It is Our Flagship: Surveying the Landscape of Digital Interactive Displays in Learning Environments

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ABSTRACT

This paper presents the findings of an environmental scan conducted as part of a Digital Exhibits Intern Librarian Project at the Edmonton Public Library in 2016. As part of the Library's 2016–2018 Business Plan objective to define the vision for a digital exhibits service, this research project aimed to understand the current landscape of digital displays in learning institutions globally. The resulting study consisted of 39 structured interviews with libraries, museums, galleries, schools, and creative design studios. The environmental scan explored the technical infrastructure of digital displays, their user groups, various uses for the technologies within organizational contexts, the content sources, scheduling models, and resourcing needs for this emergent service. Additionally, broader themes surrounding challenges and successes were also included in the study. Despite the variety of approaches taken among learning institutions in supporting digital displays, the majority of organizations have expressed a high degree of satisfaction with these technologies.

INTRODUCTION

In 2020, the Stanley A. Milner Library, the central branch of the Edmonton (Alberta) Public Library (EPL) will reopen after extensive renovations to both the interior and exterior of the building. As part of the interior renovations, EPL will have installed a large digital interactive display wall modeled after The Cube at Queensland University of Technology (QUT) in Brisbane, Australia. To prepare for the launch of this new technology service, EPL hired a digital exhibits intern librarian in 2016, whose role consisted of conducting research to inform the library in defining the vision for a digital display wall serving as a shared community platform for all manner of digitally accessible and interactive exhibits. As a result, the author carried out an environmental scan and a literature review related to digital display, as well as their consequent service contexts. For the purposes of this paper, "digital displays" refers to the technology and hardware used to showcase information, whereas "digital exhibits" refers to content and software used on those displays. Wherever the service of running, managing, or using this technology is discussed, it is framed as "digital display service" and concerns both technical and organizational aspects of using this technology in a learning institution.

METHOD

The data were collected between May 30 and August 20, 2016. A series of structured interviews were conducted by Skype, phone, and email. The study population was driven by searching Google

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and Google News for keywords such as "digital interactive AND library," "interactive display," "public display," or "visualization wall" to identify organizations that have installed digital displays. A list of the study population was expanded by reviewing websites of creative studios specializing in interactive experiences and through a snowball effect once the interviews had begun. A small number of vendors, consisting primarily of creative agencies specializing in digital interactive services, were also included in the study population. Participants were then recruited by email. The goal of this project was to gain a broad understanding of the emergent technology, content, and service model landscape related to digital displays. As a result, structured interviews were deemed to be the most appropriate method of data collection because of their capacity to generate a large amount of qualitative and quantitative data. In total, 39 interviews were conducted.

A list of interview questions prepared for the interviews is included in appendix A. Additionally, a complete list of the study population can also be found in Appendix B. Predominantly, organizations from Canada, the United States, Australia, and New Zealand are represented in this study.

LITERATURE REVIEW

Definitions

- **Public displays**, a term used in the literature to refer to a particular type of digital display, can refer to "small or large sized screens that are placed indoor . . . or outdoor for public viewing and usage" and which may be interactive to support information browsing and searching activities."[1] In public displays, a large proportion of users are passers-by and thus first-time users.[2] In academic environments, these technologies may be referred to as "video walls" and have been characterized as display technologies with little interactivity and input from users, often located in high-traffic, public areas with content prepared ahead of time and scheduled for display according to particular priorities.[3]
- **Semi-public displays,** on the other hand, can be understood as systems intended to be used by "members of a small, co-located group within a confined physical space, and not general passers-by."[4] In academic environments, they have been referred to as "visualization spaces" or "visualization studios," and can be defined as workspaces with real-time content displayed for analysis or interpretation, often placed in in libraries or research department units.[5] For the purposes of this paper, "digital displays" refers to both public and semi-public displays, as organizations interviewed as part of this study had both types of displays, occasionally simultaneously.
- **Honeypot effect** describes how people interacting with an information system, such as a public display, stimulate other users to observe, approach, and engage in interaction with that system.[6] This phenomenon extends beyond digital displays to tourism, art, or retail environments, where a site of interest attracts attention of passers-by and draws them to participate in that site.

Interactivity

The area of interactivity with public displays has been studied by many researchers, with three commonly used modes of interaction clearly identified: touch, gesture, and remote modes.

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- **Touch (or multi-touch):** This is the most common way users interact with personal mobile devices such as smartphones and tablets. Multi-touch interaction on public displays should support many individuals interacting with the digital screen simultaneously, since many users expect immediate access and will not take turns. For example, some technologies studied in this report support up to 30 touch points at any given time, while others, like QUT's The Cube, allow for a near infinite number of touch points. Though studies show that this technique is fast and natural, it also requires additional physical effort from the user.[7] While touch interaction using infrared sensors has a high touch recognition rate, its shortcomings have been identified as being expensive and being influenced by light interference, such as light around the touch screen.[8]
- **Gesture:** This is interaction is through movement of the user's hands, arms, or entire body, recognized by sensors such as the Microsoft Kinect or Leap Motion systems. Although studies show that this type of interaction is quick and intuitive, it also brings "a cognitive load to the users together with the increased concern of performing gestures in public spaces."[9] Specifically, body gestures were found not to be well suited to passing-by interaction, unlike hand gestures, which can be performed while walking. Hand gestures also have an acceptable mental, physical and temporal workload.[10] Research into gesture-based interaction shows that "more movement can negatively influence recall" and is therefore not suited for informational exhibits.[11] Similarly, people consider gestures to be too much work "when they require two hands and large movements" to execute.[12] Not surprisingly, research suggests that gestures deemed to be socially acceptable for public spaces are small, unobtrusive ones that mimic everyday actions. They are also more likely to be adopted by users.
- **Remote:** These are interactions using another device, such as mobile phones, tablets, virtual-reality headsets, game controllers, and other special devices. Connection protocols may include Bluetooth, SMS messaging, near-field communication, radio-frequency identification, wireless-network connectivity, and other methods. Mobile-based interaction with public displays has received a lot of attention in research, media, and commercial environments because this mode allows users to interact from variable distance with minimal physical effort. However, users often find mobile interaction with a public display "too technical and inconvenient" because it requires sophisticated levels of digital literacy in addition to having access to a suitable device.[13] Some suggest that using personal devices for input also helps "avoid occlusion and offers interaction at a distance" without requiring multi-touch or gesture-based interactions.[14] As well, subjects in studies on mobile interaction often indicate their preference for this mode because of its low mental effort and low physical demand. However, it is possible that these studies focused on users with high degrees of digital literacies rather than the general public with varying degrees of access and comfort with mobile technologies.

User Engagement

Attracting user attention is not necessarily guaranteed by virtue of having a public display. According to research, the most significant factors that influence user engagement with public digital displays are age, display content, and social context.

Age

Hinrichs found that children were the first to engage in interaction with public displays and would often recruit adults accompanying them toward the installation.[15] On the other hand, the Hinrichs found adults to be more hesitant in approaching the installation: "they would often look at it from a distance before deciding to explore it further."[16] These findings suggest that designing for children first is an effective strategy for enticing interaction from users of all ages.

Display Content

Studies on engagement in public digital display environments indicate that both passive and active types of engagement exist with digital displays. The role of emotion in the content displayed also cannot be overlooked. Specifically, Clinch et al. state that people typically pay attention to displays "only when they expected the content to be of interest to them" and that they are "more likely to expect interesting content in a university context rather than within commercial premises."[17] In other words, the context in which the display is situated affects user expectations and primes them for interaction.

The dominant communication pattern in existing display and signage systems has been *narrowcast*, a model in which displays are essentially seen as distribution points for centrally created content without much consideration for users. This model of messaging exists in commercial spaces, such as malls, but also in public areas like transit centers, university campuses, and other spaces where crowds of people may gather or pass by. Observational studies indicate that people tend to perceive this type of content as not relevant to them and ignore it.[18] For public displays to be engaging to end users, in other words, "there needs to be some kind of reciprocal interaction."[19] In public spaces, interactive displays may be more successful than non-interactive displays in engaging viewers and making city centers livelier and more attractive.[20]

In terms of precise measures of attention to such displays, studies of average attention time correlate age with responsiveness to digital signage. Children (1–14 years) are more receptive than adults and men spend more time observing digital signage than women.[21] Studies also indicate a significantly higher average attention times for observing dynamic content as compared to static content.[22] Scholars like Buerger suggest that designers of applications for public digital displays should assume that viewers are not willing "to spend more than a few seconds to determine whether a display is of interest."[23] Instead, they recommend presenting informational content with minimal text and in such a way that the most important information can be determined in two-to-three seconds. In a museum context, the average interaction time with the digital display was between two and five minutes, which was also the average time people spent exploring analog exhibits.[24] Dynamic, game-like exhibits at The Cube incorporate all the above findings to make interaction interesting, short, and drawing the attention of children first.

Social Context

Social context is another aspect that has been studied extensively in the field of human-computer interaction, and it provides many valuable lessons for applying evidence-based practices to technology service planning in libraries. Many scholars have observed the honeypot effect as related to interaction with digital displays in public settings. This effect describes how users who are actively engaged with the display perform two important functions: they entice passers-by to become actively engaged users themselves, and they demonstrate how to interact with the technology without formal instruction.

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Many argue that a conductive social context can "overcome a poor physical space, but an inappropriate social context can inhibit interaction" even in physical spaces where engagement with the technology is encouraged.[25] This finding relates to use of gestures on public displays. Researchers also found that contextual social factors such as age and being around others in a public setting do, in fact, influence the choice of multi-touch gestures. Hinrichs suggests enabling a variety of gestures for each action—accommodating different hand postures and a large number of touch points, for example—to support fluid gesture sequences and social interactions.[26] A major deterrent to users' interaction with large public displays has been identified as the potential for social embarrassment.[27] As an implication, the authors suggest positioning the display along thoroughfares of traffic and improving how the interaction principles of the display are communicated implicitly to bystanders, thus continually instructing new users on techniques of interaction.[28]

FINDINGS

Technical and Hardware Landscape

The average age of public displays was around three years, indicating an early stage of development of this type of service among learning institutions. Such technologies first appeared in Europe more than 10 years ago (for example, the most widely cited early example of a public display is the CityWall in Helsinki in 2007).[29] However, adoption in North American did not start until around 2013.The median year for the installation of these technologies among organizations studied in this report is 2014. Among public institutions represented in the study population, such as public libraries and museums, digital displays were most frequently installed in 2015.

While most organizations have only one display space, it was not unusual to find several within a single organization. For example, for the purposes of this study, the researcher has counted The Cube as three display spaces, as documentation and promotional literature on the technology cites "3 separate display zones." As a result, the average number of display spaces in the population of this study is 1.75.

The following modes of interaction beyond displaying video content with digital displays have been observed in the study population in descending order of frequency:

- **Sound (79%)**. While research on human-computer interaction is inconclusive about best practices related to incorporating sound into digital interactive displays, it is clear, among the organizations interviewed in the environmental scan, that sound is a major component of digital exhibits and should not be overlooked.
- **Touch or multi-touch (46%).** This finding highlights that screens capable of supporting multi-user interaction is not consistent across the study population.
- **Gesture (25%):** These include tools such as Microsoft Kinect, Leap Motion, or other systems for detecting movement for interaction.
- **Mobile (14%).** While some researchers in the human-computer interaction field suggest mobile is the most effective way to bridge the divide between large public displays, personalization of content, and user engagement, mobile interactivity is not used frequently to engage with digital displays in the study population. One outlier is North Carolina State University Library, which takes a holistic, "massively responsive design" approach in which responsive web design principles are applied to content that can be

displayed effectively at once online, on digital display walls, and on mobile devices while optimizing institutional resources dedicated to supporting visualization services.

Further, as in the broader personal computing environment, the Microsoft Windows operating system dominates display systems, with 61% of the organizations choosing a Windows machine to power their digital display. A fifth (21%) of all organizations have some form of networked computing infrastructure, such as The Cube with its capacity to process exhibit content using 30 servers. Instead, the majority (79%) of organizations interviewed have a single computer powering the display. This finding is perhaps not surprising, given that few institutions have dedicated IT teams to support a single technology service like The Cube.

Users and Use Cases

Understanding primary audiences was also important for this study, as the organizational user base defines the context for digital exhibits. The breakdown of these audiences is summarized in figure 1. For example, the University of Oregon Ford Alumni Center's digital interactive display focuses primarily on showcasing the success of its alumni, with a goal of recruiting new students to the university. However, the interactive exhibits also serve the general public through tours and events on the University of Oregon campus. Other organizations with digital displays, such as All Saints Anglican School and the Philadelphia Museum of Art, also target specific audiences, so planning for exhibits may be easier in those contexts than in organizations like the University of Waterloo Stratford Campus, with its display wall at the downtown campus that receives visitor traffic from students, faculty, and the public.

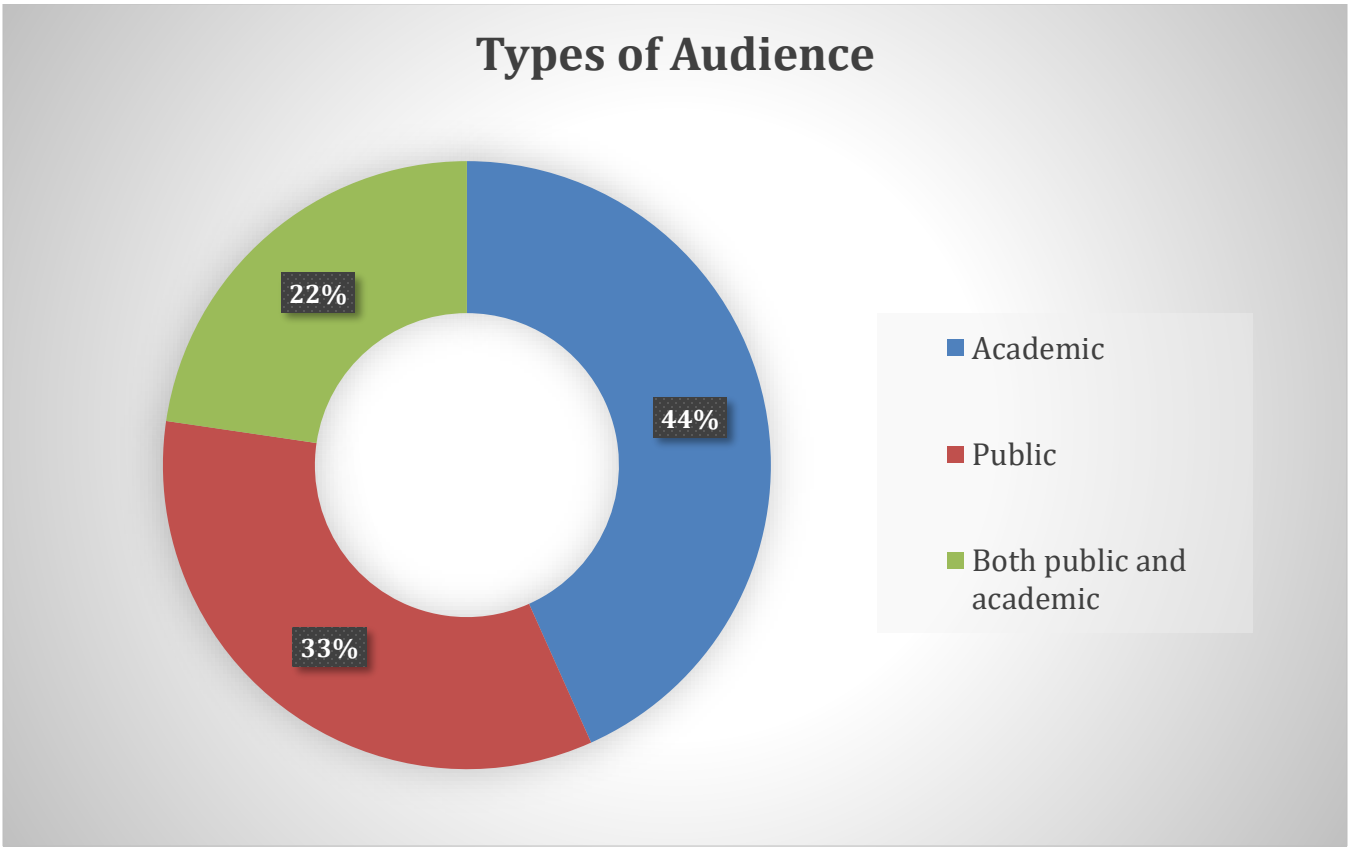

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Figure 1. Audience types for digital displays in the study population.

Digital displays serve various purposes, which depend on the context of the organization in which they exist, their technical functionality, their primary audience, their service design, and other factors. Interview participants were asked about the various uses for these technologies at their institutions. A single display could have multiple functions within a single institution. The following list summarizes these multiple uses:

1. **Educational (67%)**, such as displaying digital collections, archives, historical maps, and other informational. These activities can be summarized in the words of one participant as "education via browse"—in other words, self-guided discovery rather than formal instruction.
2. **Fun or entertainment (56%),** including art exhibitions, film screenings, games, playful exhibits, and other engaging content to entice users.
3. **Communication (47%),** which can be considered a form of digital signage to promote library or institutional services and marketing content. Displays can also deliver presentations and communicate scholarly work.
4. **Teaching (42%),** including formal and semi-formal instruction, workshops, student presentations, and student course-work showcases.
5. **Events (31%),** such as public tours, conferences, guest speakers, special events, galas, and other social activities near or using the display.
6. **Community engagement (28%),** including participation from community members through content contribution, showing local content, using the display technology as an outreach tool, and other strategies to build relationships with user communities.
7. **Research (22%),** where the display functions as a tool that facilitates scholarly activities like data collection, analysis, and peer review. Many study participants acknowledged challenges in using digital displays for this purpose and have identified other services that might support this use more effectively.

Content Types and Management

In the words of Deakin University librarians, "*Content is critical, but the message is king*," so it was particularly important for the author to understand the current digital display landscape as it relates to content.[30] Specifically, the research project encompassed the variety of content used on digital displays as well as how it is created, managed, shared, and received by the audiences of various organizations interviewed in this study. As can be observed in figure 2, all organizations supported 2D content, such as images, video, audio, presentation slides, and other visual and textual material. However, dynamic forms of content, such as social media feeds, interactive maps, and websites were less prevalent.

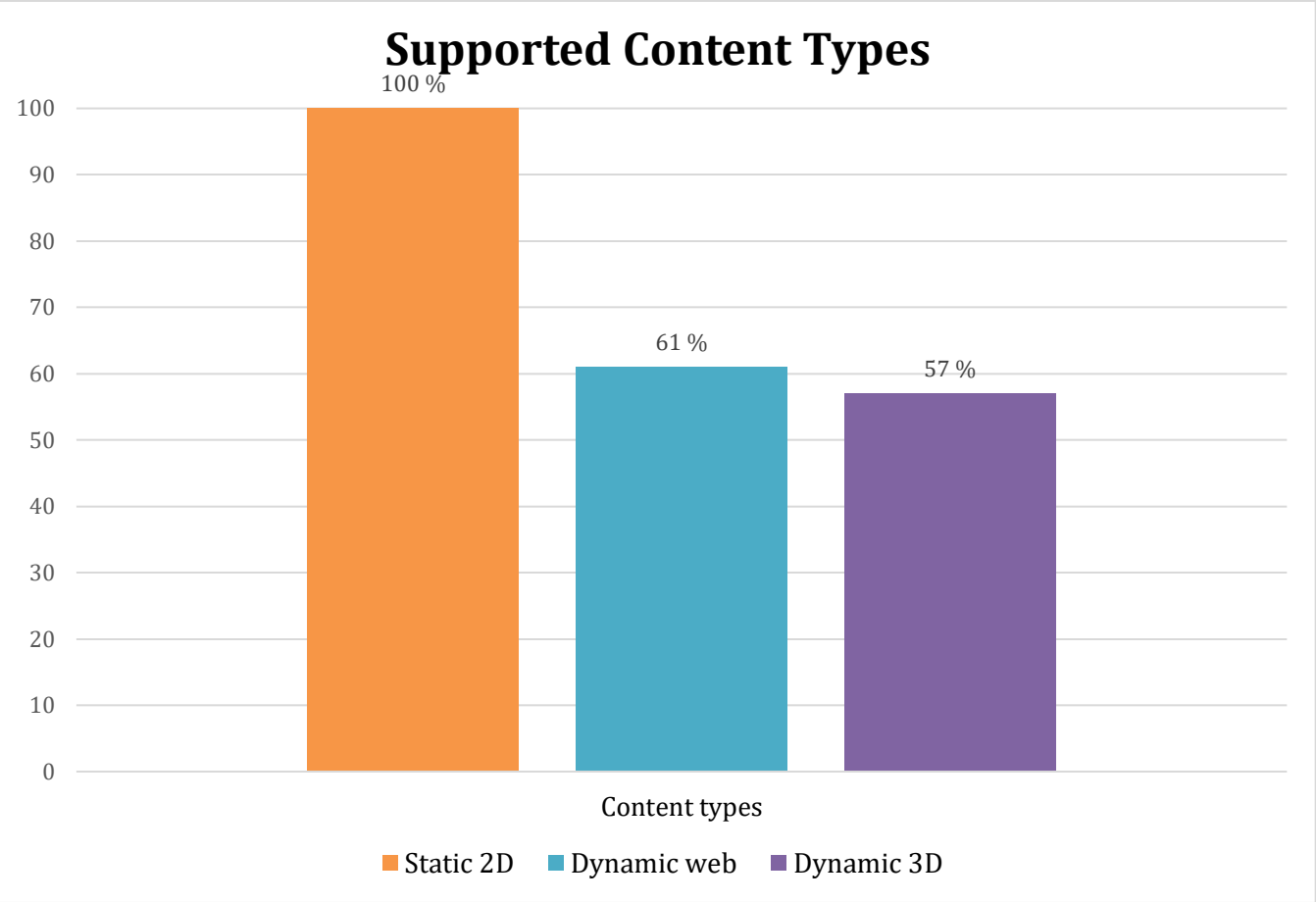

Figure 2. Types of content supported by digital displays in the study population.

Discussions around interest in emergent, immersive, and dynamic 3D content such as games and virtual and augmented reality also came up frequently in the study interviews, and the researcher found that these types of content were supported in only 16 (57%) of the 28 total cases. This number is lower than the total number of interviewees because not all organizations interviewed had content to manage or display. In addition, many organizations recognized that they would likely be exploring ways to present 3D games or immersive environments through their digital display in the near future. Not surprisingly, the creative agencies included in this study revealed an awareness and active development of content of this nature, noting "rising demand and interest in 3D and game-like environments." Furthermore, projects involving motion detection, the Internet of Things, and other sensor-based interactions are also seeing rise in demand, according to study participants.

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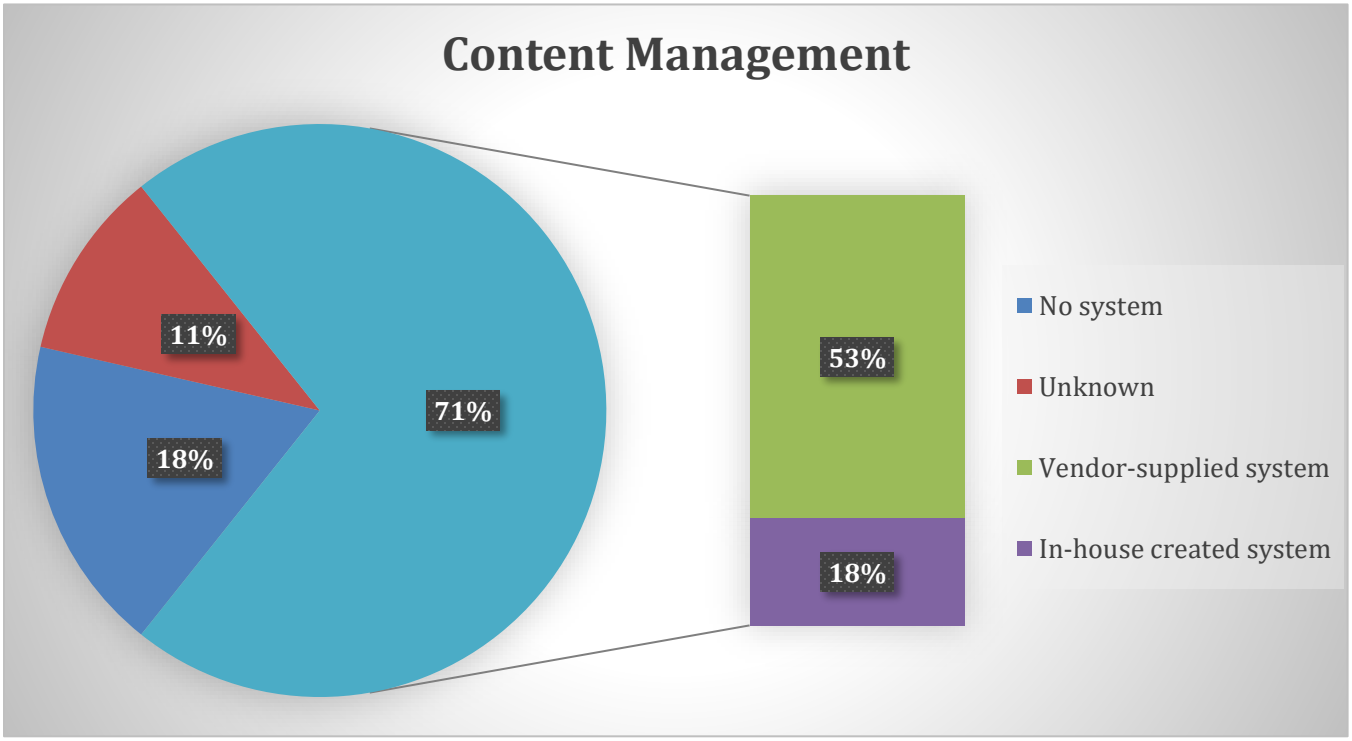

Figure 3. Content management systems for digital displays.

In terms of managing various types of content, 20 (71%) of the organizations interviewed had used some form of content management system (CMS), while the rest did not use any tool to manage or organize content. Of those organizations that used a CMS, 15 (75%) relied on a vendor-supplied system, such as tools by FourWinds Interactive, Visix, or NEC Live. The remaining 5 (18%) CMS users created a custom solution without going to a vendor. This finding suggests that since the majority of content supported by organizations with digital displays is 2D, current vendor solutions for managing that content are sufficient for the study population at this point. It is unclear how the rise in demand for dynamic, game-like content will be supported by vendors in the coming years. Table 1 reflects the distribution of approaches to managing content observed in the study population.

Table 1. Content management in study population

Content Management	Responses	%
Vendor supplied system	15	54
In-house created system	5	18
No system	5	18
Unknown	3	10

Middleware, Automation, and Exhibit Management

Middleware can be described as the layer of software between the operating system and applications running on the display, especially in a networked computing environment. For example, most organizations studied in the environmental scan supported a Windows environment with a range of exhibit applications, like slideshows, web browsers, and executable files, such as games. Middleware can simplify and automate the process of starting up, switching between, and shutting off display applications on a set schedule.

As figure 4 demonstrates, the majority of the organizations in the study population (17, or 61%) did not have a middleware solution. However, this group was heterogeneous: 14 organizations (50%) did not require a middleware solution because they ran content semi-permanently or relied on user-supplied content, in which case the display functioned as a teaching tool. The remaining three organizations (11%) manually managed scheduling and switching between exhibit content. In such cases, a middleware solution would be valuable to management of content, especially as the number of applications grows, but it was not present in these organizations. Comparatively, 10 organizations (36%) used a custom solution, such as a combination of Windows or Linux scripts to manage automation and scheduling of content on the display. One organization (3%) did not specify their approach to managing content.

These findings suggest that no formalized solution to automating and managing software currently exists among the study population. In addition to organizing content, digital-exhibits services involve scheduling or automating content to meet user needs according to the time of day, special events, or seasonal relevance. As a result, the middleware technology solution supports sustainable management of displays and predictable sharing of content for end users. This environmental scan revealed that digital exhibits and interactive experiences are still in the early days of development. It is possible that new solutions for managing content both at the application and the middleware level may emerge in the coming years, but they are currently limited.

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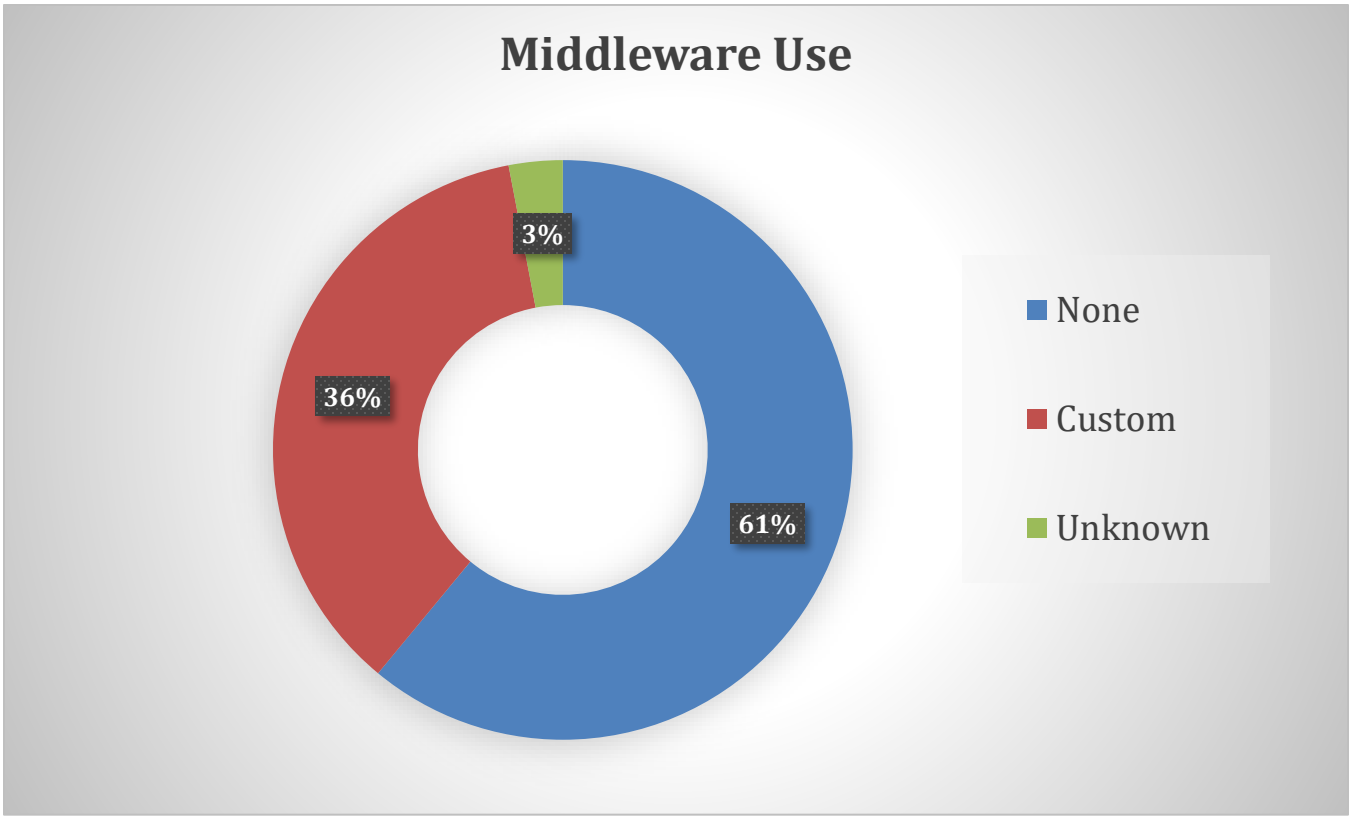

Figure 4. Middleware solutions in the study population.

Sources of Content

When finding sources of content to be displayed on digital displays, organizations interviewed used multiple strategies simultaneously. Table 2 below brings together the findings related to this theme.

Table 2. Content sources for digital exhibits

Content Source	**%**
External/commissioned	64
User-supplied	64
Internal/in-house	50
Collaborative with partner	43

For example, many organizations rely on their users to generate and submit material (18, or 64%); others commission vendors to create exhibits for them (18, or 64%). In 50% of all cases, organizations also produce content for exhibits in-house. In other words, most organizations used a combination of all sources to generate content for their digital displays. Only a few use a single

source of content, such as the semi-permanent historical exhibit at Henrico County Public Library. Others, like the Duke Media Wall, rely entirely on their users to supply content, which employs a "for students by students" model of content creation.

Additionally, only 12 (43%) of the organizations interviewed had explored or established some form of partnership for creating exhibits. Primarily, these partnerships existed with departments, centers, institutes, campus units, and/or students in academic settings, such as the computer science department, faculty of graduate studies, and international studies. Other examples of partnerships were with similar civic, educational, cultural, and heritage organizations, such as municipal libraries, historical societies, art galleries, museums, and nonprofits. Examples included study participants working with Ars Electronica, local symphony orchestras, Harvard Space Science, and NASA on digital exhibits. Clearly, a variety of approaches were taken in the study population to come up with digital exhibits content.

Content Creation Guidelines

Seven organizations (19%) in the study population shared publicly the content guidelines aimed to simplify the process of engaging users in creating exhibits. These guidelines were analyzed, and key elements were identified that are necessary for users to know in order to contribute in a meaningful way, thereby lowering the barrier to participation. These elements include resolution of the display screen(s), touch capability, ambient light around the display space, required file formats, and maximum file size. A complete list of organizations with such guidelines, along with websites where these guidelines can be found, is included in appendix C. Based on the analysis of this limited sample, the bare minimum for community participation guidelines would include clearly outlining

- the scope, purpose, audience, and curatorial policy of the digital exhibits service;
- the technical specifications, such as the resolution, aspect ratio, and file formats supported by the display;
- the design guidelines, such as colors, templates and other visual elements;
- the contact information of the digital exhibits coordinator; and
- the online or email submission form.

It should be noted, however, that such specifications are primarily useful when a CMS exists and the content solicited from users is at least somewhat standardized. For example, images, slides, or webpages may be easier for community partners to contribute than video games or 3D interactive content. No examples of guidelines for the latter were observed in the study.

Content Scheduling

Whereas the middleware section of this study examined the technical approaches to content management and automation, this section explores the frequency of exhibit rotation from a service design perspective. As can be observed in figure 5, no consistent or dominant model for exhibit scheduling has been identified in the study population. Generally, approaches to scheduling digital exhibits reflect organizational contexts. For example, museums typically design an exhibit and display it on a permanent basis, while academic institutions change displays of student work or scholarly communication once per semester. The following scheduling models have emerged in the descending order of frequency in the study population.

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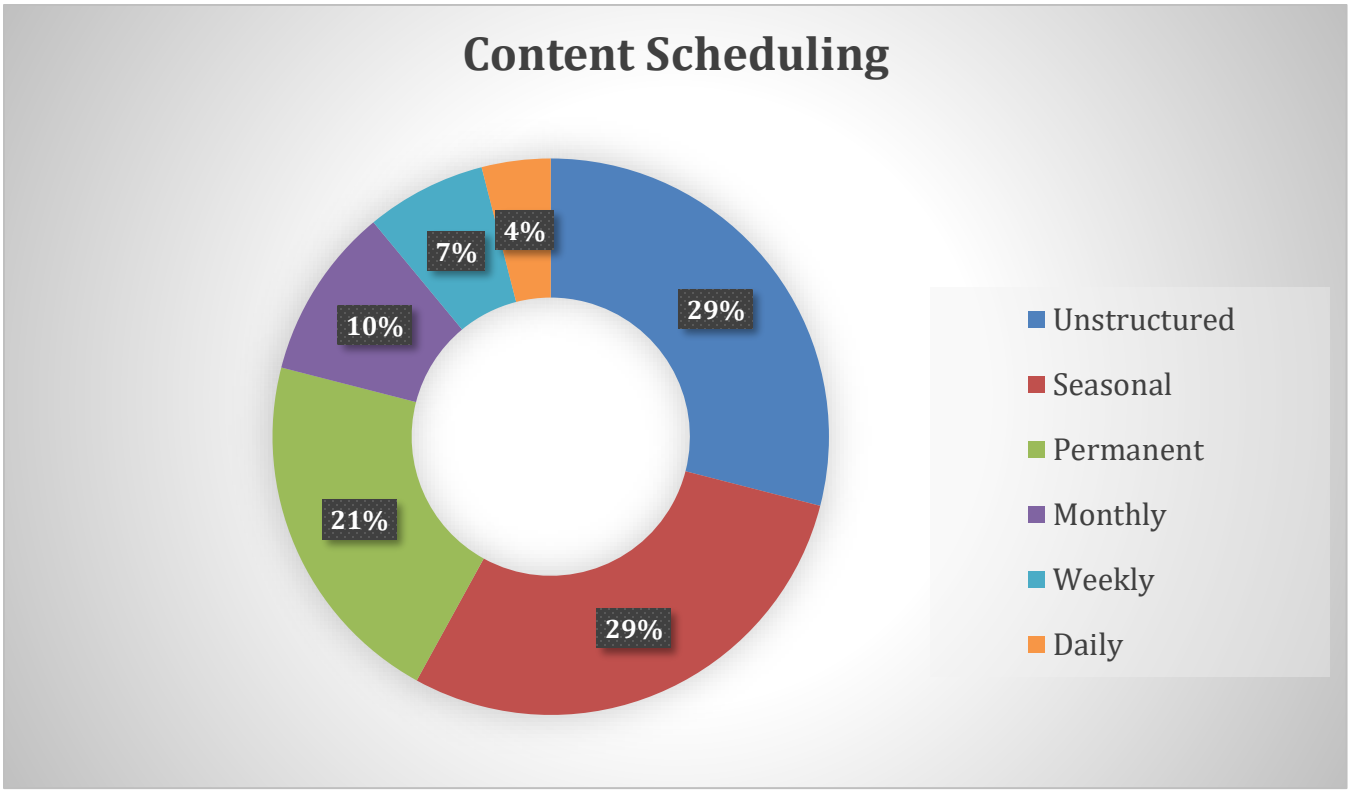

Figure 5. Content scheduling distribution in the study population.

1. **Unstructured (29%):** no formal approach, policy, or expectation is identified by the organization regarding displaying exhibits. This model is largely related to the early stage of service development in this domain, lack of staff capacity to support the service, and/or responsiveness to user needs. One study participant, for example, referred to this loose approach by noting that "*no formalized* approach and no official policy exists." For example, institutions may have frameworks for what types of content are acceptable but no specific requirements on the content subjects. Institutions adopting a lab space model (see figure 6) for digital displays largely belong to this category. In other words, content is created on the fly through workshops, data analysis, and other situations as needed by users. In this case, no formal scheduling is required apart from space reservations.
2. **Seasonal (29%),** which can be defined as a period from three to six months and includes semester-based scheduling in academic institutions. Many organizations operate on a quarterly basis, so it would seem logical that content refresh cycles reflect the broader workflow of the organization.
3. **Permanent (21%):** in the cases of museums, permanent exhibits may mean displaying content indefinitely or until the next hardware refresh, which might reconfigure the entire interactive display service. No specific date ranges were cited for this model.
4. **Monthly (10%):** this pattern was observed among academic libraries, with production of "monthly playlists" featuring curated book lists or other monthly specials.
5. **Weekly (7%):** North Carolina State University and Deakin University Libraries aim to have fresh content up once per week; they achieve this in part by formalizing the roles needed to support their digital display and visualization services.

6. **Daily (4%):** only Griffith University ensures that new content is available every day on its #SeeMore display; it does this largely by relying on standardized external and internal inputs, such as weather updates and the university marketing department content.

Staffing and Skills

One key element of the digital exhibits research project included investigating staffing models required to support a service of this nature. Not surprisingly, the theme around resource needs for digital exhibits emerged in most interviews conducted. Several participants have noted that one "can't just throw up content and leave it" while others advised to "have expertise on staff before tech is installed." Data gathered shows that the average full-time equivalent (FTE) needed to support digital display services in organizations interviewed was 2.97—around three full time staff members. In addition, 74% of the organizations studied had maintenance or support contracts with various vendors, including AV integrators, CMS specialists, creative studios that produced original content, or hardware suppliers. Hardware and AV integrators typically provided a 12-month contract for technical troubleshooting while creative studios ensured a 3-month support contract for digital exhibits they designed. The average time to create an original, interactive exhibit was between 9 and 12 months according to the data provided by creative agencies, The Cube teams, and learning organizations who have in-house teams creating exhibits regularly. This length of time varies on the complexity of interaction designed, depth of the exhibit "narrative," and modes of input supported by the exhibit application.

Additionally, it was important to understand the curatorial labor behind digital exhibits; the author did not necessarily speak with the curator of exhibits, and this work may be carried out by multiple individuals within organizations with digital displays or creative studios.

In 20 (57%) of the cases, the person interviewed also curated some of or all the content for the digital display in their respective institutions. In five (14%) of the cases, the individual interviewed was not a curator for any of the content, because there was no need for curation in the first place. For example, displays in these cases were used for analysis or teaching and therefore did not require prepared content. In the rest of the cases (10, or 29%), a creative agency vendor, another member of the team, or a community partner was responsible for the curation of exhibit content. This finding suggests that, while a significant number of organizations outsource the design and curation of exhibits, the majority retain control over this process. Therefore, dedicating resources to curation, organization, and management of exhibit content is deemed significant by the organizations represented in the study.

In terms of the capacity to carry out digital display services, skills that have been identified by study participants as being important to supporting work of this nature include the following:

1. technical skills (such as the ability to troubleshoot), general interest in technology, and flexibility and willingness to learn new things (74%)
2. design, visual, and creative sensibility (40%), as this type of work is primarily a visual experience
3. software-development or programming-language knowledge (31%)
4. communication, collaboration, and relationship-building (25%)
5. project management (20%)

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6. audiovisual and media skills (14%), as digital exhibits are "as much an AV experience as an IT experience," according to one study participant
7. curatorial, organizational, and content-management skills (11%)

The most frequent dedicated roles mentioned in the interviews are shown in table 3.

Table 3. Types of roles significant to digital exhibits work

Position	Responses	%
Developer/programmer	11	31
Project manager	8	23
Graphic designer	6	17
User experience or user interface designer	4	11
IT systems administrator	4	11
AV or media specialist	4	11

The relatively low percentages represented in this table suggest the distribution of skills mentioned above among various team members or combining multiple skills in a single role, as may be the case in small institutions or those without formalized services with dedicated roles. Nevertheless, the presence of specific job titles indicates understanding of various skill sets needed to run a service that uses digital displays.

Challenges and Successes

Many challenges were identified by study participants related to initiating and supporting a service that uses digital displays for learning. Clearly, multiple challenges could be associated with the services related to digital displays within a single organization. However, many successes and lessons learned were also shared by interviewees, often overlapping with identified challenges. This pattern suggests that some organizations can pursue strategies that address challenges faced by their library or museum colleagues while perhaps lacking resources or capacity in other areas related to this type of service. For example, some organizations have observed a lack of user engagement because of limited interactivity of the technology solution they used. Others have had successful user engagement largely by investing in technology solutions that provide a range of modes of interaction. It is important to learn from both these areas to anticipate possible pain points and to be able to capitalize on successes that lead to industry recognition and engagement from library customers. Table 4 summarized the range of challenges identified.

Table 4. Challenges related to digital display services

Challenge Identified	Responses	%
Technical	14	41
Content	11	33
Costs	11	33
User expectations	11	33
Workflow	10	29
Service design	9	26
Time	8	24
Organizational culture	8	24
User engagement	7	20

As reflected in table 4, several key challenges have been discussed:

1. **Technical**, such as troubleshooting the technology, keeping up with new technologies or upgrades, and finding software solutions appropriate for the hardware selected.
2. **Content**, such as coming up with original content or curating existing sources. In the words of one participant, "quality and refresh of content is key—it has to be meaningful, interesting, and new." This clearly presents a resource requirement.
3. **Costs**, such as the financial commitment to the service, the unseen costs in putting exhibits together, software licensing, and hardware upgrades.
4. **User expectations**, such as keeping the service at its full potential, using maximum functionality of the hardware, and software solutions. According to study participants, users "may not want what they think or they say they want," and to some extent, "such technologies are almost an expectation now, and not as exciting for users."
5. **Workflow or project-management strategies** specifically related to emergent multimedia experiences that require new cycles of development and testing.
6. **Time to plan**, source, create, troubleshoot, launch, and improve exhibits.
7. **Service design**, such as thinking holistically about the functions of the technology within the larger organizational structure. As one study participant stated, organizations "cannot disregard the reality of the service being tied to a physical space" in that these types of technologies are both a virtual and physical customer experience.
8. **Organizational culture and policy**, in terms of adapting project-based approaches to planning and resourcing services, getting institutional support, and educating all staff about the purpose, function, and benefits of the service.
9. **User engagement**, particularly keeping users interested in the exhibits and continually finding new and exciting content. Various participants have found that "linger time is

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between 30 seconds to few minutes" and content being displayed needs to be "something interesting, unique, and succinct, but not a destination in itself."

Despite the clear challenges with delivering digital exhibits services, organizations that participated in this study have identified keys to success (see table 5).

Table 5. Successes and lessons learned in using digital displays

Successful Approach or Lesson Identified	Responses	%
User engagement and interactivity	16	47
Service design	14	41
"Wow" factor	12	35
Organizational leadership	12	35
Technology solution	10	29
Flexibility	10	29
Communication and collaboration	10	29
Project management	9	26
Team and skill sets	9	26

As reflected in table 5, several approaches have been discussed:

- **User engagement and interactivity**, particularly for those institutions that invested in highly interactive and immersive experiences; the rewards are seen in interest and enthusiasm of their user groups.
- **Service design**: organizations that have carefully planned the service have found that this technology was successfully serving the needs of their user communities.
- **Promotion and "wow factor**" that has brought attention to the organization and the service. It is not surprising that digital displays are central points on tours of dignitaries, political figures, and external guests. Further, many have commented that they "did not imagine a library could be involved in such an innovative experiment," and others have added that their digital displays have "created new conversations that did not exist before."
- **Leadership and vision** at the organizational level, which secures support and resources as well as defines the scope of the service to ensure its sustainability and success: "Money is not necessarily the only barrier to doing this service, but risk taking, culture."
- **Technology solution**, where "everything works" and both the organization and users of the service are happy with the functionality, features, and performance of the chosen solution.
- **Flexibility and willingness to learn new things**, including being open to agile project-management methods, taking risks, and continually learning new tools, technologies, and processes as the service matures.

- **Communication and collaboration**, both internally among stakeholders and externally by building community partnerships, new audiences, and user participation in content creation. For example, one study participant noted that the technology "has contributed to giving the museum a new audience of primarily young people and families—a key objective held in 2010 at the commencement of the gallery refurbishments."
- **Workflow and project management** for those embracing new approaches required to bring multiple skill sets together to create engaging new exhibits. As one participant has put it, "These types of approaches require testing, improvement, a new workflow and lifecycle for the projects."
- **Having the right team with appropriate skills to support the service,** though this theme was rated as being less significant than designing services effectively and securing institutional support for the technology service. In other words, study participants noted that having in-house programming or design skills is not enough without proper definition of success for digital exhibits services.

Perceptions

Institutional and user reception of digital displays as a service to pursue in learning organizations has been identified as overwhelmingly positive, with 87% of the organizations noting positive feedback. For example, one study participant noted the positive attention received by the wider community for the digital display, stating "it is our flagship and people are in general impressed by both the potential and some of the existing content." Some participants have gone as far as to say that the reception among users has been "through the roof" and they have "never had a negative feedback comment" about their display. This finding indicates a high degree of satisfaction with such technologies by organizations that pursued a digital display. Table 6 further explores the range of perceptions observed in the study.

Table 6. Perception of digital display services

Perception	Responses	%
Positive	20	87
Hesitation or uncertainty	7	30
Concerns about purpose	4	17
Concerns about user engagement	4	17
Concerns about costs	3	13
Negative	3	13

A minority (13%) have noted some negative perceptions, largely related to concerns about costs or functionality of the technology; 30% have observed uncertainty and hesitation on behalf of the staff and users in terms of engagement as well as interrogating its purpose in the organization. For example, one study participant summarizes this mixed sentiment by saying, "The perception is

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that it's really neat and worthwhile for exploring new ways of teaching, but that the same features and functions could be achieved with less (which we think is a good thing!)." It is helpful to note this trend in perception, as any new service will likely bring a mixture of excitement, hesitation, and occasional opposition. Interestingly, these reactions have originated both from the staff of organizations interviewed and their communities of users.

DISCUSSION

The findings from this study indicate that the functions of the digital displays are highly dependent on the organizational context in which displays exist. This context, in turn, defines the nature of the services delivered through the digital display. For example, figure 6 can be useful in classifying the various ways digital displays appear in the study population, from research and teaching-oriented lab spaces to public spaces with passive messaging or active immersive game-like digital experiences.

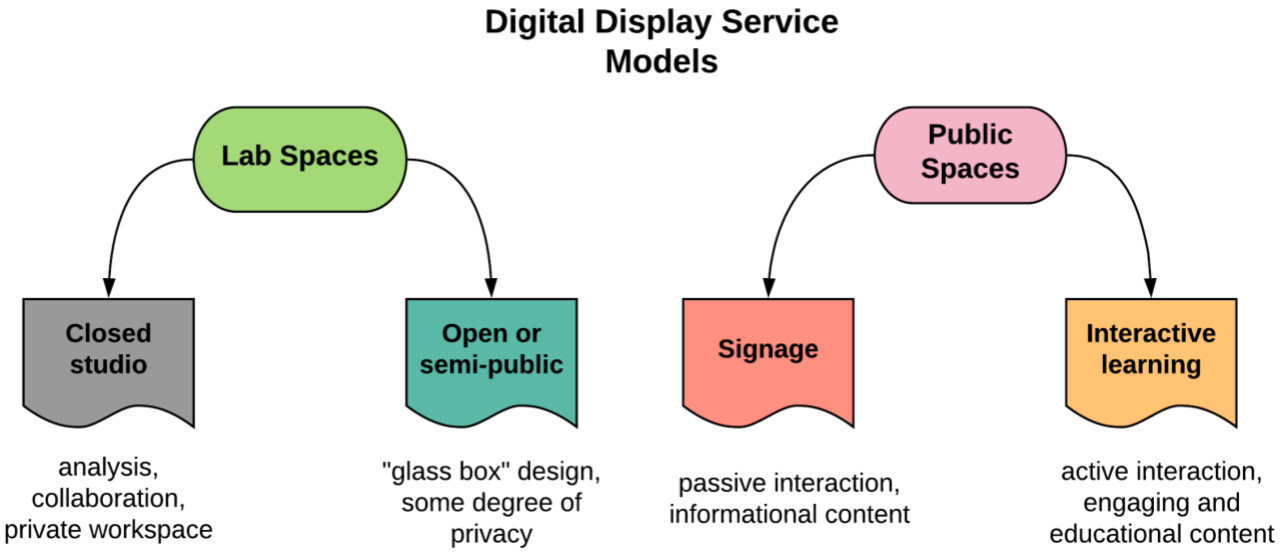

Figure 6. Types of digital displays in the study population.

As such, visualization walls might belong in the "lab spaces" category that typically appears in academic libraries or research units and do not require content planning and scheduling. What we might call "digital interactive exhibits" tend to appear in museums and galleries with a primarily public audience and may have a permanent, seasonal, or monthly rotation schedule. However, despite a range of approaches taken to provide content and in terms of use of these technologies, many organizations share resourcing needs and challenges, such as troubleshooting the technology solution, creating engaging content, and managing costs of interactive projects. Despite these common concerns, the digital-exhibits services were perceived as being overwhelmingly satisfactory in all types of organizations included in this study because they brought new audiences to the organization and were often seen as "showpieces" in the broader community.

The data gathered in the environmental scan demonstrates that there is currently little consistency among digital displays in learning environments. This lack of consistency is seen in content-development methods among study participants, their programming, content

management, technology solutions, and even naming of the display (and, by extension, the display service). For example, this study revealed that no evidently "open platform" for managing content at the application or the middleware level currently exists. A small number of software tools are used by organizations to support digital displays, but their use is in no way standardized, as compared to nearly every other area of library services. There is some indication that digital-display services may become more standardized in the coming years, and more tools, solutions, vendors, and communities of practice will be available. For example, many signage CMSs are currently on the market, and the number of game-like immersive experience companies is growing, suggesting extension of these services to libraries in the coming years. Only a few software tools exist for creating exhibits, such as IntuiFace and TouchDesigner, though no free, open-source versions of exhibit software are currently available. As well, the growing number of digital exhibits and interactive media companies currently focuses on turnkey—rather than software-as-a-service or platform—solutions.

In contrast, some consistency exists in staffing needs and skills required to support the digital-exhibits service. A majority of organizations interviewed agreed that design, software development, systems administration, and project-management skills are needed to ensure digital-exhibits services run sustainably in a learning organization. In addition, lack of public library representation in this study makes it challenging to draw parallels to the library context. Adapting museum practices is also not necessarily reliable, as there is rarely a mandate to engage communities and partner on content creation, as there is in libraries. For example, only the El Paso (Texas) Museum of History engages the local community to source and organize content.

These findings suggest that digital displays are a growing domain, and more solutions are likely to emerge in the coming years. The Cube, compared to the rest of the study population, is a unique service model because it successfully brings together most elements examined in the environmental scan. For example, to ensure continual engagement with the digital display, The Cube schedules exhibits on a regular basis and employs user interface designers, systems administrators, software engineers, and project managers. It also extends the content through community engagement, public tours, and STEM programming. It has created an in-house middleware solution to simplify exhibit delivery and has chosen Unity3D as its platform of choice for exhibit development.

LIMITATIONS

Only organizations from English-speaking countries were interviewed as part of the environmental scan. It is therefore unclear if access to organizations from non–English-speaking countries would have produced new themes and significantly different results. In addition, as with all environmental scans, the data is limited by the degree of understanding, knowledge, and willingness to share information of the individual being interviewed. Particularly, individuals with whom the author spoke may or may not have been technology or service leads for the digital display at their respective institutions. Thus, the study participants had a range of understanding of hardware specifications, functionality, and service-design components associated with digital displays. For example, having access to technology leads would have likely provided more nuanced responses around the middleware solutions and the underlying technical infrastructure required to support this service.

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A small number of vendors were also interviewed as part of the environmental scan even though vendors did not necessarily have digital displays or service models parallel to libraries or museums. They are included in appendix B. Nevertheless, gathering data from this group was deemed relevant to the study, as creative agencies have formalized staffing models and clearly identified skill sets necessary to support services of this nature. In addition, this group possesses knowledge of best practices, workflows, and project-management processes related to exhibit development.

Finally, this environmental scan also did not capture any interaction with direct users of digital displays, whose experiences and perceptions of these technologies may or may not support the findings gathered from the organizations interviewed. These limitations were addressed by increasing the sample size of the study within the time and resource constraints of the research project.

CONCLUSION

The findings of this study show that the functions of digital-display technologies and their related services are highly dependent on the organizational context in which they exist. However, despite a range of approaches taken to provide content and in terms of use of these technologies, many organizations share resourcing needs and challenges, such as troubleshooting the technology solution, creating engaging content, and managing costs of interactive projects. Despite these common concerns, digital displays were perceived as being overwhelmingly positive in all types of organizations interviewed in this study, as they brought new audiences to the organization and were often seen as "showpieces" in the broader community. The successes and lessons learned from the study population are meant to provide a broader perspective on this maturing domain as well as help inform planning processes for future digital exhibits in learning organizations.

APPENDIX A. ENVIRONMENTAL SCAN QUESTIONS

Digital Exhibits Environmental Scan Interview Questions—Museums, Libraries, Public Organizations

1. What are the technical specifications of the digital interactive technology at your institution?
2. Who are the primary users of this technology (those interacting with the platform)? Is there anyone you thought would use it and isn't?
3. What are primary uses for the technology (events, presentations, analysis, workshops)?
4. What types content is supported by the technology (video, images, audio, maps, text, games, 3D, all of the above?)
5. Where is content created and how is this content managed?
6. What is the schedule for the content and how is it prioritized?
7. Can you estimate the FTE (full-time equivalent) of staff members involved in supporting this technology/service, both directly and indirectly? What does indirect support for this technology entail?
8. In your experience, what kinds of skills are necessary in order to support this service?
9. Have partnerships with other organizations producing content to be exhibited been established or explored?
10. What challenges have you encountered in providing this service?
11. What have been some keys to the successes in supporting this service?
12. What has been the biggest success of this service and what has been the biggest disappointment?
13. What is the perception of this technology in institution more broadly?
14. Are there any other institutions you suggest we contact to learn more about similar technologies?

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Digital Exhibits Environmental Scan Interview Questions: Vendors

1. What is the relationship between creative studio and hardware/fabrication? Do you do everything or work with AV integrators instead to put together touch interactives?
2. Who have been the primary users of the interactive exhibits and projects you have completed?
3. Who writes the use cases when creating a digital interactive exhibit?
4. What types content is supported by the technology (video, images, audio, maps, text, games, 3D, all of the above?) Do you see a rise in interest for 3D and game-like environments and do you have internal expertise to support it?
5. Where is content created for the exhibits and how is this content managed? Who curates?
6. What timespan or lifecycle do you design for?
7. How big is your team? How long to projects typically take to create?
8. What types of expertise do you have in house? What might a project team look like?
9. To what extent is there a goal of sharing knowledge back with the company from clients or users?
10. What challenges have you encountered in providing this service?
11. What have been some keys to the successes in supporting this service?

APPENDIX B: STUDY POPULATION IN ENVIRONMENTAL SCAN

Organization	Location	Date Interviewed
All Saints Anglican School	Merrimac, Australia	July 25, 2016
Anode	Nashville, TN	July 22, 2016
Belle & Wissell	Seattle, WA	July 26, 2016
Bradman Museum	Bowral, Australia	July 10, 2016
Brown University Library	Providence, RI	June 3, 2016
University of Calgary Library and Cultural Resources	Calgary, AB	June 2, 2016
Deakin University Library	Geelong, Australia	June 14, 2016
University of Colorado Denver Library	Denver, CO	June 24, 2016
Duke University Library	Durham, NC	August 17, 2016
El Paso Museum of History	El Paso, TX	June 24, 2016
Georgia State University Library	Atlanta, GA	June 10, 2016
Gibson Group	Wellington, New Zealand	July 16, 2016
Henrico County Public Library	Henrico, VA	August 9, 2016
Ideum	Corrales, NM	July 26, 2016
Indiana University Bloomington Library	Bloomington, IN	May 31, 2016
Interactive Mechanics	Philadelphia, PA	August 2, 2016
Johns Hopkins University Library	Baltimore, MD	June 20, 2016
Nashville Public Library	Nashville, TN	July 22, 2016
North Carolina State University Library	Raleigh, NC	June 8, 2016
University of North Carolina atChapel Hill Library	Chapel Hill, NC	June 2, 2016
University of Nebraska Omaha	Omaha, NE	June 16, 2016
Omaha Do Space	Omaha, NE	July 11, 2016
University of Oregon Alumni Center	Eugene, OR	June 7, 2016
Philadelphia Museum of Art	Philadelphia, PA	August 10, 2016
Queensland University of Technology	Brisbane, Australia	June 30; July 29, 2016; August 16, 2016
Société des Arts Technologiques	Montreal, QC	August 8, 2016
Second Story	Portland, OR	July 28, 2016
St. Louis University	St. Louis, MO	July 4, 2016
Stanford University Library	Stanford, CA	July 22, 2016
University of Illinois at Chicago	Chicago, IL	June 22, 2016
University of Mary Washington	Fredericksburg, VA	July 7, 2016
Visibull	Waterloo, ON	August 12, 2016
University of Waterloo Stratford Campus	Stratford, ON	June 22, 2016
Yale University Center for Science and Social Science Information	New Haven, CT	July 13, 2016

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APPENDIX C: DIGITAL CONTENT PUBLISHING GUIDELINES

Organization Name	Guidelines Website
Deakin University Library	http://www.deakin.edu.au/library/projects/sparking-true-imagination
Duke University	https://wiki.duke.edu/display/LMW/LMW+Home
Griffith University	https://intranet.secure.griffith.edu.au/work/digital-signage/seemore
North Carolina State University Library	http://www.lib.ncsu.edu/videowalls
University Colorado Denver	http://library.auraria.edu/discoverywall
University of Calgary Library and Cultural Resources	http://lcr.ucalgary.ca/media-walls
University of Waterloo Stratford Campus	https://uwaterloo.ca/stratford-campus/research/christie-microtiles-wall

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