.

> **Enabling technologies** are those technologies that have the potential to transform what we expect of our devices and tools. The link to learning in this category is less easy to make, but this group of technologies is where substantive technological innovation begins to be visible. Enabling technologies expand the reach of our tools, make them more capable and useful, and often easier to use as well.

> **Internet technologies** include techniques and essential infrastructure that help to make the

technologies underlying how we interact with the network more transparent, less obtrusive, and easier to use.

> **Learning technologies** include both tools and resources developed expressly for the education sector, as well as pathways of development that may include tools adapted from other purposes that are matched with strategies to make them useful for learning. These include technologies that are changing the landscape of education and interpretation, whether formal or informal, by making it more accessible and personalized.

> **Social media technologies** could have been subsumed under the consumer technology category, but they have become so ever-present and so widely used in every part of society that they have been elevated to their own category. As well established as social media is, it continues to evolve at a rapid pace, with new ideas, tools, and developments coming online constantly.

> **Visualization technologies** run the gamut from simple infographics to complex forms of visual data analysis. What they have in common is that they tap the brain's inherent ability to rapidly process visual information, identify patterns, and sense order in complex situations. These technologies are a growing cluster of tools and processes for mining large data sets, exploring dynamic processes, and generally making the complex simple.

The following pages provide a discussion of the six technologies highlighted by the 2016 Museum Edition Expert Panel, who agree that they have the potential to foster real changes in museums, particularly in the development of education and interpretation. As such, each section includes an overview of the technology; a discussion of its relevance to education and interpretation; and curated project examples and recommendations for further reading.

Consumer Technologies
3D Video
Drones
Electronic Publishing
Mobile Apps
Quantified Self
Robotics
Telepresence
Wearable Technology

Digital Strategies
Bring Your Own Device
   (BYOD)
Flipped Classroom
Location Intelligence
Makerspaces
Preservation & Conservation
   Technologies

Enabling Technologies
Affective Computing
Electrovibration
Flexible Displays
Machine Learning
Mesh Networks
Mobile Broadband
Natural User Interfaces
Near Field Communication
Next-Generation Batteries
Open Hardware
Speech-to-Speech
   Translation
Virtual Assistants
Wireless Power

Internet Technologies
Cloud Computing
Networked Objects
Semantic Web and
   Linked Data
Syndication Tools

Learning Technologies
Adaptive Learning
   Technologies
Badges/Microcredit
Learning Analytics
Mobile Learning
Online Learning
Open Content
Open Licensing
Virtual and Remote
   Laboratories

Social Media Technologies
Crowdsourcing
Online Identity
Social Networks

Visualization Technologies
3D Printing/Rapid
   Prototyping
Augmented Reality
Computer Vision
Information Visualization
Visual Data Analysis
Volumetric and Holographic
   Displays

Digital Humanities Technologies
Time-to-Adoption Horizon: One Year or Less

*D**igital humanities technologies refers to the suite of digital and computational tools currently being used to advance scholarship in the humanities, such as data mining, visualizing, mapping, and audio and video recording.[234] Information visualization, described later in the report, is transforming the way in which humanists and social scientists do their work by enabling the analysis of texts to reveal patterns, presenting complex histories through interactive maps, and creating 3D modeling to aid in the recreation of historical sites and artifacts.[235] These analyses and maps enable deeper understanding, help academics and non-academics understand complex data, and aid in preservation and conservation efforts. While primarily anchored in the academic field, museum humanists and technologists have been working together over the past few years to define the field and identify and share tools that help open up new forms of multi-disciplinary research.*

Overview

Digital humanities has origins in the humanities computing movement that began in 1949 when a priest harnessed IBM computing power to create an index of writings by Saint Thomas Aquinas and related authors.[236] While this topic has roots in university language departments, the advancement of high-speed networked computing, digitization and data analytics, and sophisticated algorithms has given researchers and curators the capacity to transform the museum field through new forms of knowledge production.[237] Several key documents and initiatives emerged in the mid-2000s under the new umbrella term, digital humanities.[238] The 2004 seminal publication, "The Companion to Digital Humanities," provided a comprehensive survey of history, principles, and uses. The inauguration of the Digital Humanities Initiative by the National Endowment of the Humanities in 2006 "accelerate[d] development of new tools and applications to the study of the humanities."[239]

A variety of new digital humanities technologies have recently emerged; Northwestern University Library provides a taxonomy to help digital humanists experiment, research, teach, and publish. Their website compiles a list of specific tools for analyzing text, making maps and visualizations, publishing online, and organizing research.[240] Similarly, the Digital Research

Tools Directory leverages information from the European project Taxonomy of Digital Research Activities in Humanities to help researchers and scholars develop interactive works, search visually, and make dynamic maps.[241] To create visualizations of complex, multi-dimensional data, for example, museum professionals may use Palladio, a data analysis platform. After uploading data, users can select a map view to display relationships between distinct points, a graph view to compare relationships between data sets, and a gallery view where data is displayed in a quick-reference grid.[242] More detailed examples on information visualization for museum exhibits are featured later in this report.

Use of digital humanities technologies in museums is largely driven by the proliferation of university and other professional development programs that are introducing a new generation of museum leaders to innovative research and conservation tools. UCLA, for example, provides an undergraduate minor and graduate certificate in digital humanities.[243] During a final project for the digital humanities class DH150 at UCLA, students create digital stories, data visualizations, or exhibits based on databases ranging from "Toys at the Powerhouse Museum" to "Sculpture at the Museum of Modern Art."[244] For in-service museum professionals, the Netherlands' Centre for Digital Humanities provided a one-week Crash Course in Digital Humanities that included a demonstration and explanation of tools, such as Project Drive+ that explores linked open data and Voyant, a web-based reading and analysis platform for digital texts.[245]

Relevance for Museum Education and Interpretation

Emerging digital humanities technologies are helping museums more effectively preserve and mine their collections as well as surfacing collaborative opportunities. At the Victoria and Albert Museum, for example, the Colour Lens collection, which provides color-based information visualizations, is powered by code created by the Tate and Cooper-Hewitt Museums combined with public domain images from the Rijksmusuem and the Walters Museum.[246] Research initiatives are also furthering collaboration in the museum field. Digital Mellini was a Getty Research Institute project focused on an unpublished 17th century manuscript by Pietro Mellini; the author created a hybrid document that combined a conventional

inventory of paintings and drawings from his family's collection with an unusual example of poetic text. The project made previously unpublished research freely available and explored new research and dissemination methods and tools.[247] Digital Mellini leveraged the Getty Scholars' Workspace, an online scholarly collaboration environment referred to as Wordpress for scholars.[248]

Increasingly, museums are collecting digitally-born objects, requiring them to ensure that patrons can access a bit-for-bit authentic copy of the object far into the future. This need is fostering the development of new kinds of tools for managing digital preservation. The Museum of Modern Art has created an open-source database that allows museum staff and researchers to conduct queries across their large data vault of collections information, helping to paint a bigger picture of their repository's contents. Additionally, this tool helps conservators and researchers manage the media of an artwork so that video and audio components continue to work as they were intended.[249]

Digital humanities technologies have had the dual effect of increasing the relevance of scholarly research and opening up new realms of scholarship through the marriage of data and the humanities. At the University of Wisconsin, Green Bay, students are using these tools to help museums better engage visitors and foster interactive experiences. Using the open-source 3D animation software "Blender," one student digitally constructed a model of an 11th century Norwegian bed inspired by a museum visit. It served as an example of how curators can create globally accessible digital replicas that can be manipulated without damaging the original and provide a more intimate experience through zooming capabilities.[250] One of the most notable applications of humanities technologies is in digital heritage preservation. Project Mosul, now known as Rekrei, was created by two archeology students in response to the destruction of numerous ancient artifacts and buildings in Iraq and Nepal. Using crowdsourced imagery, photogrammetry, and drone imagery, the group has digitally preserved artifacts and cultural sites that would have otherwise been lost forever.[251]

Digital Humanities Technologies in Practice
The following links provide examples of digital humanities technologies in use that have direct implications for museums:

Digitization and Diversity: Potentials and Challenges for Diversity in the Culture and Media Sector
go.nmc.org/ntnu
Researchers at the Norwegian University of Science and Technology are studying how public and private digitization initiatives affect diversity in an effort to develop a new digital culture and media policy across four industries: library and e-books, museums and their digital collections, film and digital cinema, and the press and e-papers. **>** *Policy*

Dance Hackathon, from Prague to London
go.nmc.org/fromprague
The EuropeanaSpace Dance Hackathon invited dancers, choreographers, hackers, coders, scientists, and artists together to explore the possibilities in creative reuse of Europeana and dance content, culminating in ideas ranging from measuring brain waves to interactive performance technologies. **>** *Leadership*

The Clark and WCMA Receive Grants To Examine, Utilize Technology In Art
go.nmc.org/wcma
The Williams College Museum of Art is currently digitizing its 14,000-item collection, with the next step being to implement deeper cataloguing, leveraging metadata that allows people to visualize and understand data on collections as a whole, and not just as individual pieces of art. **>** *Practice*

For Further Reading
The following articles and resources are recommended for those who wish to learn more about digital humanities technologies:

Big Data and Cultural Data in the Emerging Field of Digital Humanities Research
go.nmc.org/humanre
(AArnet, 28 May 2015.) A presentation at last year's Museums Australia National Conference brought attention to how the increasingly networked world is changing the way people engage with information; in response, galleries, libraries, archives, and museums are joining forces with the research sector to support the digitization and access of collections data in a manner that is queryable, brought together quickly from diverse collection stores, and provides a high-quality and exploratory visual experience. **>** *Leadership*

Generous Interfaces for Digital Cultural Collections
go.nmc.org/generous
(Mitchell Whitelaw, *Digital Humanities Quarterly*, 2015.) This article argues that as cultural heritage collections are increasingly being digitized and made available online, the current incarnation of search is inadequate as a dominant interface because it demands a query and discourages exploration. Cultural heritage collections require more generous interfaces that invite exploration using overviews to establish context and maintain orientation while revealing various levels of detail. **>** *Practice*

Makerspaces
Time-to-Adoption Horizon: One Year or Less

Creativity, design, and engineering are making their way to the forefront of educational considerations, as tools such as robotics, 3D printers, and 3D modeling applications become more accessible. Makerspaces are deeply rooted in the Maker movement, a following comprised of artists, technology enthusiasts, engineers, builders, tinkerers, and anyone else with a passion for making.[252] Today, makerspaces are progressively being looked to as a method for engaging learners in creative, higher-order problem solving through hands-on design, construction, and iteration.[253] These learning environments are rich with possibilities and serve as gathering points where communities of new and experienced creators connect to work on real and personally meaningful projects, informed by helpful mentors and experts, using new technologies and traditional tools.[254] Museums are increasingly creating dedicated makerspaces where visitors can act on their ideas and engage more deeply with artistic and scientific concepts and media.[255]

Overview

Makerspaces are part of a growing movement of immersive, hands-on spaces where people of all ages can participate in creative, innovative design experiences.[256] They have been demonstrated to cultivate problem-solving and critical thinking skills while allowing individuals to explore electronic hardware, manufacturing tools, and programming techniques and tricks.[257] Museums, as leaders in participatory learning, are ideal settings for community makerspaces and are increasingly leveraging their collections, networks, and staff resources for the creation and maintenance of makerspaces. These maker environments align with museums' mission by enriching the lives of their patrons. Additionally, by providing visitors access to learning opportunities that advance their skills and knowledge, museums increase the adeptness of the overall community.[258]

Enthusiasm for makerspaces continues to accelerate and gain mainstream traction. In the US, the Obama administration's commitment to providing learners more access to tools, mentors, and spaces has led to the strategic investment and support of makerspaces and maker-related programming in libraries and museums.[259] The White House expanded on its "Day of Making" event by establishing the "National Week

of Making," inviting people to host events around the United States celebrating ingenuity, inspiring creative problem-solving, and supporting opportunities to tinker and make.[260] The week coincided with the National Maker Faire, held at the University of the District of Columbia, which featured makers from around the country in addition to federal agencies and departments. Further, IMLS has provided more than $4 million in funding to support a variety of creative learning spaces and to advance best practices for makerspaces and maker programming nationwide.[261]

Digital making has increased as museums implement spaces for computer-based design, programming, and innovation. The Exploratorium's Tinkering Studio is an example of a creative space where museum patrons can deeply engage in an investigation of scientific phenomena through hands-on activities.[262] At the Tinkering Studio, visitors are provided with a wide assortment of materials and technologies to use as they investigate and make. In one activity called "Digital Bling," patrons use electronic components such as LEDs, wires, coin-cell batteries, and switches to create wearable art.[263] The goal is to inspire patrons to turn more complex ideas into revolutionary wearable art. Similarly, the Gwacheon National Science Museum in Seoul, Korea features exhibits that inspire visitors' creativity and imagination through the use of advanced technology experiences.[264] In the Imagine Infinite Hall, patrons are led through a series of rooms to facilitate the design process from inception to production using a variety of high-tech applications and software including industry-grade cutting tools and 3D printers.

Relevance for Museum Education and Interpretation

Museums are taking advantage of makerspaces to provide visitors and artists with a place for experimentation, bolstering creativity and technical skills across their communities. The Tech Museum was honored with the National Medal for Museum and Library Service for their commitment and service to its community.[265] The museum partnered with a local school where nearly all students come from low-income families and English is the second language, and provided teachers with professional development workshops and free field trips for the students to participate in activities or workshops related to STEAM Learning.[266] Similarly, Boston's Learn 2 Teach, Teach 2

Learn program at South End Technology Center at Tent City provides a creative space for young adults to use a design-engineering process to imagine and create a better and more just future.[267] Youth not only learn new skills but also teach their newly acquired skills to others in their community.

One hurdle for implementing this technology development is the upfront investment needed for real estate, equipment, and staff. To address this challenge, the Children's Museum of Pittsburgh partnered with the crowdfunding site, Kickstarter, to support local schools in integrating making activities in their schools.[268] Pittsburgh schools participated in the Kickstarting Making in Schools pilot program, which sought to develop a sustainable national model of integrating making in schools. Each school created separate campaigns that successfully raised funds to build their makerspaces.[269] Teachers from each school worked with the Children's Museum to learn about making and explore curricular connections and project ideas. The money raised funded professional development within the museum as well as design services that provided furniture plans and inventories for custom makerspaces in each of the participating schools.

The exponential increase in availability of commercial digital fabrication technologies, such as 3D printing and laser-cutting tools, combined with the increasing popularity of local and online making communities, have empowered people to participate in these creative environments in compelling ways.[270] An innovative model that expands access to these technologies is Australia's Museum of Applied Art and Sciences, which has implemented a new exhibition model that provides a 3D FabLab traveling exhibit to local venues such as galleries, museums, and libraries.[271] These spaces are provided with tools and support needed to foster an exploratory and participatory environment, including 3D printers, laser cutters, computers, and a staff member that assists with the installation and training of the venue staff. Visitors are provided the opportunity to explore how new digital technologies have revolutionized design practice and production methods.

Makerspaces in Practice
The following links provide examples of makerspaces in use that have direct implications for museums:

Children's Creativity Museum's Tech Lab Robot Coding
go.nmc.org/roboshop
The Children's Creativity Museum's Wonder Workshop offers hands-on activities for children to discover coding through engaging problem-solving activities, including programming robots to play music or navigate mazes.
> *Practice*

Montréal Science Centre's Fabrik Creativity Factory
go.nmc.org/fabrik
At the Montréal Science Centre, visitors can innovate and make in the Fabrik Creativity Factory. Participants exercise critical thinking and experience failure as a learning tool as they experiment to solve technological challenges. **>** *Practice*

For Further Reading
The following articles and resources are recommended for those who wish to learn more about makerspaces:

Framework to Support Learning in Museum and Library Makerspaces Workshop
go.nmc.org/makeframe
(Peter Wardrip and Lisa Brahms, Institute of Museum and Library Services, 7 March 2016.) IMLS and the Children's Museum of Pittsburgh have collaborated on a framework to help museum and library professionals ground their makerspace activities in active learning through experiential programs. The framework was distributed and refined through a series of practitioner workshops, and will be housed on a website with additional resources for making. **>** *Policy*

Museums and 3D Printing: More Than a Workshop Novelty, Connecting to Collections and the Classroom
go.nmc.org/musemake
(Megan Hancock, *Bulletin of the Association for Information Science and Technology*, October 2015.) Museum makerspaces can provide new learning opportunities through 3D printers and scanners as patrons gain the ability to reproduce exhibit pieces and engage in additional active sensory experiences. This paper also describes makerspace programming at the Hirschhorn Museum and Sculpture Garden and the British Museum. **>** *Leadership*

Museums as Creative Labs: 3D Food Printing Inspired by Culinary Heritage in the Context of Makerspaces
go.nmc.org/3Dfood
(aja Antlej and Angelina Russo, *MWA2015: Museums and the Web Asia 2015*, 14 August 2015.) This paper discusses the use of 3D food printers (which utilize edible materials) in the museum context, particularly in resident makerspaces. These tools can engage visitors in deeper aspects of culinary heritage and understanding of global food supply chains. **>** *Leadership*

Location Intelligence
Time-to-Adoption Horizon: Two to Three Years

ocation intelligence refers to the mapping of the geographic relationships associated with data. Resources including GIS are used to provide individuals and organizations with information about how people are interacting with various applications and services based on their location.[272] Mobile devices are naturally driving the proliferation of this technology because of their built-in location-sensitive sensors. A growing facet of location intelligence in museums is location-based services (LBS), which provide content that is dynamically customized according to the user's location. Advancements in the underlying technologies are extending that capability into buildings and interior spaces with remarkable accuracy. A recent development for LBS is the emergence of indoor geolocation, which is affording users with very specific information tailored to their exact location within a space, allowing fine-tuned information or services to be accessed from their exact location in 3D spaces, so that even different floors of a building can be identified.

Overview

Location intelligence involves the use of geospatial data to derive insights and solutions to problems.[273] A historic example of the value of linking data to location is the 1854 cholera epidemic in London; by charting cholera deaths and local water pumps on a single map, a doctor was able to identify the contaminated water source that caused the outbreak.[274] An important application of location intelligence is location-based services, which deliver relevant information in response to users' surroundings and enable collection of demographic data and usage statistics. According to Research and Markets, the global market for mobile LBS is projected to grow to €34.8 billion by 2020.[275] Location-based services can strengthen two-way communications between businesses and their audiences. Salesforce surveyed consumers in the UK and reported that nearly 30% of customers respond positively to the use of location-based technologies to customize retail interactions, including tailored special offers and in-store navigation assistance.[276]

As supporting tools continue to develop, museums can harness the potential of location intelligence to personalize visitor experiences. The 2016 Museum Edition Expert Panel believes this technology will achieve broader adoption within the next two to three years as audiences increasingly expect it to be a part of everyday life. Museum patrons have likely encountered location intelligence from its applications in the consumer and retail sectors and it has now become intuitive for them. For instance, Facebook users can enable Place Tips, notifications that appear at the top of users' newsfeeds as they physically enter participating locations. Businesses can share information including hours of operation, upcoming events, and related posts from friends.[277] The Metropolitan Museum of Art served as a Place Tips launch partner and is using the service to augment visitors' experience with ancillary content.[278]

Indoor positioning solutions are being explored to improve the user experience through wayfinding and supplemental content delivery.[279] Due to the thick walls and multistory layouts of many museums, smart devices cannot communicate with satellites to utilize GPS.[280] Museums are primarily harnessing location intelligence through the use of beacons, wireless tools installed in galleries and exhibitions that advertise their location and enable content delivery to nearby smart devices via Bluetooth.[281] The Italian company Nextome is poised to make uptake of beacon technology more affordable through software that reduces interference with the Bluetooth signal, enabling museums to use fewer beacons within their space.[282] Location intelligence apps can also improve access for disabled populations by automatically triggering multisensory content such as audio and providing navigational assistance for blind and low-vision patrons.[283]

Relevance for Museum Education and Interpretation

Location intelligence is often integrated into mobile apps that provide tracking capabilities and enhance the user experience. The Indianapolis Museum of Art has received IMLS funding to transmit location-specific collection content using the open-source TAP mobile tour app and beacons. Analytics generated by app data provide information on visitors' movement and demographics to inform future exhibit development.[284] Meanwhile, the Australian Maritime Museum is capturing location analytics without requiring visitors to download an app. Patrons who make use of the facilities' free lockers during their visit receive key rings with beacons attached. iPods stationed throughout the museum detect the beacons and send data via WiFi to

an online dashboard, where staff can monitor exhibit engagement.[285]

Location-based technology can also provide a framework for patrons to develop more meaningful, personalized connections with works on display and cultivate their understanding of exhibits' regional contexts. The Brooklyn Museum of Art is using location data to foster personal connections and encourage deeper explorations of their exhibits and collections. Visitors can use the text messaging feature of the museum's app, "ASK," to engage in dialog with art historians and educators in real time.[286] Beacons installed in the galleries provide the questioner's location; on the back end, responding staff members can see the artworks nearest to the corresponding beacon.[287] Similarly, the "Wifarer" app at the San Diego Museum of Natural History offers navigational services and multimedia storytelling. Patrons can watch videos featuring local residents' historical perspectives as well as behind-the-scenes exhibit preparation; these opportunities connect the museum visits to real locations and real narratives.[288]

Museums can also bolster audience participation through location intelligence. "Muzze," an audio tour app that communicates with beacons placed in museum galleries, provides patrons with instant content based on their location in the space. With support for five languages and operability in more than 40 museums across Europe, the app supports cultural inclusion for a variety of audiences. "Muzze" audio tours increase visitors' average time of engagement with exhibits and even individual pieces of art.[289] The Cleveland Museum of Art's "Artlens" app deploys indoor wayfinding technology to guide visitors to works with enhanced content that reveals multiple critical interpretations;[290] visitors can also design personalized tours accessible to other users.[291] At Leicester Castle in the UK, a beacon-based app sheds light on the rich history of a site where much of the original structure no longer exists. Visitors experience an infamous Victorian courtroom trial or follow family-friendly pathways through games. Integration of this app has increased visit lengths by an average of 80%.[292]

Location Intelligence in Practice
The following links provide examples of location intelligence in use that have direct implications for museums:

Applications Get Smarter With Real-world Content: TapArt and the Push to Modernize Museums
go.nmc.org/tapart
The Netherlands' Groningen Museum is using the beacon-based app "Tapart" to discern user behavior patterns and deliver exhibit information to increase audience engagement. **>** *Practice*

Experimenting with an Intermuseum Gallery Guide
go.nmc.org/carnapp
"Gallery Guide for iOS," a mobile app for the Carnegie Museum of Art and the Carnegie Museum of Natural History, fosters a cohesive cross-museum experience by connecting various exhibits to overarching themes between the museums through location-based content. **>** *Practice*

HPE Shows off Engagement Project with Madrid museum Based on Aruba Technology
go.nmc.org/artnav
At Real Academia de Bellas Artes de San Fernando, an art museum in Madrid, visitors receive turn-by-turn navigational guidance and guided tours through a beacon app, while staff can collect data on visitor preferences. **>** *Leadership*

For Further Reading
The following articles and resources are recommended for those who wish to learn more about location intelligence:

Beacons: Exploring Location-Based Technology in Museums
go.nmc.org/metloc
(Veronika Doljenkova and Grace Tung, Metropolitan Museum of Art Blog, 30 March 2015.) At the Metropolitan Museum of Art, experimentation with location-aware content delivery through Bluetooth beacons highlighted the potential learning value for patrons; efficacy issues related to physical conditions of the space were also surfaced. **>** *Leadership*

The Realities of Installing iBeacon to Scale
go.nmc.org/bkbeac
(Shelley Bernstein, Brooklyn Museum Blog, 4 February 2015.) The Brooklyn Museum provides a roadmap for the field by detailing the gallery installation of Estimote beacons to power the location-based "ASK" app. Significant challenges include signal disruption, replacement and battery life concerns, and a lack of centralized management control of the devices. **>** *Leadership*

Virtual Reality
Time-to-Adoption Horizon: Two to Three Years

Virtual reality (VR) refers to computer-generated environments that simulate the physical presence of people and objects and realistic sensory experiences.[293] Early incarnations of the technology have taken the form of 3D images that users interact with and manipulate via mouse and keyboard. More sophisticated applications of virtual reality allow users to more authentically feel the objects in these displays through gesture-based and haptic devices, which provide tactile information through force feedback. Thanks to advances in graphics hardware, CAD software, and 3D displays, virtual reality is becoming more mainstream, especially in the realm of video games and VR.[294] Museums are embracing VR-enabled products such as Oculus Rift and Google Cardboard to provide their audiences with more immersive opportunities to experience and learn from their exhibits and collections.

Overview

The museum field is no stranger to virtual reality as several previous projects have integrated primitive versions of the technology. In 1992, Apple Computer's Virtual Museum was one of the first documented implementations, which consisted of a demonstration disc for Apple's QuickTimeVR. Users could experience a 3D simulation of three intertwined museum spaces.[295] In 1999, the Guggenheim Foundation commissioned the Guggenheim Virtual Museum — a project that was intended to create a 3D experience that people could explore in real time through a virtual reality modeling language-based interface.[296] Outside of gaming, VR did not catch on as anticipated, and with the high cost of development, museum interest in VR faded in the late 1990s.[297]

The current wave of VR has permeated the mainstream with virtual reality headset revenues projected to reach $895 million in 2016 globally, and 77% of that value consisting of newly launched premium devices from Oculus, HTC, and Sony.[298] The Oculus Rift and HTC Vive, designed with a primary focus on gaming, video, and photo experiences recently garnered widespread attention. The headsets, which tether to a desktop or laptop, encompass a pair of screens and lenses that generate a stereoscopic 3D image as well as sensors that monitor the user's movements to adjust the images accordingly.[299] Virtual reality is also branching out

beyond gaming platforms; in the last year, smartphone users have seen an influx of low-cost VR options. The Samsung Gear VR and Google Cardboard both leverage the screens and sensors built into smartphones, and by 2025, the market for content on these platforms is projected to reach $5.4 billion.[300]

Virtual reality delivers fully immersive, simulated worlds, enabling complete focus on the content without distractions. A compelling method for storytelling, it allows users to feel the experience throughout their body.[301] Major VR investments are being made in prerecorded content for entertainment and sports, marketing, and education, and will eventually graduate to live offerings. In a recent report on VR and augmented reality (AR), Goldman Sachs estimates that entertainment revenue will reach $3.2 billion by 2025 and the education sector will attract 15 million users.[302] *The Verge* released a VR-enabled interview with Michelle Obama about her engagement with social media. The 360-degree video overlaid with infographic-style animations created a mixed reality 3D space so viewers could move around the room and see production crew and staff.[303] Live content for virtual reality is also being actively developed; in April 2016, Medical Realities, a company that integrates VR, AR, and serious games into medical training, became the first organization to live stream a surgery in VR.[304]

Relevance for Museum Education and Interpretation

Museums realize that audience expectations are evolving and many people have already begun to embrace VR as an opportunity to experiment with new methods for engagement.[305] The Ricoh Theta S 360-degree camera starts at $350,[306] and the process of editing for VR varies minimally from 2D.[307] YouTube, Steam, and Facebook are just a few of the platforms that currently support VR, giving content producers the key ingredients to facilitate an accessible ecosystem for VR development. WoofbertVR, a company that specializes in VR-based art education, collaborated with curators, museum professionals, and educators to develop an app for museums that enables users to virtually tour marquee museums from around the world in an immersive 360-degree environment.[308]

VR can also be used to provide museum patrons with unique perspectives of specific works. For example,

"Bruegel, Unseen Masterpieces" is a collaboration between the Google Cultural Institute and eight major museums,[309] incorporating VR into many of Pieter Bruegel's works and producing materials such as a YouTube video that takes viewers on a tour of "The Fall of the Rebel Angels" in an animated 3D space optimized for Google Cardboard.[310] For the Dali Museum's "Disney and Dali: Architects of the Imagination" exhibit,[311] a VR world called "Dreams of Dali" has been created to engross viewers in a virtual environment inspired by the surrealist's creations including "Archeological Reminiscence of Millet's 'Angelus.'"[312] By using Oculus Rift at the museum or Google Cardboard at home, patrons can fly with the birds around the massive stone structures, discover a lobster telephone, and sit down with Alice Cooper.

Virtual reality can expose people to new worlds typically inaccessible to most, and esteemed broadcaster and naturalist Sir David Attenborough is embracing this potential. His Natural History Museum exhibit, "First Life," is a foray into the prehistoric world. London patrons strap on headsets and take a trip in a virtual time machine through 500 million years to explore the world's ancient oceans.[313] The Australian Museum in Sydney is featuring another VR experience from Sir Attenborough. "Great Barrier Reef Dive VR" showcases the extraordinary sea life and visuals of the modern day Great Barrier Reef in an immersive environment.[314] Shot at the museum's Lizard Island Research Station, viewers wear a headset and headphones to join the naturalist and his crew in a submarine as they venture beneath the water's surface. In recognition of the 30th anniversary of the Chernobyl disaster, Farm 51, a software development company, gathered thousands of photos, 360-degree videos, and 3D models with special drones and scanners to create the "Chernobyl VR Project," an interactive virtual tour of the inhabitable zone, which debuted at Museum of Kyiv. Users explore the area as a narrator provides information about the events and inhabitants to preserve the decaying site.[315]

Virtual Reality in Practice
The following links provide examples of virtual reality in use that have direct implications for museums:

A Look at the Museum of the Future
go.nmc.org/pollock
The New York Metropolitan Museum of Art has been experimenting with VR using Jackson Pollock's "Autumn Rhythm (Number 30)." Museum guests, equipped with VR goggles, experience the artwork in an alternate universe as the splattered paint seemingly floats in front of them. **>** *Policy*

Implicit and Explicit Information Mediation in a Virtual Reality Museum Installation and its Effects on Retention and Learning Outcomes
go.nmc.org/denmark
A museum in Denmark is capitalizing off the recent flood of virtual reality technology into the mainstream market by developing historical scenes that immerse audience members into the action. **>** *Practice*

See the World's Greatest Stolen Artworks in This Virtual-Reality Museum
go.nmc.org/stolenart
Pieces of art that have been missing for decades can now be seen by audiences around the world, thanks to virtual reality. For example, The Museum of Stolen Art recently opened its doors to the public through the lenses of virtual reality gear. **>** *Practice*

For Further Reading
The following articles and resources are recommended for those who wish to learn more about virtual reality:

Museums are Using Virtual Reality to Preserve the Past – Before It's Too Late
go.nmc.org/past
(Jenny Kidd, *The Conversation*, 14 July 2015.) Virtual reality has opened the door for more accessible and immersive experiences with art, history, and science – the ethical debate around this use of technology to recreate the past is centered on the historical and cultural accuracy of the scenes being depicted. **>** *Policy*

Increasing Accessibility Through Virtual Reality: A Look AT VR's Therapeutic Potential
go.nmc.org/therapyVR
(Christine Nolan, *Arts Management & Technology Laboratory*, 22 February 2016.) The goal of virtual reality is to immerse people into scenes in which they otherwise could not go – this possibility afforded by VR gear is expanding its reach by creating ways for autistic children to have the museum experience from any location. **>** *Leadership*

Terrorism Destroyed This Museum – But VR Has Brought it Back to Life
go.nmc.org/recreate
(James Peckhan, *TechRadar*, 16 March 2016.) Recreating destroyed or lost art is one of the many facets of museum work that is made possible with virtual reality technology. For example, the Mosul Museum in Iraq destroyed during warfare is now available through VR headsets. **>** *Leadership*

Information Visualization

Time-to-Adoption Horizon: Four to Five Years

nformation visualization is the graphical representation of technical, often complex data, designed to be quickly and easily understood. This type of media is highly valuable in the age of ubiquitous knowledge, and the skillset required to create visualizations is in demand by organizations seeking to share messages that make an impact.[316] The format is particularly compelling for museums as the use of linked open data increases, helping them to graphically present the totality of content and information related to all of their collections.[317] A well-crafted visualization can illuminate perspectives and relationships that would otherwise remain buried in databases and content repositories or interpret a detailed concept, such as the history of art in a specific culture, and connect ideas to each other with clarity and simplicity. Museums are increasingly embracing these graphics to make complex ideas more digestible, giving them a creative spin.[318] Also inherent in this development is the recognition of information visualizations as a form of art, as effective examples are often aesthetically compelling by nature.[319]

Overview

While information visualization is an emerging technology development for museums, it is an area rich in history. Early incarnations include 19th century maps of weather patterns and 20th century depictions of the human metabolism at work, among many other examples.[320] As long as scientists have been collecting data on people and the environments around them, there has been a need to display important findings to both educate and engage the public. The advent of mapping and design technologies is continuously pushing the boundaries of how data can be represented. As gatekeepers of vast amounts of history and cultural heritage, museums have a responsibility to facilitate interpretation in accessible and engaging ways, drawing upon visual representations. Digital visualizations enable viewers to instantly recognize connections and patterns that could take hours to determine from raw data and text alone.

Museums are excited by the affordances of this development, but it remains on the far-term horizon because of the associated challenges. In an influential early study conducted by the Exploratorium on designing interactive visualizations for informal learning environments, they found that visitors often lack the background to interpret visualizations of scientific data and have limited time to spend at an exhibit trying to comprehend them.

Furthermore, visualizations must be personal, fostering opportunities for deeper connections between the patron and the content. The Exploratorium designed a prototype exhibit based on these findings; "Living Liquid" enabled museumgoers to view complex scientific data, posing and answering their own questions while exploring the time-varying global distribution of simulated marine microbes via touchscreen.[321]

Indeed, it is not enough for the visualizations to be two-dimensional and stagnant; the ability for patrons to manipulate them is an essential part of the learning process. In a recent study published in the *Journal of Research in Science Teaching*, researchers in the US and UK highlighted the use of a complicated interactive visualization of an evolutionary tree of life consisting of over 70,000 species, displayed at two natural history museums. Nearly 250 youth were split into different groups — some were exposed to the tree visualization through a multi-touch table while others watched a 10-minute video covering similar subject matter. The study revealed that information visualization proved effective for helping the children sift through large scientific datasets; visitors who had access to it were significantly more likely to reason correctly about core evolutionary concepts such as common descent and shared ancestry.[322]

Relevance for Museum Education and Interpretation

The advent of information visualization is also helping museum staffs advance their digitization strategies. As museums increasingly adopt open data policies to provide online visitors with access to a wealth of information related to their collections, they are using linked data protocols to make connections between each artifact in their cultural repositories. However, these connections are not easy to identify as visitors are being exposed to an overwhelming amount of information, shifting the challenge for museums from content access to quality of presentation. To mitigate this issue, researchers at MIT have created a set of tools that aggregate data from collections, as well as related open data elsewhere on the web, and generate visualization dashboards that provide virtual patrons more meaningful context.[323] In face-to-face settings, museum curators and scholars are also turning to computational tools that produce information visualizations to explore material features of works, such as spatial density and shifting palettes, to glean new insights about form, genre, and creativity.[324]

While this technology development is at least a few years away from mainstream adoption, progressive institutions are spurring its long-term growth by sharing their resources. The Cooper Hewitt Museum has acquired the iPad music app "Planetary," which reflects the relationship between data visualization and the composition of the solar system. They freely released the underlying source code to make it available to all developers to build into their software and apps.[325] Learning how to use the technology needed to create information visualizations, especially for museums without sufficient expertise on staff, is critical. The University of California, San Diego established the Software Studies Initiative to develop user-friendly techniques for the visualization and computational analysis of large collections of images and video, tailored toward people without technical backgrounds.[326] A Harvard University workshop sponsored by the Getty Foundation taught art museum staff how to use data visualizations and interactive media to more effectively present "difficult collections" — materials that do not naturally lend themselves to digitization.[327]

Another unexpected but compelling way visualizations are emerging in the field is as unique art forms. By nature, they appeal to the senses, spinning complex webs of information into vibrant and often colorful graphics or objects.[328] The new category, data artists, consists of those whose media are large bodies of scientific data or the data collected through self-tracking devices. One such artist, for example, interprets military budgets as bold diagrams while another is creating installations that display her walking patterns as gathered by a Fitbit.[329] This movement is largely a response to the growing use of technology to capture nearly every human interaction as a data point; the artists seek to find deeper meaning in the chronic documentation. The Hyundai Card Design Library in Seoul, Korea[330] launched "Data Visualization," which leveraged 3D maps, diagrams, and other graphics to explore the information generated by sensors, software, and ever-expanding networks.[331]

Information Visualization in Practice
The following links provide examples of information visualization in use that have direct implications for museums:

Carnegie Museums of Pittsburgh's Gallery Guide
go.nmc.org/galguide
As part of the H2Oh! exhibition at the Carnegie Science Center, the Innovation Studio's Anika Wilcox built a touch-based interactive exhibit that visualizes real-time data collected by the US Geological Survey. The interactive data visualization helps visitors explore water temperature, and pH levels and gauge the height of the Allegheny, Monongahela, and Ohio Rivers, which converge at Pittsburgh's point and form one of the city's most notable landmarks. **>** *Practice*

CDC Museum - Mapping Science Exhibition
go.nmc.org/cdc
Information visualization is used by the Centers for Disease Control and Prevention Museum to help both scientists and the public quickly understand the scope and context of complex health threats. Their current "Places & Spaces: Mapping Science" exhibit leverages science maps and visualization tools from leading international experts in the natural, physical, and social sciences, as well as from industry and government to help audiences grasp abstract concepts. **>** *Practice*

Smithsonian X 3D
go.nmc.org/smithx
Smithsonian X 3D utilizes various 3D capture methods to allow researchers to document 3D data regarding a site or a find. This data tells the story of not only the object but the quest of discovery. **>** *Practice*

For Further Reading
The following articles and resources are recommended for those who wish to learn more about information visualization:

Start-Up Plans 3-D Visualizations of Pot Strains, Using Genetic Data
go.nmc.org/galax
(John Markoff, *The New York Times*, 20 April 2016.) Phylos Bioscience, an Oregon biotechnology start-up, has partnered with the American Museum of Natural History to visually portray the genetic relationships of almost 1,000 types of cannabis as a colorful 3-D map and interactive guide that explains statistical relationships between different breeds of plants. The tool they have developed, Galaxy, has potential to map genetic data for other types of plants as well as animals. **>** *Leadership*

UNITE Data Visualization Panel
go.nmc.org/unite
(Grace Moen, Design Museum Portland, 9 February 2016.) The Design Museum Portland hosted a panel discussion on data visualization in which experts in the field discussed a number of new projects and tools; a theme highlighted was the importance of developing data visualization tools that provide an interactive experience so that users can personally verify the data they are working with. **>** *Leadership*

Digital Realism through the Data Visualization Exhibit – Seoul
go.nmc.org/seoul
(Sey Min, The Museum of Modern Art, 10 December 2015.) In this article designers discuss how data collected from peoples' daily lives can be a medium for digital realism, especially as data gathering technologies and sensors that collect data become more prevalent. An exhibit in Seoul, Korea demonstrated how designers and scientists create diagrams, three-dimensional maps, and other graphics to help people make sense of the copious amount of information they are confronted with daily. **>** *Practice*

Networked Objects
Time-to-Adoption Horizon: Four to Five Years

Networked objects link the physical world with the world of information through the web. Encompassing the Internet of Things (IoT) which began in 2006 when TCP/IPv6 was launched, it expanded the capabilities of the Internet and enabled objects and devices to communicate across the web.[332] In networked objects, embedded chips, sensors, or tiny processors are attached to an object and can transmit information about it such as cost, age, temperature, color, pressure, or humidity to another smart device or piece of machinery. This connection allows remote management, status monitoring, tracking, and alerts if the objects are in danger of being damaged. For cultural heritage institutions, networked technologies have vast potential for improving conservation efforts, increasing access to contextual knowledge, and reinventing interaction with cultural works. Museum leaders envision collections of networked objects that tell their own stories; with IoT, histories and metadata can be potentially downloaded from the objects themselves, changing the paradigm of interpretation and public engagement.

Overview
It is no longer far-fetched to envision a world where all people, objects, and devices are connected to act in concert via a network, regardless of brand or vendor. This idea is also known as The Internet of Everything (IoE), which is comprised of machine-to-machine (M2M), machine-to-person, and person-to-person networked technologies. In this environment, sensors embedded on machines, people, and objects can capture events, which are sent through the IPv6 network to applications that create actionable information. Although not gaining the same traction in the cultural heritage sector as it currently is in the consumer sector, Gartner projects that 6.4 billion connected things will be in use in 2016, up 30 percent from last year.[333] The penetration of this technology is only going to accelerate, as BI Intelligence predicts that by 2020, 34 billion devices will be connected to the Internet; they break down their forecast into two categories: IoT devices and remotes. IoT devices are stand-alone networked objects, and remotes are primarily mobile devices that connect with and control objects.[334]

Many people are already familiar with networked objects through their experience with wearables such as Apple Watches and Fitbits, smart home products such

as Nest thermostats, and the smart cities movement that is working to reduce pollution and improve traffic management.[335] In the future world where the Internet of Everything is realized, many choices and decisions will be automated, making life, and potentially learning, an efficient, streamlined experience. Smart buildings are one area where museums are beginning to look to the potential of networked objects to foster greater interconnectivity. CallisonRTKL, a global architecture design firm, has been working with museums to improve their buildings' energy use and overall operational efficiency. They are incorporating integrated building technologies for monitoring mechanical, electrical, and plumbing systems as well as enabling museum employees to discretely interact with a number of control systems that adjust temperature and lighting to the appropriate levels as they scan in and out during the work day.[336]

Networked objects integrated into the built environment have fostered the notion of the term "phygital," which imagines museum spaces as bridges between digital technologies and the physical world of objects. Some museum leaders believe that the appeal of the original analog object and in-person interactions will continue to grow, but will be augmented and informed by increasingly connected digital tools and processes.[337] Nowhere is this idea best embodied than at the Cooper Hewitt Museum. Beside every object on display is a digital marker that visitors can touch with near-field communication-enabled pens that deliver collection information and photographs to their personal online museum collection housed on the museum's website.[338]

Relevance for Museum Education and Interpretation
Networked objects carry the potential to create a museum without walls; that is, the Internet of Everything can give rise to an environment where cultural knowledge is embedded into everyday activities, and it can be accessed anytime, anyplace, and anywhere. Museum leaders see the trajectory as being aligned very closely with wearable technology, because it provides greater mobility, interactivity, and self-reflection.[339] The San Francisco de Young Museum began offering Google Glass tours in 2014,[340] and in 2016 they introduced a mobile app that leveraged the network capabilities of smartwatches. For example, when a visitor enters the museum to view the Oscar de la Renta retrospective

through an Apple Watch with the museum's app installed, they are notified of additional interpretive information available through a vibration on their wrist. If the wearer is interested, they can hear a recording of a curator or the designer himself talk about the influences behind a particular garment.[341]

Increasing accessibility of Bluetooth and network technology is also creating conditions for multi-sensory exhibits that engage with the visitor in unique ways. A pop-up installation titled "Elegy for forgotten sounds" at the Concert Hall of Burges used timpani sticks powered by beacon technology to enable visitors to experience the cacophony of a World War I battlefield. Patrons choose one of five drum sticks and as they walk around a central sculpture, battle sounds and cloud of smoke are emitted at different intervals and volumes based on the visitor's proximity to three invisible zones.[342] Similarly the Buxton Museum and Art Gallery's "Fragility of Memory" exhibition featured an interactive audio soundscape using iBeacon technology. The exhibition features four sculptures and as a patron walks from one object to another, voices and sounds blend together evoking feelings as if the museum goer was eavesdropping on different conversations.[343]

The potential of networked objects for education and interpretation has been explored in a number of workshops and events at museums. ThingWeek, hosted by the Design Museum of Portland, joined design and technology communities around shaping the future of the Internet of Things. The featured SmartThings PDX workshop taught attendees about the potential of networked objects as they developed their own apps.[344] Future exhibition designers at the Academy of Art University in San Francisco studied IoT through field trips including museum exhibits. At the Children's Creativity Museum, they met with an exhibits manager who took them through the design thinking process that informs the development of educational interactive exhibits that incorporate networked objects. One student was inspired to use his pulse information from a smartwatch to control motors that are connected to a drawing machine.[345]

Networked Objects in Practice
The following links provide examples of networked objects in use that have direct implications for museums:

UK's Ofcom Allocates VHF Radio Spectrum for Internet of Things Communication
go.nmc.org/ofcom
The United Kingdom's Office of Communications has dedicated a spectrum within three Very High Frequency radio bands to be used for Internet of Things services and Machine-to-Machine applications, and aims to address international harmonization relating to VHF radio spectra. **>** *Policy*

Bluetooth Data Loggers Streamline Museum Environmental Monitoring
go.nmc.org/datlogg
The Idemitsu Museum of Arts in Tokyo leverages Bluetooth Low Energy data loggers to monitor the museum's temperature and humidity and ensure its art objects, including paintings, calligraphy, and ceramics, are displayed and stored in optimal conditions for their preservation. **>** *Practice*

Notes on the Ephemeral Objects Exhibition at San Diego Art Institute
go.nmc.org/eph
The Ephemeral Objects exhibition at San Diego Art Institute explored the implications of expanding the definition of "object" beyond materiality, but as part of an experience not defined by walls. Some of the art used programming, data, information, and the Internet of Things to question assumptions about the perceived world, while others delved into the idea of de-prioritizing visual experience. **>** *Practice*

For Further Reading
The following articles and resources are recommended for those who wish to learn more about networked objects:

EM-Sense: Touch Recognition of Uninstrumented, Electrical and Electromechanical Objects
go.nmc.org/emsen
(Gierad Laput, et al., ACM, 2015.) Carnegie Mellon University and Disney Research have developed a technique called EM-Sense and proof-of-concept smartwatch that could enable on-touch object detection based on an object's unique electromagnetic noise to contribute to more powerful assistive, context-sensing, and communication applications. **>** *Policy*

The Internet of Things: An Overview
go.nmc.org/anover
(Karen Rose, et al., *Internet Society*, October 2015.) The Internet Society has published a white paper considering how standards, regulations, and rights will play into the development of the internet of things and its interrelated security and privacy issues. They hope to initiate informed dialogue and collaboration across stakeholders on how to meet these challenges. **>** *Policy*

MoMA R&D Salon: The Object, Connected
go.nmc.org/salonten
(Fiona Romeo, 10 June 2015.) This recap from a salon series at the Museum of Modern Art in New York explores how connected objects may relate to design at the level of the object, a museum collection, a museum building, the city, and the larger network. **>** *Practice*

The 2016 Museum Edition Expert Panel

Endnotes

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For the *NMC Horizon Report: 2016 Museum Edition*, an expert panel identified 18 topics very likely to impact technology planning and decision-making: six key trends, six significant challenges, and six important developments in technology.

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