Mapping the Current Landscape of Research Library Engagement with Emerging Technologies in Research and Learning:

Building and Managing Learning and Collaboration Spaces

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This is the seventh and final installment of a forthcoming report, *Mapping the Current Landscape of Research Library Engagement with Emerging Technologies in Research and Learning*, that will be published in its entirety by late 2020.

The following installments are being published as they become available at https://doi.org/10.29242/report.emergingtech2020.landscape:

- Executive Summary [published March 26, 2020]
- Introduction, Methodology, and Cross-Cutting Opportunities [published April 2, 2020]
- Facilitating Information Discovery and Use [published April 14, 2020]
- Stewarding the Scholarly and Cultural Record [published May 27, 2020]
- Advancing Digital Scholarship [published July 6, 2020]
- Furthering Learning and Student Success [published October 14, 2020]
- Building and Managing Learning and Collaboration Spaces [published November 12, 2020]

Landscape Overview

As libraries adopt off-site and compact storage options and grow their collections of digital content, the amount of space required for physical collections in library buildings has dramatically diminished. Spaces that were historically "configured around collections and their use" are being reconceived as flexible, interactive environments that connect users to the people and technologies that support learning, research, and creativity.[1] The impact of emerging technologies on library spaces is evident in the growing prevalence of makerspaces, studios, and labs outfitted with specialized equipment, and a movement towards thoughtfully integrating technology into all aspects of the library visitor experience.

Technologies such as high-resolution LED displays utilized in public spaces can showcase the library's involvement in the full "content lifecycle (creation, access, management, curation) for both e-content and analog content."[2] Tablets and touch-screen kiosks can display real-time information and facilitate room booking, event registration, circulation, and other activities. And as the broader focus of public spaces planning has shifted towards designing user experiences—that is, creating environments that respond and adapt to user needs, provide convenience and satisfaction, and empower users to reach their goals—libraries are considering how technology can productively shape user interactions with the full range of library spaces and services. Thoughtful integration of technology in library spaces has the potential to "reverse the library experience from one in which we expect the user to learn the library—how to navigate it both physically and virtually—to one in which the library 'learns' the user and adapts itself to the user's needs."[3]

Descriptions of libraries as "living labs"[4] and aspirations to transform buildings from "containers" into "living organisms"[5] signal a vision of library *spaces* as adaptable, communicative, experimental collaborators in knowledge creation.

Thoughtful integration of technology in the library building can support a range of user needs, from active collaboration to reflection and focused study. Research libraries "can and should accommodate multiple forms of knowledge-seeking—and better yet, and most critically for the continued vibrancy of the institution, forge connections between the old and new."[6] The following sections explore the ways in which libraries are addressing this challenge in their space planning and programming, specifically addressing the effects of the Internet of Things (IoT), immersive reality, and artificial intelligence on how libraries conceptualize and create the learning and collaboration environments of the future.

Strategic Opportunities

Transform the library building into a living lab

While leading-edge technology is often most conspicuous in makerspaces and labs, some of the most transformative potential lies in the seamless and often invisible integration of emerging technologies into the full library visitor experience. The use of IoT technologies presents a particularly compelling opportunity for library spaces and services to dynamically adapt to user behaviors. The "ubiquitous use and integration of networking, sensing, and tracking technologies in physical environments" could transform the academic library into "a living-learning lab that senses and studies human dynamics, human-computer interactions, and human-building interactions."[7] The data generated by large-scale implementations of sensors and networked devices could become a dynamic data set for the entire community to mine. Libraries have an opportunity to pioneer inclusive, privacy-aware approaches to this integration of sensing technologies in the public sphere.

While the notion of flexibility in library space design has largely come to connote movable furniture, technology enables much broader and more transformative ideas of flexibility.[8] The use of tablets, smart devices, and custom applications can turn static spaces into

personalizable environments. The pop-up Alterspace project from the Harvard Library Lab, for example, allows users to select from a series of preset lighting and sound environments designed to enhance specific activities, such as focused learning, meditation, or creativity. Users can tweak the presets to create their optimal study environment.[9] Experimental spaces like the Alterspace inspire visions of entire library buildings outfitted with sensors that continuously monitor temperature, traffic flow, occupancy, light levels, and other metrics; and technologies that give users control over and insight into their environment. The data generated by a large-scale implementation of sensors could allow libraries to better understand users, improve spaces and services, and engage the community in designing ideal environments in real time.

Advances in "computationally-enabled devices and building architectures" are transforming the way people navigate and engage with their university campuses.[10] These technologies are lauded for making the student experience "seamless, simple, and streamlined."[11] Specifically, IoT technologies are being used to provide students with individual access to campus facilities and events, easy payment at campus dining, seamless connection to campus printers or other devices, and just-in-time, location-based information.

From virtual assistants (think Amazon's Alexa device) in each student's dorm room to Bluetooth beacons that record student attendance, college campuses are becoming sites of increased surveillance. While IoT and other smart spaces technologies may make students' lives more convenient and productive, they permit (and rely on) data-intensive monitoring and evaluation of students, generating significant concerns about privacy, bias, and the ethics of continuous data collection.

Data collected from IoT technologies around campus—such as an individual's visits to certain academic buildings like the library, their class attendance, or their participation in campus events—can be aggregated with other metrics—like grades and test scores—and demographic information to measure (or even predict) a student's

success.[12] While often well-intentioned, this approach to student monitoring has alarmed privacy advocates and generated serious concerns about how the collection and use of student data could harm students, especially those from already marginalized and underrepresented populations.

Continuous surveillance and the use of black-box algorithms to analyze data introduces opportunities for bias and misuse. Much has been written on the potential consequences of over-reliance on predictive models and AI in making decisions that could impact an individual's future. People of color and other marginalized groups are especially at risk of losing out in this environment. A recent study published in *Nature* found "rampant racism in decision-making software" widely used in hospitals, leading to poorer health care outcomes for people of color.[13]

There are also risks that user data could be compromised by human error or malicious actors, potentially exposing identifying or sensitive information, or providing third parties with access to a treasure trove of mineable data. Beacons technologies, for example, do not collect user data and "typically do not connect to the Internet without an additional layer of software that can interpret their signals."[14] However, those additional software layers can be used to collect and transmit information about a user's location, activities, or identity. Libraries have a particularly vested interest in ensuring user privacy, given their commitment to intellectual freedom. The use of sensors, even those that do not transmit data in compromising ways, could create an environment where users feel surveilled and therefore inhibited, potentially affecting "how they view the library and what information they seek out from library resources."[15]

There is little evidence that most research libraries have widely adopted IoT technologies in their buildings. Where they have been implemented, they are generally focused on making the user experience more convenient and on making spaces comfortable for both users and collections. At Concordia University's Webster Library,

for example, librarians developed a prototype system to measure and display noise levels in various areas of the library, allowing users to "choose the area with the right amount of noise for their purposes."[16] Although the prototype had not been deployed at scale as of the publication date, it is an example of an IoT-based technology that does not rely on invasive surveillance. The system does not record or process sound; it merely measures decibel levels. It makes no attempt to track or identify individual users or their behaviors. At the root, the system enhances, rather than compromises, a user's autonomy within the library space by allowing them to make an informed decision about appropriate study environments depending on their mood or intended activity.

Highlighted Initiatives

Alterspace
Harvard metaLAB and Library Innovation Lab
https://alterspace.github.io/

Harvard's Library Innovation Lab, embedded in the Law School Library, develops experimental projects that engage with the future of libraries. Their Alterspace project allows library users to control various aspects of their physical environment, including "light, color, sound and space" to give them the ability to optimize the space for specific activities, such as study, meditation, or creativity. Alterspace is an open-source project with code released on GitHub that can be reused or modified by other libraries.

Enhance the user experience in library spaces

Poor wayfinding in libraries has long preoccupied librarians, who strive to give visitors better tools to navigate warren-like stacks and intimidating service points. Enter Hugh, the robot librarian at Aberystwyth University, who can "search the catalog, identify a book's shelf location, and lead a patron to it."[17] Hugh is touted as a way to make the visitor experience more pleasant while freeing librarians to focus on more complex visitor needs as Hugh handles routine interactions.

While robot librarians remain a novelty, libraries are experimenting with a range of other emerging technologies to support wayfinding and just-in-time visitor services. Beacon technologies, which communicate with mobile devices via Bluetooth low-energy proximity sensing, hold particular promise. The move to 5G networks will accelerate the use of networked devices as data transmission speeds increase. One of the earliest proposed uses of beacons was to support wayfinding within buildings, particularly for those individuals with sight or other impairments that prevent them from benefiting from visual signage and navigation aids.[18]

Beacons can be used in conjunction with specially designed apps to create interactive maps that guide users through the library building with turn-by-turn directions and present students with just-in-time, location-aware information.[19] This could include information that makes visiting the library building more convenient (for example, alerts that direct users to unoccupied seating or during busy periods like the Waitz app deployed at UCSD and UC Santa Barbara[20]); more pleasant (for example, push notifications that remind users when they are entering a designated quiet area); more welcoming (for example, invitations to join library workshops or events as visitors enter the building); or more productive (for example, location-based recommendations systems that suggest nearby books of interest).[21]

A number of libraries have experimented with beacon technology to create self-guided library tours and navigational aids;[22] build augmented reality (AR) exhibits;[23] provide location-specific mobile alerts;[24] and help users locate materials in the library stacks.[25] An app developed at the University of Illinois at Urbana-Champaign, for example, can direct a user to a book in the stacks while providing real-time recommendations based on the user's location and the popularity of nearby items using circulation data.[26] Wearable devices could even provide real-time translation to help users identify materials in their non-native language in the stacks.[27] IoT technologies can also be used to give students access to restricted or reservable spaces (such as bookable study rooms)[28] or physical materials (such as smart lockers that hold course reserves for students in a given class).

Emerging technologies can also be used to enhance a sense of community within library spaces. One recent project uses beacons to create virtual micro-communities or zones within a large, flexible makerspace.[29] Several researchers have proposed hypothetical apps that use beacons to help users connect with one another around shared interests or goals.[30] An article on using beacon technology in study spaces asks readers to imagine "walking into a library commons and receiving recommendations on your phone about locations to sit based on the similarity of the research others are conducting nearby."[31] A similar project proposes an app that would "promote the portfolios, research work, etc. of people in the immediate vicinity by temporarily 'attaching' links to beacons," helping to "build a sense of collegiality as a diverse community of learners, researchers and practitioners."[32]

It is easy to see beacon technologies as simultaneously convenient and intrusive. While some users may appreciate location-based assistance and information, others may find it creepy or bothersome. Frequent alerts may be counterproductive in an environment designed to encourage focused study. Clear opt-in policies (and/or use of beacons exclusively in the context of a voluntarily downloaded app) are therefore advisable. General library privacy policies will require revision and expansion to address the many new ways in which user data may be collected and used.

Highlighted Initiatives

Waitz Find A Seat app
UC San Diego Library
https://libraries.ucsd.edu/visit/study-spaces/index.html

UC San Diego Library has created a study spaces app that shows students real-time space availability based on anonymized WiFi and Bluetooth traffic, in partnership with a startup, Waitz. Waitz sensors are installed throughout the library, and collect anonymized web traffic data to display the busyness of various study spaces to students.

Spaces planning and assessment

While many libraries have found foot traffic to their buildings remains as robust as ever, especially after space renovations that establish new learning and information commons,[33] they face increasing pressure to demonstrate the specific value and impact of their spaces. New tools can help libraries gather and interpret metrics well beyond gate counts and circulation statistics. Smart devices, machine learning, and other technologies have the potential to give libraries insight into library usage patterns that can help them plan for future space and service improvements.

Over a dozen articles in the library literature describe IoT-based approaches to spaces assessment.[34] Data from beacons and sensors, thermal imaging cameras, and other networked devices can provide real-time data about traffic flow (for example, how many visitors browse the stacks versus head straight for the learning commons) and space usage (for example, the number of occupied seats in various zones of the library, busy and slow times).

The Measure the Future Project developed a toolkit for using webcams and a computer vision algorithm to assess space usage.[35] The webcam identifies and tracks visitors to see where they congregate and how they move through a space, generating usage heat maps that librarians can use to understand what kinds of spaces are popular, address overcrowding, or learn about user behavior. The use of thermal cameras mitigates privacy concerns, making it significantly more difficult to identify individual users. Further, the cameras will not record activity when fewer than three individuals are in the frame.

Continuous data collection (think hundreds of sensors running 24 hours a day) will rapidly overwhelm traditional methods of data analysis. Libraries will need machine learning tools to sift through massive troves of sensor data to identify patterns and actionable insights. To fully leverage the data they collect, librarians will need data dashboards that support real-time monitoring and that aggregate data from a range of sources. At the University of Rochester, librarian

Lauren Di Monte and data scientist Nilesh Patil are using machine learning to study traffic patterns in the library building. The team set out to determine how many people who entered the library had come to use library spaces and services and how many were just passing through to access other buildings or areas of campus. The team developed a recurrent neural network model and trained an algorithm on data gathered from bidirectional gate counters. The model was then used to predict traffic based on previous patterns.[36]

While these new assessment tools offer exciting opportunities, they also come with limitations and risks. Few libraries have implemented networked monitoring devices at scale because equipping an entire building with sufficient beacons and other sensors to generate useful data remains expensive, and thoughtfully outfitting an entire library building to collect meaningful data takes intensive planning. As data analysts constantly caution, poor data collection methods lead to misleading or inaccurate conclusions.

Finally, data generated by sensors and other passive collection mechanisms will require complementary qualitative research to provide context. For example, using sensors to measure sound volume in a library space "does not reveal what people actually hear, nor how people value or use sound."[37] Emerging technologies represent an exciting addition to, rather than a replacement for, existing methods of space planning and evaluation.

Highlighted Initiatives

Measure the Future Project
http://jasongriffey.net/mtf/

The Measure the Future Project, funded by the Institute for Museum and Library Services, has created an open-source hardware and software toolkit that libraries can use to monitor and assess space usage. The project solves for patron privacy by using thermal cameras that make it difficult to identify individual users. The first phase of the project launched with pilots in a mix of public and academic libraries, including SUNY Potsdam and the New York Public Library.

Smart Commons project
Virginia Tech University Libraries
https://github.com/VTUL/smart-commons

Virginia Tech University Libraries' Smart Commons project has taken a different approach to collecting space usage data without compromising patron privacy. WiFi-connected motion sensors are attached to the bottom of individual chairs in the library Learning Commons, allowing for granular data collection on the number of seats occupied at any given time. The hardware plans and source code have been released on GitHub so other libraries can recreate the project.

Key Takeaways

1. **Libraries are thinking beyond the makerspace in considering emerging technologies in their spaces.** While many libraries have now built technology-rich makerspaces, VR/AR spaces, and digital media labs, transforming libraries into smart buildings can also mean infusing technology into the entire building and user experience, from sensors that anonymously monitor space usage to networked devices that allow users to customize their own study environments. Rather than drawing an artificial distinction between "hi-tech" and "traditional" library spaces, librarians are

considering how emerging technologies can inform all aspects of space planning and design.

2. **Libraries can leverage their historical commitment to patron privacy in designing user experiences that incorporate sensing technologies.** One notable commonality in the highlighted initiatives included in this section is they all incorporate privacy-aware approaches to collecting data about spaces, whether through anonymized WiFi data, thermal cameras that don't identify faces, or use of motion sensors. Although no longer an emerging technology, infrared beam door counters became ubiquitous in libraries over the past 30 years because they provided a convenient and low-cost way for libraries to track visitors without collecting identifiable user data. As the emerging projects described in this section become more mature and easier to implement, we can similarly expect widespread adoption by libraries.
3. **Develop library apps and tools with sustainability in mind.** Readers will note that many of the projects described in academic literature and featured in this section are no longer active. While some of this can be attributed to the nature of pilot projects that were not necessarily intended to continue, other projects have ended due to a staff member departing or grant funding running out. To mitigate against this tendency, libraries should take the same approach to apps and sensing projects that they do with digital content, and plan for sustainability. On a positive note, many of the projects included in this section have released their code on GitHub, so even if a project becomes inactive, another institution would be able to pick the project up later.
4. **Sensing technologies can empower users by giving them agency in library spaces.** Sensors, beacons, and microcontrollers can improve the user's experience of library spaces by helping them find the least crowded or noisy places to study in real time, be guided to finding books in the stacks, and give them control over their physical study environment. Emerging technologies "have the capacity to reverse the library experience from one in

which we expect the user to learn the library—how to navigate it both physically and virtually—to one in which the library "learns" the user and adapts itself to the user's needs."[38]

Endnotes

1. Lorcan Dempsey and Constance Malpas, "Academic Library Futures in a Diversified University System," in *Higher Education in the Era of the Fourth Industrial Revolution*, ed. Nancy W. Gleason (Singapore: Palgrave Macmillan, 2018), 65–89, https://doi.org/10.1007/978-981-13-0194-0_4.

2. Joan Lippincott, "The Link to Content in 21st-Century Libraries," *EDUCAUSE Review* 53, no. 1 (2018): 64-65, https://er.educause.edu/articles/2018/1/the-link-to-content-in-21st-century-libraries.

3. Steven J. Bell, "Staying True to the Core: Designing the Future Academic Library Experience," *portal: Libraries and the Academy* 14, no. 3 (2014): 369–382, http://dx.doi.org/10.1353/pla.2014.0021.

4. Yi Shen, "Intelligent Infrastructure, Ubiquitous Mobility, and Smart Libraries–Innovate for the Future," *Data Science Journal* 18, no. 11 (March 21, 2019): 11, https://doi.org/10.5334/dsj-2019-011.

5. Jonathan Bradley, Patrick Tomlin, and Brian Mathews, "Building Intelligent Infrastructures: Steps toward Designing IoT-Enabled Library Facilities," *Library Technology Reports* 54, no. 1 (2018): 23–27, https://doi.org/10.5860/ltr.54n1.

6. Dan Cohen, "Libraries Contain Multitudes," *Humane Ingenuity*, October 8, 2019, https://buttondown.email/dancohen/archive/humane-ingenuity-5-libraries-contain-multitudes/.

7. Shen, "Intelligent Infrastructure."

8. Cohen, "Libraries Contain Multitudes."

9. Reena Karasin, "From Public to Personalized: Alterspace Turns Libraries into Rooms of Requirement," *Scout Cambridge*, July 19,

2019, https://scoutcambridge.com/from-public-to-personalized-alterspace-turns-libraries-into-rooms-of-requirement/.

10. Shen, "Intelligent Infrastructure."

11. Itai Asseo et al., "The Internet of Things: Riding the Wave in Higher Education," *EDUCAUSE Review* 51, no. 4 (2016): 11-31, https://er.educause.edu/articles/2016/6/the-internet-of-things-riding-the-wave-in-higher-education.

12. Asseo et al., "Internet of Things."

13. Heidi Ledford, "Millions of Black People Affected by Racial Bias in Health-Care Algorithms," *Nature*, no. 574 (October 31, 2019): 608-609, https://doi.org/10.1038/d41586-019-03228-6.

14. Valeda Dent et al., "Wayfinding Serendipity: The BKFNDr Mobile App," *Code4Lib Journal*, no. 42 (November 8, 2018), https://journal.code4lib.org/articles/13811.

15. Matthew B. Hoy, "Smart Buildings: An Introduction to the Library of the Future," *Medical Reference Services Quarterly* 35, no. 3 (2016): 326–31, https://doi.org/10.1080/02763869.2016.1189787.

16. Janice Yu Chen Kung, "Raspberry Pi and Arduino Prototype: Measuring and Displaying Noise Levels to Enhance User Experience in an Academic Library," *Library Technology Reports* 54, no. 1 (2018): 18–22, https://doi.org/10.5860/ltr.54n1.

17. Steven Bell, "Promise and Peril of AI for Academic Librarians," *Library Journal*, April 14, 2016, https://www.libraryjournal.com?detailStory=promise-and-peril-of-ai-for-academic-librarians-from-the-bell-tower.

18. Ian Glover and Kieran McDonald, "Digital Places: Location-Based Digital Practices in Higher Education Using Bluetooth Beacons," in *Proceedings of EdMedia: World Conference on Educational Media and Technology*, ed. Theo Bastiaens (Association for the Advancement of Computing in Education (AACE), 2018): 950–959, http://www.learntechlib.org/p/184298/.

19. Glover & McDonald, "Digital Places."

20. Waitz website, accessed October 30, 2020, https://waitz.io/.

21. Jim Hahn, "Mobile Augmented Reality Applications for Library Services," *New Library World* 113, no. 9/10 (September 29, 2012): 429–38, https://doi.org/10.1108/03074801211273902.

22. Jonathan Bradley et al., "Creation of a Library Tour Application for Mobile Equipment Using IBeacon Technology," *Code4Lib Journal*, no. 32 (April 25, 2016), https://journal.code4lib.org/articles/11338.

23. Brandon Patterson, "Talking Portraits in the Library: Building Interactive Exhibits with an Augmented Reality App," *Code4Lib Journal*, no. 46 (November 5, 2019), https://journal.code4lib.org/articles/14838.

24. Sidney Eng, "Connection, Not Collection: Using iBeacons to Engage Library Users," *Information Today* 35, no. 10 (December 2015), http://www.infotoday.com/cilmag/dec15/Eng--Using-iBeacons-to-Engage-Library-Users.shtml; Somaly Kim Wu, Marc Bess, and Bob R. Price, "Digitizing Library Outreach: Leveraging Bluetooth Beacons and Mobile Applications to Expand Library Outreach," in *Digitizing the Modern Library and the Transition From Print to Electronic*, ed. Raj Kumar Bhardwaj (Hershey, PA: IGI Global, 2018), 193–203, https://doi.org/10.4018/978-1-5225-2119-8.ch008.

25. Dent et al., "Wayfinding Serendipity."

26. Jim Hahn, "The Internet of Things: Mobile Technology and Location Services in Libraries" *Library Technology Reports* 53, no. 1 (2017), https://doi.org/10.5860/ltr.53n1.

27. Ayyoub Ajmi and Michael J. Robak, "Wearable Technologies in Academic Libraries: Fact, Fiction and the Future," in *Mobile Technology and Academic Libraries: Innovative Services for Research and Learning*, ed. Robin Canuel and Chad Crichton (Chicago, IL: Association of College & Research Libraries, 2017), https://mospace.umsystem.edu/xmlui/handle/10355/60599.

28. Hubert C.Y. Chan and Linus Chan, "Smart Library and Smart Campus," *Journal of Service Science and Management* 11, no. 6 (November 28, 2018): 543–64, https://doi.org/10.4236/jssm.2018.116037.

29. Glover & McDonald, "Digital Places."

30. Bradley et al., "Building Intelligent Infrastructures"; Glover & McDonald, "Digital Places"; Hahn, "Internet of Things."

31. Bradley et al., "Building Intelligent Infrastructures."

32. Glover & McDonald, "Digital Places."

33. DeeAnn Allison et al., "Academic Library as Learning Space and as Collection: A Learning Commons' Effects on Collections and Related Resources and Services," *Journal of Academic Librarianship*, no. 45 (2019): 305-314, https://digitalcommons.unl.edu/libraryscience/384.

34. Jason Griffey, "How to Measure the Future," *Library Technology Reports* 54, no. 1 (2018): 11–17, https://doi.org/10.5860/ltr.54n1.

35. Griffey, "How to Measure."

36. Lauren Di Monte and Nilesh Patil, "Deep Learning for Libraries" (presentation, Code4Lib, Washington, DC, February 14, 2018), https://2018.code4lib.org/talks/deep-learning-for-libraries.

37. Andrew M. Cox, "Learning Bodies: Sensory Experience in the Information Commons," *Library & Information Science Research* 41, no. 1 (January 2019): 58–66, https://doi.org/10.1016/j.lisr.2019.02.002.

38. Steven J. Bell, "Staying True to the Core: Designing the Future Academic Library Experience," *portal: Libraries and the Academy* 14, no. 3 (2014): 369–382, https://doi.org/10.1353/pla.2014.0021.