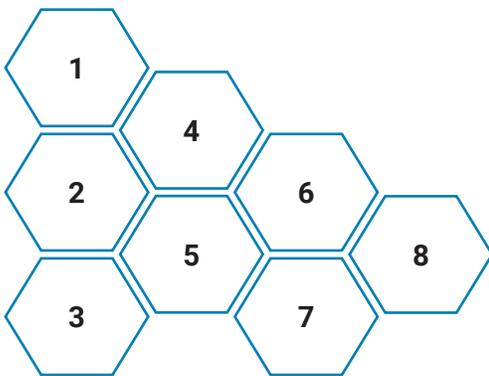


TECH AS ART

Supporting Artists Who Use Technology
as a Creative Medium



FRONT COVER:



1. Daniel Suominen in *16 [R]evolutions* by Troika Ranch. Photo by Richard Termine, full photo page 20
2. Refik Anadol, *Machine Hallucination*. Photo courtesy of Refik Anadol Studio, full photo page 88
3. Stephanie Dinkins, *Not the Only One*. Image courtesy of Stephanie Dinkins, full photo page 92
4. Paisley Smith and Lawrence Paul Yuxweluptun, *Unceded Territories*. Photo courtesy of the artists, full photo page 20
5. Darcy Neal. Photo courtesy of Darcy Neal, full photo page 93
6. Sondra Perry, *Young Women Sitting and Standing And Talking and Stuff (No, No, No)*. Photo by Sondra Perry, courtesy of the artist and Bridget Donahue, NYC, full photo page 20
7. Kyle McDonald, ELEVENPLAY, and Rhizomatiks Research, *discrete figures*. Photo by Suguru Saito, full photo page 24
8. Design I/O, *Connected Worlds*. Photo courtesy of David Handschuh, full photo page 89

TECH AS ART

Supporting Artists Who Use
Technology as a Creative Medium

Based on a field scan by the National Endowment for the Arts
in collaboration with the Knight Foundation and the Ford Foundation

June 2021

National Endowment for the Arts

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ABOUT THE REPORT

This report, *Tech as Art: Supporting Artists Who Use Technology as a Creative Medium*, presents findings from a field scan commissioned in 2019 by the National Endowment for the Arts in partnership with the Ford Foundation and the Knight Foundation. The purpose of the scan was to more fully understand how artists are incorporating digital technologies in their creative work and to learn more about the current and prospective sources of support for these artistic practices. Funders reading the report then can make smarter decisions on how to enhance support for this field. The research is grounded in literature reviews, interviews, and group discussions with artists and practitioners across the United States.

The report shares detailed findings; identifies challenges; and ends with recommendations for different stakeholder groups, including funders, arts practitioners, policymakers, and educators.

There are five main findings:

- **Code, computation, data, and tool-building are fundamental to technology-centered (“tech-centered”) artistic practice.**
 - ♦ Code, computation, and data can facilitate artists’ creative collaborations by enabling artists to create works across artistic forms and contexts.
 - ♦ Tool-building is both an artistic pursuit and a vital practice for this field. It expands access to software and computational thinking, and it supports the creativity of other artists through an open-source ethos.
- **Because the field is so diverse and dynamic, it has eluded easy labels. As a result, more traditional arts organizations and funders often have trouble finding entry points to engage with it.**
 - ♦ Tech-centered artists work fluidly across disciplines and formats, creating genre-defying artworks and spanning discipline-based curatorial and academic specialties.
 - ♦ Artists create projects within and between virtual and physical spaces, requiring distinct approaches to presentation, public engagement, accessibility, and archiving.
 - ♦ Arts organizations and funders face numerous challenges engaging with tech-centered artistic practices. These challenges include limited staff expertise, limited infrastructure, and difficulties in understanding how to evaluate artistic projects in this field.
- **Tech-centered artists have managed successfully to establish peer organizations, regional hubs, exhibition spaces, festivals, information networks, and academic departments across the United States.**
 - ♦ Physical hubs, in-person gathering spaces, and festivals provide opportunities for core community-building, learning, debate about contemporary trends, public engagement, training, exhibition, and specialized programs such as residencies and incubators.
 - ♦ Online resources and communities provide training and networking opportunities that often are free to the public. They enable participation beyond physical hubs and are particularly important for artists outside urban centers.

- ◆ Colleges and universities are prominent employers, incubators, and resource providers for tech-centered artists.
- ◆ While there are interconnected networks supporting tech-centered artistic practices, there are also significant resource gaps in the U.S.-based arts infrastructure, such as access to technical facilities, training, and exhibition opportunities, which can inhibit the growth of opportunities for artistic and professional development.
- **Career pathways for tech-centered artists are highly varied, though as a group these workers encounter many of the same obstacles as artists in general.**
 - ◆ Despite formal educational attainment, tech-centered artists described themselves as largely self-taught and reliant on artist-founded organizations, community hubs, and online resources for artistic and professional growth.
 - ◆ Artists cultivate multiple income streams to make a living—balancing freelance and creative gigs, employers, grants and awards, donations, and other income sources. Though corporate and commercial work are prominent income streams, these artists as workers share the same income instability and time constraints as artists in other disciplines.
 - ◆ Many of the artists observed in the field scan are entrepreneurial, collaborating across industry sectors, contributing to their local arts and cultural communities, and establishing businesses that draw on creative and digital skills.
- **Tech-centered artists are admirably poised to grapple with larger societal and sectoral challenges—whether engaging with audiences during the COVID-19 pandemic or responding to calls for greater equity and inclusion in the arts and technology. They can be invaluable partners for policymakers, educators, and practitioners in arts and non-arts sectors alike.**
 - ◆ These artists bring specialized expertise in using digital technology to connect with audiences across physical and virtual spaces.
 - ◆ Diversity, equity, and inclusion are common themes in this growing field of practice, and they can contribute to accelerated action in addressing racial inequities and social injustices across the arts and technology and other sectors.
 - ◆ Many of the artists discussed in this report seek to engage local communities, address social issues, and bridge digital divides through their tech-centered arts projects. Boundless opportunities exist for the arts and cultural sector to build beneficial partnerships with tech-centered artists and collaboratively imagine directions for future creative programming.



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PREFACE

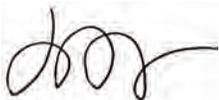
This National Endowment for the Arts report is a field scan of arts and technology in practice, reflecting upon the ways artists engage with—and develop—technology to remix, augment, and interrogate structures within arts and culture. While these tech-focused artists often pioneer new forms of expression, they also contribute to innovation in the wider sector, alongside potential avenues for economic growth. For these reasons and more, a comprehensive look at these artists and their support systems was of interest to the Arts Endowment and its partners, the Ford Foundation and the Knight Foundation.

This report offers insights for the broader arts and cultural sector, and also the fields of science, technology, engineering, and math (STEM), to discover shared goals and priorities with tech-focused artists and related practices. For example, the artists profiled in this report have established a range of culturally relevant arts projects and organizations that bridge digital divides and build 21st-century skillsets—services of profound importance to communities with limited access to training and education. In addition, they increasingly embrace the principles of diversity, equity, inclusion, and accessibility in their work, while routinely exploring ethical issues around technology—such as data privacy, artificial intelligence, and representation—valuable topics for those seeking to build a more equitable and diverse future.

The backdrop to this research is the COVID-19 pandemic, which forced the closure of public gathering spaces around the world in 2020. Artists and cultural organizations had no choice but to pivot practices to reach audiences virtually. As the shutdowns demonstrated, audiences are more than ready to engage digitally—yet many of the practitioners in this report view cultural organizations as underprepared to support the growing digital and virtual needs of artists and audiences. This context magnifies the role of the present report and suggests that more strategic investments are needed to boost the cultural sector’s capacity to serve artists and the public both in physical and in virtual spaces. While the need for these investments was evident prior to the COVID-19 pandemic, it has certainly become a preeminent concern today.

Here at the Arts Endowment, we have deepened our commitment to support activities at the intersection of arts and technology through our flagship Grants for Arts Projects program in the Media Arts discipline. We encourage applications for projects of all sizes from a variety of organizations—large and small, rural and urban. In addition to providing outreach and technical assistance to prospective applicants, we act as a catalyst for future partnerships and raise the visibility of existing initiatives that offer exemplary models and practices for connecting local communities with tech-focused arts programming.

As you embark on this report, I urge you to devote time to understanding how arts-and-technology practitioners can benefit your constituents and professional networks now and in the near future. Together, we can build the foundation for a more resilient and thriving arts and cultural ecosystem that includes greater support for arts practices focused on technology as a creative medium.



Jax Deluca
Media Arts Director
National Endowment for the Arts

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INTRODUCTION

Purpose of the Research

This report responds in part to the National Endowment for the Arts' FY 2017-2021 Research Agenda, which called for new investments in exploratory studies that describe factors that enhance or inhibit arts participation and/or arts and cultural assets, including the arts-and-cultural workforce.¹

Even before the COVID-19 pandemic pushed many facets of life online, Americans spent a significant proportion of their lives there. The Pew Research Center's 2019 data (pre-COVID) showed that 90 percent of American adults used the internet, and roughly three-quarters of American adults had broadband internet service at home.² Nearly all American adults—96 percent—reported owning a cellphone of some kind in 2019, and the share of Americans who owned smartphones in 2020 reached 81 percent.³ The Pew 2019 data also showed that about 72 percent of American adults used social media, including Facebook, Twitter, Pinterest, Instagram, and LinkedIn.⁴ Data from the Arts Endowment's 2017 Survey of Public Participation in the Arts showed 74 percent of U.S. adults used electronic/digital media to consume artistic or arts-related content, while 29 percent of adults who created art shared it on the internet.⁵ Among U.S. adults who created and shared art, the internet was a major vehicle for doing so.⁶ A previous version of the survey revealed that 46 percent of all adults who created visual art did so using electronic/digital media, while 28 percent of adults who created or performed music relied on media for this purpose.⁷

Research Methodology and Scope

The project's research plan focused on learning directly from the lived experiences of working artists engaging with technology through formal and informal arts settings, including those working in nonprofit, commercial, and community-based contexts spanning multiple sectors and artistic disciplines. Artists participating in the research were selected by National Endowment for the Arts staff in consultation with funding partners at the Ford and Knight foundations, with members of the project's Technical Working Group of national experts, and with the research team. Artists were chosen both to reflect the breadth of the U.S. in terms of race, gender, age, and geography, and to account for diverse areas of creative practice, levels and types of academic preparation, and stages of career.

1 National Endowment for the Arts, "Research Agenda," 4.

2 Pew Research Center, "Broadband Fact Sheet."

3 *ibid*, "Mobile Fact Sheet."

4 *ibid*, "Social Media Fact Sheet."

5 National Endowment for the Arts, 2017 Survey of Public Participation in the Arts. This percentage does not include other musical forms, including classical music or opera, jazz, or Latin, Spanish, or salsa music.

6 National Endowment for the Arts, *U.S. Patterns of Arts Participation*, 13.

7 National Endowment for the Arts, *A Decade of Arts Engagement*.

Data for this field scan was collected through the following activities:

1. **Four in-person roundtables** with a total of 66 practicing artists, held in New York City, Los Angeles, Miami, and Detroit,⁸ all conducted in fall 2019;
2. **One virtual town hall event**, open to the public, engaging 104 artists and arts leaders from 24 states and two foreign countries, held in early 2020;
3. **Twenty field interviews** with leading practitioners, including curators, arts writers, and leaders of academic departments, conducted in spring 2020;
4. **Nine artist case studies**, each involving multiple interviews in 2020;
5. **A literature review** of resources and publications relevant to the research questions;
6. **A grant portfolio analysis** of 150 recent National Endowment for the Arts grant awards related to arts and technology; and
7. **Three meetings with a Technical Working Group** of field representatives to review and discuss preliminary findings and draft of the report.

Through these activities, the research team explored the following research questions:

1. What are the ways artists use technology as a creative medium in their artistic practice?
 - a. *What is the range of examples of such work across artistic disciplines and technology platforms? Are there categories or classifications for identifying and describing this work, for example, by genre or sub-discipline or by type of technology used?*
 - b. *What is the range of career paths or trajectories taken by artists working with technology as a creative medium? Across artistic disciplines, how are these pathways similar or different? How do artists identify themselves within their range of work?*
 - c. *How do artists working with technology as a creative medium engage in cross-sectoral and/or cross-disciplinary partnerships? How do they engage within their local creative economies? How are these relationships formed and to what purpose? What are the associated risks, challenges, and opportunities for artists?*
2. What are current and prospective sources of support (financial and non-financial) for artistic practices using technology as a creative medium, and how might they be improved and/or sustained?
 - a. *What types of technical training and resources are used and needed to support artistic practices using technology as a creative medium? What gaps in training and resources currently exist for these artists across artistic disciplines and technology platforms?*
 - b. *What are current and emergent models for supporting artistic practices (financially and non-financially) using technology? Across artistic disciplines, how are these models similar or different? What are the pros and cons of these models for artists?*

⁸ Selection of regional roundtable sites was made collaboratively with the Ford and Knight foundations. Two sites—Miami and Detroit—are cities in which the Knight Foundation has offices and a history of community investment.

- c. *What are organizational risks, challenges, and opportunities in supporting artists working with technology as a creative medium? How do these differ among for-profit and nonprofit organizations? How do they differ by sector, artistic discipline, and/or technology platform?*
- d. *What techniques and frameworks provide on-ramps for artists representing under-resourced voices, perspectives, and practices in using technology as a creative medium?*

The field scan sought to document, clarify, and describe the practices, career pathways, and challenges of artists who make technology central to their practices. The research team also identified artists' levels of educational preparation, as well as the ways they make their livings and gather support for their work from diverse revenue sources. The field scan included not only the artistic fields that the Arts Endowment is currently supporting, but also emergent art forms.

A final set of roundtables will be held in 2021 to discuss findings with arts leaders, enable participants to connect with one another, and enlist attendees' assistance in amplifying the research findings and considering ways to seed new partnerships that act on the report's recommendations.

The Report's Focus

The intent of this report is to document the work of artists who make, interrogate, and disrupt contemporary digital technologies for creative and aesthetic purposes, and whose practices are enmeshed in the possibilities inherent in technology itself. The report examines the ecosystem of educational institutions, online forums, arts organizations, and public art programs that provide support structures around these artists, helping them to navigate and build unique career pathways and to share their work.

This report closely examines a growing field of artistic practice, with a focus on artists who “make digital technologies central” to their creative work—also referred to as “tech-centered artistic practice” throughout this report. These phrases refer to a robust collection of artistic activities that contribute value to the broader arts and cultural ecosystem and enrich the communities that surround them, including:

- **Creating artworks** with digital technologies—by writing code, employing computation, using datasets as material, and much more;
- **Building community** by developing shared digital tools, establishing and participating in online forums for knowledge exchange, and founding organizations and businesses in order to facilitate the creativity of others and improve access to digital literacy and training; and
- **Critiquing the influence** of digital technologies on daily life through an artistic practice that questions pervasive practices such as data collection and surveillance, and their disproportionate impact on communities of color, or confront the impact of technologies on the way we relate to ourselves and others.

This report was prepared principally for current and potential field supporters, many of whom manage funding programs or lead cultural organizations dedicated to provide artist support for specific artistic disciplines or geographic areas. Throughout the report, the research findings strive

to introduce potentially unfamiliar artistic processes and to help readers discover shared affinities and existing intersections across the many forms of contemporary artistic practice.⁹

Notably, by design, this report does not address the ways cultural institutions are deploying digital technology for the engagement of audiences or for the distribution of their existing programs through online platforms such as live or archived performance streaming, virtual museum and gallery tours, or digitization of analog collections. Absent is any discussion of the influence of blockchain on this sector, including the use of non-fungible tokens to assign digital signatures to works of art.¹⁰ Further, the report does not focus on the ways that traditional artistic disciplines now rely on digital tools for creative production: for example, the ways a composer uses software to write music or an architect uses software for drawing and drafting in 3D. And, while there are references to the COVID-19 pandemic, this report does not incorporate detailed information about the economic effects of the pandemic on artists and cultural institutions, or about the vitality and innovation of the field's response as it moves rapidly toward virtual programming and digital engagement in response to the closing of many arts institutions.

The report also does not address creative digital endeavors in the commercial entertainment industry or in pop culture. Research did not specifically examine the arts and sciences intersection of digital art practices or delve deeply into the expanding practices around "bio-art" (practices which, themselves, are worthy of research). Survey work or other research into digital technology in education initiatives is largely absent, as is detailed information about how participation is inhibited by a lack of broadband access.

The report's focus was honed during the research process as the study team learned about the broader arts and technology field, mapped clusters of artistic activities, and identified gaps in understanding and recognizing artists whose practice centers on technology as a creative medium. Research identified the dynamic breadth of artists whose practices are based in a technology itself. This cohort includes not only artists drawing on the expressive and narrative capabilities of digital technology, but also creative tool-builders who make digital tools for their own use and to benefit other creators. It also includes artists whose digital work engages audiences in questions around technology, inviting both participation and critique. Research also helped map the new support structures these artists have built to meet specific requirements for training, space, time, and money. In some cases, these structures have provided decades-long support for artists working with technology.

9 This report analyzes artists' practices and modes of self-identification in relation to established arts disciplines and categories, but the research is also informed by existing scholarship on artists working with digital technologies. There are many approaches to organizing information on the subject. Many extant studies take a chronological approach, outlining the ways that the development of particular technologies has intersected with historical art movements. Other studies focus thematically, delving into collaborations between arts and sciences, or exploring particular technologies and disciplines. Additional publications that have influenced this report organize artists' work around topics such as the body and identity, data collection and surveillance, activism and the democratization of participation, networked communities, and the concept of "virtuality." Examples of projects, artists, and practices included throughout this report have been informed by roundtable attendees; artists featured in case studies; field interviewees; the report's Technical Working Group; publications and online resources; festivals and conferences; and research to fill gaps in representation across demographics, geographies, and artistic practices. Key references on the history of the field that informed this report include Rush, *New Media in Late 20th-Century Art*; Wands, *Art of the Digital Age*; Shanken, *Art and Electronic Media*; Paul, *Digital Art*; Respini, *Art in the Age of the Internet: 1989 to Today*; and Conner, Dean, and Espenschied, *The Art Happens Here: Net Art Anthology*.

10 Blockchain is a growing area of inquiry, providing a method of ensuring authenticity of digital works of art and creating a record of the provenance of artworks while also providing a way for artists to monetize their work. For more information, please read <https://www.aam-us.org/2019/06/05/two-artists-on-the-future-of-blockchain-and-art/>.

These artists are also forging new entrepreneurial paths. Such paths often entail business model innovation for the cultural sector, demonstrate imaginative forms of public engagement, and forge inventive ways to partner across sectors. These emerging models suggest pathways for more traditional arts institutions seeking alternative ways to work. Particularly in the COVID-19 environment, artists who work with technology have the experience and orientation to reinvent digitally and to envision bold futures for cultural participation.

How the Report is Organized

Following this introduction, the report is organized in three chapters:

- **Exploring the Work:** The first chapter explores the work itself, probing and defining its borders, highlighting clusters of activity and creative energy, and tying contemporary practice to historical influences.
- **Navigating the Ecosystem:** The second chapter maps the creative ecosystem that supports and surrounds these artistic practices, including an overview of interconnected in-person and online communities, an examination of artists' career pathways, and ways of earning a living.
- **Next Steps for Supporters:** The third chapter details challenges for both artists and supporters of this work and offers recommendations for arts organizations, arts funders, educators, and policymakers who seek to build a flourishing creative economy nationwide.

Many terms used in this report are unique to the arts and technology sector. To aid the reader, a glossary of terms is provided in Appendix B.

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CHAPTER 1

Exploring the Work

“Given how we now live in a world where computation governs how we vote, how we shop, how we play, and how we make everything and anything, artists need open access to the same workbench of tools that the commercial technology community takes for granted... There has never been a more important time in history for artists to make their needed mark with the right set of computational tools to humanize our collective future.”

—John Maeda, Artist, Designer, Technologist

This chapter is divided into two sections:

- **Artistic Influences and Foundations** provides an overview of artistic practices in this field, their recent historical antecedents, and common working methods.
- **Crossing Contexts and Disciplines** examines the work itself—how artists traverse physical and virtual environments, creating work that both bears affinities with and differs from established artistic disciplines.

The first section begins by mapping the historical precedents for contemporary artists' inquiries into the capabilities of digital technologies. The section continues by featuring common ways that contemporary artists write and use code, data, and computation as essential building blocks for artistic creation, resulting in imaginative works that are wholly new conceptually, not based in prior art forms and disciplines. The section also provides insight into how and why artists engage in the process of digital tool-building, a uniquely generative artistic practice powering experimentation across the globe and influencing industry, education, and entertainment.

The second section illuminates the multifaceted nature of this field, which is deeply collaborative and often spans across traditional disciplinary boundaries. Such practitioners are not easily shoehorned into existing academic or artistic disciplines, and they benefit from organizations and approaches that are trans-, multi-, or post-disciplinary, working across multiple curatorial and programming departments.

The findings highlight the ways that artists work in virtual, physical, and hybrid spaces; the ways that artists forge transdisciplinary paths in areas such as new media art; and the ways that artists innovate from within artistic disciplines. Following this examination of history, process, context, and categorization, Chapter 1 comes full circle—starting and ending with a picture of artists with expansive practices who envision new creations made possible by the advanced technologies at their fingertips as well as by the technologies these artists develop.

ARTISTIC INFLUENCES AND FOUNDATIONS

“At different points, my work has been called by different names: hacking, trans-media, creative technology, VR/AR/XR, artificial intelligence. But fundamentally, the goal of my work has remained the same: to create art for diverse audiences that reflects our lived experience. Since our lives are intermediated through changing technologies, my work has taken different forms.”

—Amelia Winger-Bearskin, Artist, Technologist, Community-builder

A basic understanding of artistic influences and foundations is essential to capture the spirit of how (and why) artists experiment with technology across multiple disciplines, mediums, formats, and genres. While there is a novelty factor often associated with digital technologies, contemporary artists build on a solid basis of precedents spanning more than half of a century.

This section begins with a brief historical overview, followed by contemporary influences and methods at the core of creative work with digital technologies today:

- Artists have a rich history centering technology as core to their practice.
- Code, computation, and data are essential building blocks for artistic creation.
- Tool-building is an artistic pursuit and a vital foundation for creators.

Artists have a rich history centering technology as core to their practice.

Recent Historical Overview: 1960s to the Present

When the National Endowment for the Arts was founded in 1965, it entered a creative landscape influenced by active multimedia experimentation and technological development. Precursors to home computers were in the works, and in 1966, the U.S. Department of Defense launched ARPANET (Advanced Research Projects Agency Network), which became the foundation of the internet. Artists were already stretching the capabilities of early computers to create works such as elaborate or precise drawings impossible for the human hand,¹¹ and working across art forms and technologies to develop media-rich environments, performances, and events—from Andy Warhol in New York to the Brotherhood of Light in San Francisco, Gutai in Japan, and Fluxus internationally. Galleries had taken note and featured early computer artworks in exhibitions throughout the latter 1960s.¹²

11 For further analysis and history of the early use of computers for drawing projects, see Crowther, *Digital Art, Aesthetic Creation: The Birth of a Medium*.

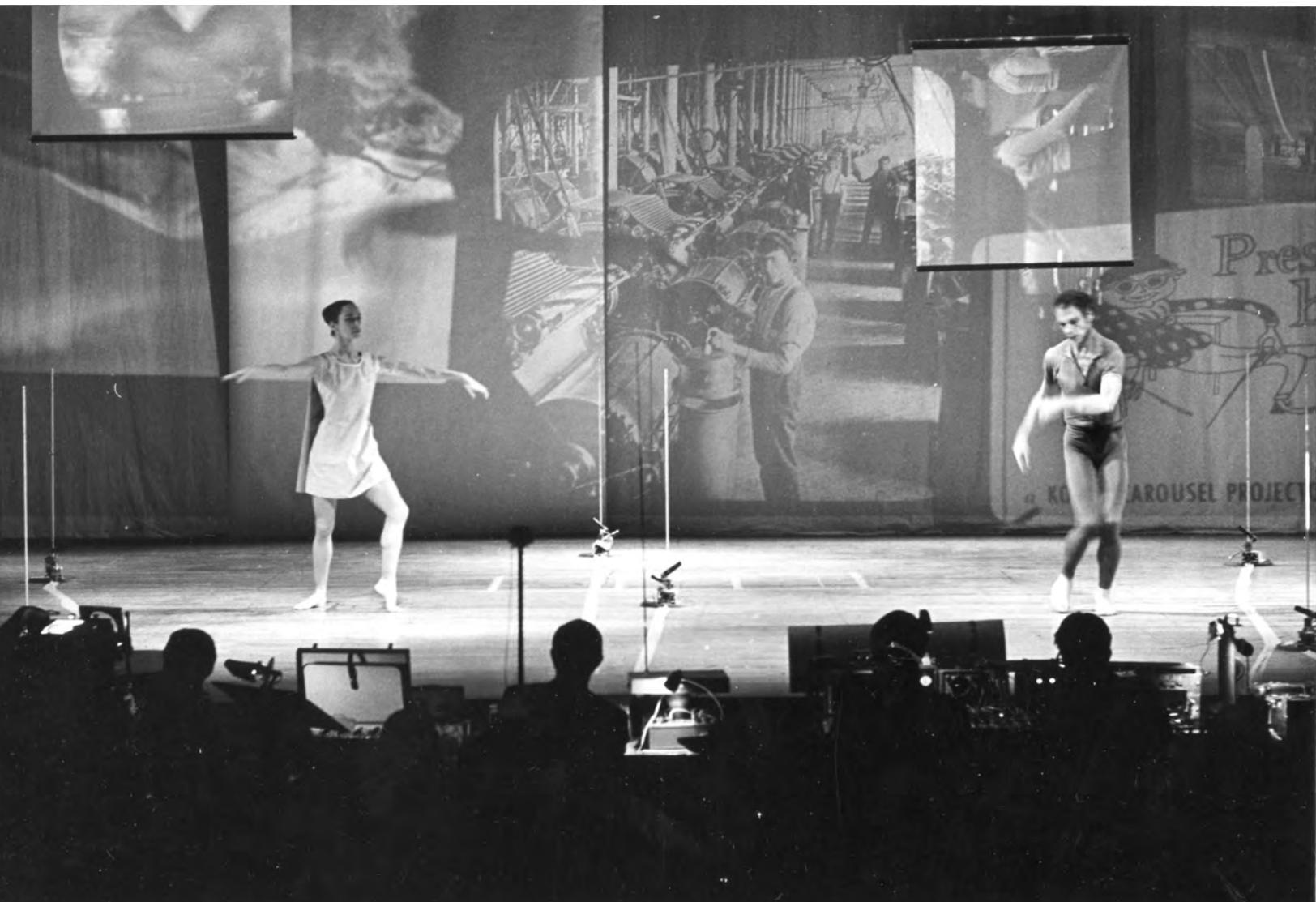
12 Exhibition examples include *Computer Generated Pictures* at the Howard Wise Gallery (New York City, NY, U.S.: 1965), *Generative Computergrafik* at the Technische Hochschule (Stuttgart, Germany: 1965), *Cybernetic Serendipity* at the Institute for Contemporary Arts (London, U.K.: 1968), and *Software—Information Technology: Its New Meaning for Art* at the Jewish Museum (Brooklyn, NY, U.S.: 1970).

Cross-sector collaborations were also developing. In 1966, a series of performances bringing together artists and engineers from Bell Laboratories, *9 Evenings: Theatre and Engineering*, paved the way for the establishment of Experiments in Art and Technology (E.A.T.), an organization which supported dozens of arts and engineering projects over several decades via tech-centered collaborations.¹³



Artists and engineers demonstrating a light and sound control system during a technical rehearsal for the performances at *9 Evenings: Theatre & Engineering*. From Left: Herb Schneider, Robert Rauschenberg, Lucinda Childs, Roby Robinson, Per Biorn, and Billy Klüver. Photo by Franny Breer, courtesy of E.A.T./Klüver/Martin Archive

13 Candy, Edmonds, and Poltronieri, *Explorations in Art and Technology*; Klüver's "E.A.T. – Archive of published documents."



Variations V is an example of an early intermedia performance collaboration among John Cage, Merce Cunningham, Gordon Mumma, David Tudor, Stan VanDerBeek, Nam June Paik (1966). Photo courtesy of E.A.T./Klüver/Martin Archive

Alongside the growth of television, video was becoming a medium for technical and artistic experimentation that would continue to develop over subsequent decades. Artists used the form to critique mass communication industries, test technical methods, explore different forms of storytelling, and remix found footage. Artists also blended video with other art forms, developing large-scale installations and melding video and performance.

In 1967, the U.S. government established the Corporation for Public Broadcasting (CPB) to promote and support the public broadcast ecosystem of noncommercial media and makers. Beyond CPB-supported public broadcasting entities, a range of organizations were promoting media as a platform for creative expression and public participation. Community radio, media arts centers, community media centers, and cable access began providing both avenues for creative output¹⁴ as well as classes and training, access to equipment, and mentorship for emerging content creators.¹⁵

¹⁴ Isgro, "Video Commune: Nam June Paik at WBGH-TV, Boston"; Kane, *Chromatic Algorithms: Synthetic Color, Computer Art, and Aesthetics After Code*.

¹⁵ Johnson and Menichelli, *What's Going on in Community Media*.

The 1970s saw the formation of notable artistic practices and convening spaces. For example, the Kitchen, a performance venue founded by artists Steina and Woody Vasulka in New York City in 1971, became a hub for video, performance art, and cross-disciplinary exploration. Sampling, looping, and remixing grew as a form of creative expression, influenced by Jamaican sound system culture and DJs like Grandmaster Flash, Kool Herc, and Afrika Bambaataa.¹⁶ In 1979, the Ars Electronica Festival was launched in Linz, Austria, as a “Festival for Art, Technology, and Society,” with an opening speech delivered by the robot SPA 12 and a “cloud of sound” that spread across the city’s public spaces.¹⁷

By the mid-1980s, artists were active on electronic Bulletin Board Systems—geographically networked communities that linked terminals and televisions through phone lines. The World Wide Web, developed by Tim Berners-Lee at CERN in 1989, enabled the formation of online artist communities in the early 1990s (such as rhizome.org and The Thing), as well as the growth of internet art, also known as net.art—bolstered by efforts such as the online mailing list nettime and the online gallery äda’web.

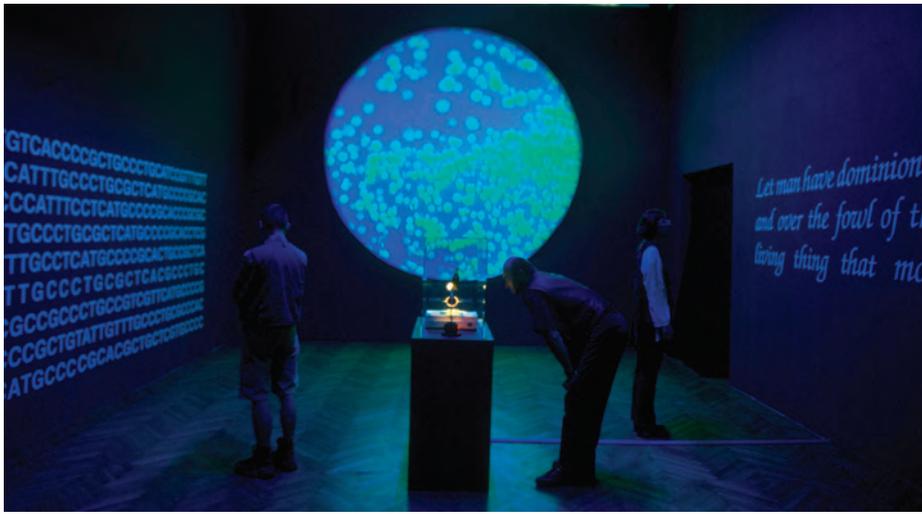
Early generations of artists working with digital technologies have followed many paths. The performing arts served as fertile ground for interweaving movement and multimedia effects. Technologies such as VR headsets offered artists avenues for worldbuilding. Consumer electronics provided ready-made products to hack, modify, and repurpose for creative use. Web pages created spaces for narratives to unfold across links that opened new screens and portals. Artists also used digital technologies to manipulate images, to create networked projects connecting disparate locations, to develop novel forms of interaction, and to collaborate across scientific specializations. Emergent technologies also provided future-facing artists with a framework for imagining relationships and societies beyond the injustices of the present, overlapping with influences from science fiction to social justice movements, and taking the shape of cultural currents such as Afrofuturism and Cyberfeminism. This spectrum of practices is only the tip of the iceberg, a glimpse of the many ways that artists were working with digital technologies as creative materials in the late 20th century.



Composer and synthesizer pioneer Suzanne Ciani was awarded a National Endowment for the Arts Composer Grant in 1976 to explore audio synthesis with the Buchla modular synthesizer. The resulting “Report to National Endowment” 40-page paper, which documented her live performance practices with the Buchla 200, has continued to be a standard reference for teaching. Photo by Bob Lichtman

¹⁶ For more information on the historic intersections of early hip-hop with technical and stylistic innovations, see Eshun, *More Brilliant Than the Sun: Adventures in Sonic Fiction*; Huang, “Original Creator: Hip-Hop and Electro Pioneer Afrika Bambaataa”; Banks, “From Jamaica to the Bronx”; and Flash and Ritz, *The Adventures of Grandmaster Flash*; Vineyard, “How Grandmaster Flash’s ‘Torque Theory’ Drove Hip-Hop”; Butler, “Grandmaster Flash on ‘The Get Down’ and how he used science to pioneer DJ techniques”; Howell, “The Lost Art of Sampling.”

¹⁷ Hirsch, *Creating the Future*, 49-50.



(Left) Transgenic artist Eduardo Kac is a pioneer of the bioart movement exploring the intersection of biotechnology, art, and bioethics, as shown by *Genesis* (1999), a transgenic work with artist-created bacteria, ultraviolet light, internet, and video. Photo by Otto Saxinger



(Above) Dancer Daniel Suominen accompanied a swash of light that follows his movement in Troika Ranch's work *16 [R] evolutions* which premiered in New York City at Eyebeam in 2006. Photo by Richard Termine



(Below) Interdisciplinary artist Sondra Perry combines video, computer-based media, and performance to explore themes of race, identity, family history, and technology, such as this performance of *Young Women Sitting and Standing And Talking and Stuff (No, No, No)* at the Miriam & Ira D. Wallach Art Gallery in 2015. Photo by Sondra Perry, courtesy of the artist and Bridget Donahue, NYC



(Right) *Unceded Territories* (2019) is a virtual reality experience created in collaboration between Paisley Smith and Indigenous artist Lawrence Paul Yuxweluptun, which features themes of colonialism, climate change, and indigenous civil rights. Photo courtesy of the artists

Technology in a New Era

At the turn of the millennium, Web 2.0, a “second generation” of the World Wide Web, expanded access to users less familiar with code and specialized digital production equipment through straightforward websites designed to facilitate user-generated content. Interactive websites and apps facilitated the rise of social media platforms, which in turn spurred a shift in cultural habits toward increased online activity and content creation. Smartphones and mobile devices presented artists with a new set of tools with which to experiment for artistic production and creation, such as augmented reality and location-based works that offer users playful interventions in public space.

This brief historical sketch provides background for the focus of this report: recent, current, and emerging practices at the intersection of arts and digital technologies. As digital technologies and capabilities have become more widespread, artists have continued to take them up for creative ends, honing their skills to innovate and adapt new tools along the way. In doing so, artists not only chart new paths in art forms—they also provide audiences, arts venues, and the arts sector with a fresh perspective on these technologies and our relationships with them.

Code, computation, and data are essential building blocks for artistic creation.¹⁸

Computation is an increasingly essential addition to the artist’s tool box, with the use of code and data acting as a bridge that allows artists to work fluidly across disciplines, genres, and formats. While practitioners working with computation may not typically consider themselves as being part of the same artistic field, what connects them is a shared practice of centering their work around these aspects of digital technology.

Creative and Functional Approaches

Artists are approaching the use of code as a creative material that gives life to ideas and that offers meaningful outlets for expression. The field of computation is itself a broad category. Now-familiar hardware devices such as tablets, laptops, and smartphones are just one face of computation. Artists today are developing and deploying computation that drives artificial intelligence and machine-learning programs, projection mapping, and immersive sound design, and they are utilizing devices for 3D printing, LED displays, robotics, and gaming—to name only a few examples.

Tech-centered artists elevate the aesthetic, social, and educational aspects of working with code, highlighting the creative along with the functional aspects of the medium. Both artist John F. Simon, Jr. and the School for Poetic Computation (SFPC) have compared coding to creative writing, with Simon emphasizing that “writing software is as creative as it is technical.”¹⁹ SFPC teaches the craft of code with a core motto of “more poetry, less demo” to encourage the creation of “strange, whimsical, and beautiful work”²⁰ rooted in computational thinking.

18 For explanations of code, creative processes using code, and applications of code across disciplines, see *Form + Code in Design, Art, and Architecture* by Casey Reas and Chandler McWilliams. In this book, Reas and McWilliams provide a basic orientation to terms and concepts referenced throughout this report. They begin describing code in terms of familiar associations—communication, clarification, and obfuscation—using examples of Morse code as a communication system; DNA/genetic code and legal codes as each a “set of rules”; and codes used to obscure meaning (11). Within their focus, they further define code in relation to a series of instructions (algorithms), explaining that, “In computer programming, code... is used to control the operations of a computer. It is an algorithm written in a programming language. There are thousands of programming languages, and new ones are developed every year” (15). For more exploring the range and definitions of computation, see Denning, “What is Computation?” and Horswill, “What is Computation?”

19 Simon, Jr. “Code as Creative Writing.”

20 School for Poetic Computation, “Mission.”



Onyx Ashanti

Onyx Ashanti combines street performance, free-jazz principles, and computer programming with his creation of a musical exoskeleton for live improvisational sound performances.

Musician Onyx Ashanti performs using his 3D printed musical exoskeleton designed for live improvisational sound performances using gestural movements. Photo by Paul Fomiletti, courtesy of Blank Forms

Creative application of code can also solve concrete problems. For example, members of Free Art and Technology (FAT) Lab, OpenFrameworks, the Graffiti Research Lab, and the Ebeling Group collaboratively developed the [Eyewriter](#) with a graffiti artist who had been diagnosed with Lou Gehrig's disease, a condition that left him paralyzed except for the movement of his eyes. At the time, commercial eye tracking tools cost upwards of thousands of dollars. With a goal of making this technology affordable for individuals facing mobility issues, Eyewriter's team of software developers, hardware hackers, and urban projection artists invented a low-cost creative solution using inexpensive cameras and open-source computer vision software. The developed software was released for free public use, and it also became the basis of larger public art project that allowed participants to draw temporary graffiti on buildings using light beams instead of paint.²¹

Code and Data as Artistic Material

A growing number of "data artists" are using information collected from mobile apps, GPS trackers, archives, or other means to create conceptual art works. Data sources are innumerable and include measurements, statistics, facts, and images. A few examples of data used by artists include satellite transmissions, crowdsourced content, and weather patterns. Streams of datasets can also be sourced in real-time, such as through the internet or captured using consumer and DIY electronics, such as MIDI controllers, accelerometers, microcontrollers, and facial recognition software.²²

As inputs, datasets serve as a core material for many artists who write code or use computational processes to transform the collected data into artistic interpretations, such as interactive visualizations for video projections, 3D-printed sculptural objects, or audio for live performance. For example, street performer Onyx Ashanti captures datasets using motion sensors embedded in a 3D-printed exoskeleton called a "Sonocyb." The data is captured through gestural movement, which is transformed into different sounds dictated by a custom-built software programmed by the artist. Through this process, Ashanti is able to generate live improvisational sound performances by freely moving his body.

Content generated by code often includes a deliberate set of instructions and parameters determined by the artist. A comparable reference to this type of conceptual arts approach is the

²¹ "The Eyewriter." Accessed April 5, 2021. <http://eyewriter.org/>

²² Urist, "From Paint to Pixels."

minimalist artist Sol LeWitt, who would provide instructions for the creation of his wall drawings to be executed by other people, and once famously stated, “the idea becomes a machine that makes the art.”²³ In this case, the “machine” is literal, generating art work in conjunction with the instructional concepts provided by the artist. Artistic output generated by machine can be seen in a variety of forms, such as Nettrice Gaskins’ “algorhythmic” visual illustrations, which use artificial intelligence and machine learning algorithms to represent concepts of rhythm and repetition rooted in Black cultural expression; and the global “live-coding” movement that relies on music and visuals generated from algorithms coded live by artists during experimental multimedia events called “algoraves.”²⁴



Nettrice Gaskin

Nettrice Gaskins is an artist and STEAM educator exploring algorithms and programming in her artistic and education-based practice. This portrait of Jessye Norman was created using a machine-learning process of deep learning and deep image style transfer.

Nettrice Gaskins, *Prima*, 2021, Deep Image Style Transfer. Image courtesy of the artist

The use of computational processes to visualize data can also make the invisible visible, revealing hidden connections and dynamic processes that surround us through visual projections, architecturally embedded screens, and immersive installations. Coining the terms “data sculpture” and “data painting,” artist Refik Anadol describes algorithms as his “brushes,” capable of producing intricate artworks, and data as “pigment.”

See case study on
Refik Anadol



Codie

Codie, a live-coding collective comprised of artists Sarah Groff Hennigh-Palermo, Melody Loveless, and Kate Sicchio, is part of a global movement of live-coding and algoraves.

A live-coding performance by Codie. Photo by Westley Hennigh-Palermo

23 F. Guner, “In Sol LeWitt’s Head is a Machine that Makes Art,” *The Arts Desk*, Oct. 31, 2015, <https://theartsdesk.com/visual-arts/sol-lewitts-head-machine-makes-art>

24 “Art & Algorhythms.” Accessed April 5, 2021. <https://www.nettriccaskins.com/>

Data as Critical Lens

Data play many roles within creative processes. Artists may involve the audience in data collection, analyze large datasets to reveal trends or connections, or collaborate with scientists to present information about pressing topics such as climate change. Artists also use data to shed light on invisible systems; question ethical data use; and explore technologies that are poised to have a large societal impact, such as data mining, facial recognition, and location tracking.

Datasets also serve as lenses for uncovering cultural indicators and viewing histories in a new light. Tahir Hemphill's Hip Hop Word Count is a database that includes lyrics to more than 50,000 songs. The project is a rich source for deepening the cultural analysis of hip-hop prose and is searchable by a variety of metadata fields, such as date, artist, word complexity, and geography. As an extension of this work, Hemphill established the Rap Research Lab, a creative technology studio that combines rap and data visualization as an access point to engage communities in data literacy and to explore questions of social justice. During Hemphill's 2018 tenure as the Harissios Papamarkou Chair in Education for the Library of Congress, his practice as a "radical archivist" deepened investigations in the scholarly humanities field by examining archival documents and data to "pressure the idea of The Library as a neutral space."²⁵

Code, Computation, and Data as Connective Tissue

In addition to serving as creative materials, the foundational elements of code, computation, and data open the door for artists to navigate across areas of practice. Artists combine fluency in code with other skills and goals—to produce objects, live performances, web-based interactions, mobile apps, interactive installations, and other art forms. In this manner, digital competencies serve as a bridge between artists and other communities and collaborators.



Kyle McDonald

Kyle McDonald is an artist and technologist working across multiple fields of practice. His collaborative work with Rhizomatiks Research and the dance troupe ELEVENPLAY has resulted in interactive multimedia performances that explore the relationship between choreographed movement, the human body, and computer-generated beings through the use of drones, artificial intelligence, and machine learning.²⁶

The multimedia dance performance *discrete figures* (2018) is a collaboration of Kyle McDonald, the dance troupe ELEVENPLAY, and Rhizomatiks Research. Photo by Suguru Saito

Artists are also gathering around particular skillsets, such as the use of code and computation across various disciplines and platforms, rather than gathering around a particular artistic medium, genre, or form. For example, [Kyle McDonald](#) identifies as "an artist working with code," using skills

25 Mears, "Creative Technologist and 2018 Papamarkou Chair Tahir Hemphill Looks Back on His Year in the Archives."

26 McDonald, "Dance x Machine Learning: First Steps."

in machine learning, computer vision, and surveillance technologies. His projects span a variety of disciplines and forms and have included large-scale immersive installations, interactive visuals for dance performances, and social media interventions. His practice also includes the development of open-source software toolkits that enable other artists to easily employ these skillsets into their own creative projects.²⁷

Interest in such interdisciplinary approaches to arts and technology is reflected by newer academic programs that teach students the skills to navigate coding languages, datasets, and related hardware and/or software in order to create physical and virtual works across multiple mediums and genres. For example, the [University of Nebraska's Bachelor of Fine Arts in Emerging Media Arts](https://arts.unl.edu/academics/carson-center/bachelor-fine-arts-emerging-media-arts) program includes four tracks: code, computational media, visual expression, and story. This program enables students to “to create media across a continuum from filmmaking to game design, virtual reality, experience design, special effects sensory media, sonic art and data.”²⁸ [New York University's Interactive Media Arts \(IMA\)](https://itp.nyu.edu/ima/) program involves “creating and critiquing everything from networked software and apps to objects with embedded interactions—games, wearable devices, computational clothing, social tools, novel controllers, the whole range of objects and interfaces that have at their core interaction with a user.”²⁹ The role of colleges and universities in supporting this growing field of practice is explored in Chapter 2.

Although digital technologies can make complex artistic visions come to life, the process of getting there can be arduous. Such work often requires access to specialized hardware and software; extensive time for development, testing, and troubleshooting; and ongoing learning to become familiar with evolving and newly developed tools. Digital divides and disparities in race, class, and gender across the arts and technology sectors create additional barriers. While artists and organizations exist to provide accessible on-ramps to this field of practice, this is labor-intensive work that requires even more robust support systems and entry points.

Tool-building is an artistic pursuit and a vital foundation for creators.

“I think what’s really important right now is understanding that the technologies around us are not these systems or black boxes that we have to just operate within, that you can pull them apart and question them and make your own things.”

—Lauren Lee McCarthy, creator of p5.js and Processing Foundation board member

Among tech-centered artists, building creative tools is a significant pursuit alongside art making, and artists develop software and hardware for both themselves and other artists. Some artists consulted in this field scan consider tool-building as central to their artistic practices and may self-identify as hackers, circuit benders, software developers, robotics engineers, and audio or visual instrument builders. Others develop custom tools on a case-by-case basis determined by need.³⁰ Whether it is to incorporate interactivity in a gallery installation or generate audio-visual effects, artists are actively developing custom-made software and hardware for use within their projects.

27 “Kyle McDonald.” Accessed April 5, 2021. <https://kylemcdonald.net/>

28 “Bachelor of Fine Arts: Emerging Media Arts.” *University of Nebraska-Lincoln*. Accessed April 6, 2021. <https://arts.unl.edu/academics/carson-center/bachelor-fine-arts-emerging-media-arts>

29 “Interactive Media Arts.” *NYU*. Accessed April 6, 2021. <https://itp.nyu.edu/ima/>

30 Since 2015, Signal Culture has offered residencies for toolmakers building devices or software used in the production of experimental media art. Their list of participating artists, a resource that provides insight to the range of toolmaking practice, is available at <http://signalculture.org/tir.html>

The notion of artists developing their own tools to produce work is certainly not new, building on roots established by early pioneers of electronic media art such as Nam Jun Paik. However, the accelerated means of creation in this current digital domain is different, as is the centrality of the process to artistic practice. Hackerspaces, open-source software and hardware, and code repositories have all enabled a flourishing and inventive tool-building movement that hinges upon technologies old and new. Some of these tools, even if built for a particular project, evolve and grow to underpin multiple artistic or even commercial projects.

Overview of the Tool-Building Process

Toolmakers might rely on existing open-source software toolkits for the arts, commercial software, and consumer or DIY electronics to develop customized tools. In some cases, they might even build new programming languages or design integrated systems for interactivity that are easy to use, such as custom-built software that allows artists to control sound and image by facial tracking or light sensitivity during live performance. Online communities and forums often accompany such tools, a phenomenon further explored in the “Navigating the Ecosystem” section of this report.

OVERVIEW OF THE TOOL-BUILDING PROCESS

COMMON TOOL-BUILDING INGREDIENTS

Open-source Software Toolkits for the Arts

Examples: openFrameworks, Processing, Wekinator, Scratch, p5.js)

Commercial Software

Examples: MAX/Msp (by Cycling '74), Isadora (by TroikaTronix), Touch Designer (by Derivative)

Electronics or Hardware

Examples: Micro-controllers and programmable circuit boards like the Arduino and Raspberry Pi; repurposing or hacking existing hardware devices, such as a Microsoft Kinect controller

Artist Builds Customized Hardware or Software Tool

ARTIST OUTPUT

Artist uses the custom tool within an arts project.

Example: To generate sounds, images, 3D models, or other assets for a live performance or installation.

Development of the tool is the art project, becoming an ingredient for building new tools or artworks.

Example: Releasing free tools as a democratizing and/or disrupting social practice.

Tool or prototype openly shared.

Example: Open Source Software Toolkits, for use (or modification) by other artists

Reasons for Tool-Building

Artists in the study expressed a number of reasons for building their own software or hardware, such as:

- A natural extension of skills in computer science or DIY electronics;
- A need for affordable alternatives to expensive commercial options;
- A need for customized technical solutions to fulfill an artistic or conceptual vision; or
- A curiosity to disassemble, repurpose, or invent new uses for existing consumer technology.

In many cases, an entrepreneurial spirit drives such creation as well—several artists in the study either license or freely distribute their own created tools for others to use. Such distribution often embodies core principles of the free software and open-source movement, also known as **FLOSS** (Free, Libre, Open-Source Software). While some artists may end up developing or contributing to proprietary tools, creative modification and re-use are pervasive in the ecosystem, in part due to the emergence of less restrictive licensing protocols. These so-called “copyleft” licenses³¹ give artists more control over the ways their work is distributed and re-used. The ready availability of online instructional materials further encourages artists to build exactly the tools they need rather than accepting what is already available.

A Collective Ethos

Beyond innovating for personal projects, artists make it possible for others to learn, use, and expand artistic expression with digital technologies across ages and skill levels. The open-source toolkits created by artists, designers, and educators provide accessible starting points for students in the arts, open-source, and technology fields. Many of the artists who informed this report openly share their research and process with online communities, reflecting a generative aspect to this practice. They write code to be shared, establish code languages and toolkits, develop custom software, hack existing hardware, and build their own devices. Their tools and contributions provide on-ramps for users new to creative coding, and they also advance creative capabilities for fellow artists.

The practice of tool-building is done both independently and with collaborators. In some cases, artists have adopted an open-source model of development, in which many collaborators contribute to a single project. This type of development is facilitated by code repositories like GitHub and GitLab, which enable users to contribute their own work or develop variations on existing work by copying source code to make derivative works, a practice known as “forking” code. Code repositories have also given artists platforms for sharing and distributing the tools they make. The open-source development model has allowed communities of practice to spring up rapidly, and many of them are founded and self-organized by artists.³²

Affordability and easy access are central values for artists developing tools made freely available online and able to be shared, edited, and improved upon by user communities. Such resources serve many sectors and users: artists, hobbyists, researchers, grade school students, museum professionals, and others whose work depends on a shared knowledge base that is freely available, extensible, and participatory. Without these resources, practitioners would be forced to use more expensive commercial software—a significant financial barrier to participation.

31 “What is Copyleft?” GNU. Accessed April 5, 2021. <https://www.gnu.org/licenses/copyleft.en.html>

32 For more on open-source models, and related challenges, see Nadia Eghbal’s publications *Working in Public: The Making and Maintenance of Open Source Software* and *Roads and Bridges: The Unseen Labor Behind Our Digital Infrastructure*.

Artist-Designed Tools

Projects focused on the design of new creative tools can include:

- Software development enabling affordable [access to a specific technological process](#).
- Building code libraries for visual programming languages critical to the process of rapid prototyping for artists working across fields, from design, audiovisual, and dance.
- Making 3D models available for design fabrication or for use in digital environments.
- Development of new hardware enabling video capture for 360-degree video experiences.
- New creation/distribution platforms.

Examples of artist-designed tools:

- [Isadora](#) (Mark Coniglio) is a customizable software tool that provides interactive control over digital media, such as video and sound, with an emphasis on real-time processing for live performance.
- [Processing](#) (Casey Reas, Ben Fry, and Daniel Shiffman) is a programming language and set of code libraries for visual artists, composers, those programming electronics, and other creatives.
- [p5.js](#) (Lauren Lee McCarthy) is an open-source Javascript library for artists and designers modeled on Processing.
- [openFrameworks](#) (Zach Lieberman, Theodore Watson, and Arturo Castro) uses the coding language C++, and provides a basis for artistic experimentation across different operating systems like Windows, iOS, and Linux.
- [Jitter](#) (R. Luke DuBois, Cycling '74) allows real-time manipulation of video and 3D imagery and is part of the larger [Max](#) suite of tools, which includes audio, graphics, interaction, and hardware, and enables makers to develop interactive media software.
- [Depthkit](#), developed by the design studio [Scatter](#) (James George, Yasmin Elayat, and Alexander Porter), is a software solution that allows artists, designers, and filmmakers to capture volumetric video for use in 3D environments, such as virtual reality or augmented reality projects.
- [REACH](#), by the immersive journalism company Emblematic Group (Nonny de la Peña), is a browser-based web platform that allows users to generate volumetric content using a simplified drag-and-drop interface.

Hacking Devices

In addition to crafting custom software and hardware from scratch, artists repurpose existing tools—for example, by hacking existing hardware and software systems—to explore new and innovative applications. Consumer electronics—like Microsoft’s motion-sensing Xbox game controller [Kinect](#)³³—and existing technologies used in science and engineering provide artists with a base of capabilities upon which to build once they crack open the system. These artists’ work mirrors and draws from much larger trends of open-source software, DIY electronics, makerspaces, hackerspaces, and digital fabrication laboratories known as “fab labs,” which offer access to digital fabrication tools such as 3D printers and laser cutters.

Unseen Labor

Tool-building is a crucial but often overlooked form of artistic labor that needs support from foundations and funders. Whether a tool was built for an independent project or through collaborative workshopping, the final product is achieved as a result of “many hundreds of hours of hard work from the artist,” most of which is invisible to audiences or users.³⁴ Tool-building also requires the flexibility to rework and troubleshoot along the way, learning and retooling through practical application. The process is difficult, time-consuming, iterative, and highly creative work in and of itself. The field would not exist or grow without it.

However, there is a need to generate opportunities for understanding, recognizing, and supporting this field of practice. For example, in an Open Source Software Toolkits for the Arts (OSSTA) report³⁵ from a 2018 convening, contributors documented challenges associated with the development, maintenance, funding, sustainability, and community management of open-source arts toolkits, as well as their values and goals for the future. The published report highlights common issues facing OSSTA practitioners, such as difficulty demonstrating the value of their work to potential funders and challenges describing their work to fit within funding categories and guidelines. These issues provide evidence that tool-building may be a challenging artistic practice for funders to understand. In order for these tools to remain free and open to the public, more work needs to be done to better understand and support this valuable field of practice.

Artists engaging in toolmaking, especially in experimental media arts, allows artists to explore new ways of seeing the electronic image that is not based on industry tools. It opens up a dialog for questioning all tools and their relationship to what is possible.

—Eric Souther, Assistant Professor of Video Art NYSCC School of Art and Design at Alfred University and Signal Culture board member

33 Schmidt, “Microsoft Makes Hacking Kinect Easier,”

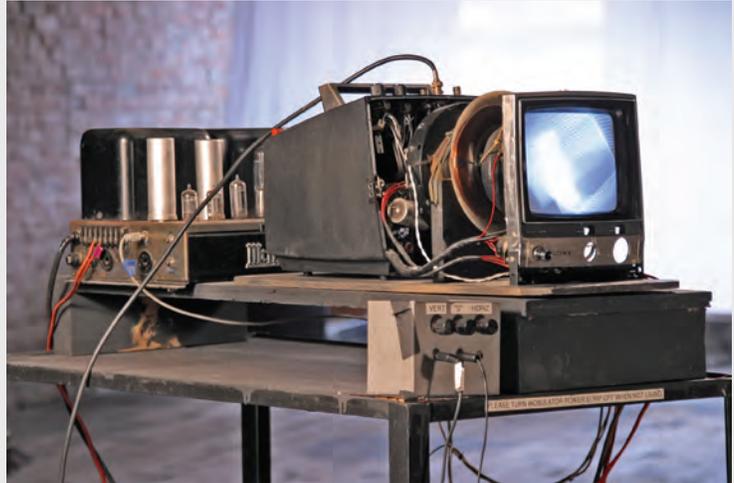
34 In his essay “[Computers Do Not Make Art, People Do](#),” Aaron Hertzmann emphasized the time-intensive nature of work with digital technologies, as well as processes of “iteration, experimentation, and refinement.” Rather than efficiently reaching a point of completion, Hertzmann described hundreds of hours of work, explaining, “The artist does not simply write a program and let it go. The artist writes a piece of software and then tinkers and refines the algorithms over a long period of time.”

35 McCarthy, Hughes, and Levin, “Open Source Software Toolkits for the Arts (OSSTA): a Convening.”

Early Tools, Still Influential

Wobbulator and Ritual for Hybrid Media

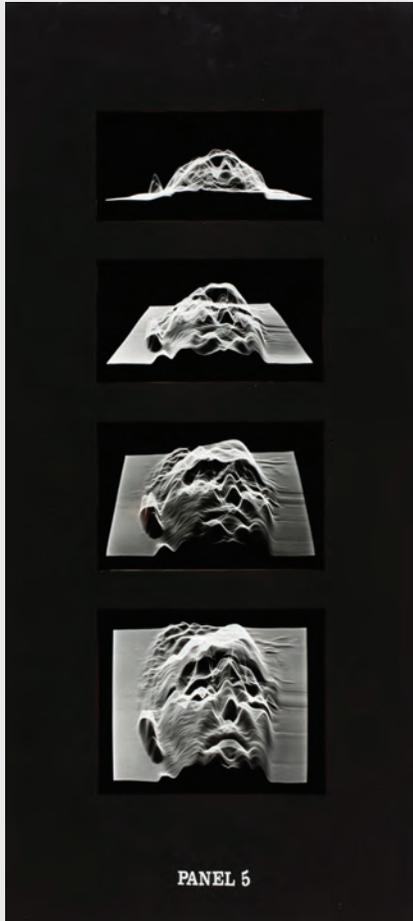
In 1970, Nam June Paik and Shuya Abe developed the [Wobbulator](#), an early video processing tool that allowed users to manipulate video into abstracted images and patterns using audio signals and electromagnets placed behind a cathode ray television screen. An innovation in its time, this artist-designed hardware is still used by artists today. In 2015, Jason and Debora Bernagozzi's audiovisual performance [Ritual for Hybrid Media](#) included the use of a color wobbulator and other custom-built signal processing tools. The color wobbulator featured was built in collaboration with Dave Jones, an engineer that also created video processing tools frequently used by media artists, such as Gary Hill.



Top: Photograph of Paik Raster Manipulation Unit (aka the Wobbulator) constructed for the Artists Residency Program at the Experimental Television Center, 1973. Photo courtesy of Experimental Television Center Ltd

Bottom: Wobbulator in use during a live performance of Jason and Debora Bernagozzi's *Ritual for Hybrid Media* at Squeaky Wheel Film & Media Art Center in 2015. Photo by Mark Longolucco, courtesy of the artists

Early Tools, Still Influential (cont'd)



Rutt/Etra... Not-A-Rutt-Etra?

In 1972, the Rutt/Etra video synthesizer was co-invented by Steve Rutt and Bill and Louise Etra. Early video pioneers, including Gary Hill and Woody and Steina Vasulka, used this video synthesizer for live image processing and real-time animation during audio-visual performance. The lineage of the Rutt/Etra aesthetic continues to influence artists and designers today, and numerous digital tools, such as Signal Culture's Re:Trace app, have been created to emulate the Rutt-Etra effect for the purpose of making this type of image processing tool available for other artists. The image below features Eric Souther's Not-A-Rutt-Etra, another video instrument built using TouchDesigner to simulate the Rutt/Etra.



Top: Woody Vasulka, *Panel 5*.
Photo courtesy of Steina Vasulka
and Berg Contemporary

Bottom: Still image created by
Eric Souther's Not-A-Rutt-Etra,
another video instrument built
using TouchDesigner to simulate
the Rutt/Etra. Image courtesy of
the artist

HIGHLIGHT

CROSSING CONTEXTS AND DISCIPLINES

Artists working with digital technologies intersect with many artistic disciplines and frequently belong to multiple communities based on their multifaceted artistic practices. This chapter sketches a high-level picture of some of the ways that artists work within, across, and beyond the discipline categories most frequently used by funders, arts organizations, and arts venues. As the research findings demonstrate, tech-centered artists:

- Work fluidly among disciplines, genres, and formats;
- Create projects within and between virtual and physical spaces; and
- Extend established arts disciplines through creative experiments with technology.

Artists work fluidly among disciplines, genres, and formats.

Tech-centered artists regularly combine art forms to create complex works that span established categories and provide audiences with experiences that go beyond the sum of their parts. While interdisciplinary projects are not unique to artists working with digital technologies, these technologies do allow such projects to take distinctive forms. In addition, practitioners are actively pioneering new modes of collaboration and innovating creation processes that represent diverse visions for personal and creative expression.

Crossing Disciplines and Categories

Cross-disciplinary endeavors involving digital technologies as creative materials vary greatly in form, with artists drawing on a range of artistic disciplines, technologies, and areas of study.

Photo of *Future Sketches* (2020), an interactive and immersive experience produced by ARTECHOUSE in collaboration with artist Zach Lieberman. Photo courtesy of ARTECHOUSE



For example, in the performing arts, technological innovations have enabled the weaving together of movement and theatrical staging with elements such as lighting, video, sound, and other multimedia components. Developing such interdisciplinary productions involves methodical and time-consuming work. These efforts have been aided by tools such as [Isadora](#), [Max/MSP](#), and [QLab](#), which add efficiency and reliability to multilayered processes. Motion-sensing technologies developed for the gaming industry (Microsoft Kinect) and other gesture-tracking devices (the Leap Motion Controller and Max/MSP/Jitter's Gesture Controlled Performance Tool) have further facilitated experiments with music and movement.³⁶

³⁶ For an overview of the history and recent developments in musical performance applications of gesture-controlled tools, see Doughty, "With a Wave of the Hand: Creating Gesture Controlled Soundscapes and Video with the Leap Motion Controller and Max/MSP/Jitter."

Artists working with digital technologies also work within art forms that are inherently boundary-blurring. Their work intersects with fields such as public art, social practice art, community-engaged work, as well as multifaceted interactive, installation-based, and immersive projects.³⁷ Each of these forms, terms, and related contexts is complex in its own right and opens up myriad possible intersections with digital technologies. For example, “immersive” work ranges from performances to installations to commercial experiences in theme parks, escape rooms, and haunted houses.³⁸ Immersive experiences like those featured at [Meow Wolf](#) (Santa Fe, opening in Denver and Las Vegas in 2021), [ARTEHOUSE](#) (Washington, DC, New York City, and Miami) or [teamLab Planets](#) (Tokyo, Japan) cross divisions between “art” and “entertainment” within spaces specifically designed to accommodate technologically complex projects.

One challenge of working outside established categories involves questioning how grantmakers, arts journalists, and audiences might approach and evaluate projects. Commercial or entertainment venues have gauges of success that differ from those of arts venues, festivals, and biennales. Likewise, community-based arts projects focused on bridging digital divides may have differing expectations depending on geography and audience skill-levels. Additionally, a number of interviewees for this research study held variable viewpoints on critiquing technological savvy and artistic merit, indicating a need for more rigorous study and journalistic coverage to further develop and inform critical frameworks for evaluation.

Complex Movements

Detroit-based arts collective Complex Movements combines community organizing, hip-hop performance, and interactive technology. Their mobile art installation, *Beware of the Dandelions* (2016), functioned as a performance, workshop space, and visual arts exhibition. The project involved a cross-disciplinary team of lead artists and collaborators, including Invincible/ill Weaver (lyricist, performance artist), Carlos “LO5” Garcia (multimedia artist, technologist), Wesley Taylor (graphic designer, musician), Wajeed (music producer, filmmaker), Sage Crump (producer, cultural strategist), Aaron Jones (architect), Tyrone Clemons (artist, technologist).



Complex Movements performing inside the multimedia pod constructed for *Beware of the Dandelions* (2016). Photo by Doug Coombe, courtesy of the artists

37 Even without emerging technologies, public art projects may necessitate architectural or engineering expertise, require permits or city buy-in, and benefit from extensive community engagement. Curators and researchers Tanya Toft and Susa Pop underscored such intersections in their preface to *What Urban Media Art Can Do: Why, When, Where, and How*, situating technology-based art in public spaces “in between practice fields such as ‘new media,’ public art, urban design and media architecture” and in relation to “a mix of genealogies of fine art, architecture, design and technology,” as well as and many other specific genres (24).

38 Brigante and Elger, *2020 Immersive Entertainment Industry Annual Report*.

Explaining Cross-Disciplinary Practices

The artists who participated in this research identify and work within a range of practices and art forms. In addition, they explain their creative investigations to audiences, presenters, and funders in different ways. Some artists focus on particular areas of expertise, influences, or technologies; others emphasize expansive virtual reach. Many of the artists who participated in research for this report used words such as inter-, multi-, trans- or post-disciplinary, trans- or multimedia, or even anti-disciplinary to describe their expansive arts practices. Such terms reject commonplace categorization and reflect artists' ability to pursue questions or drive interests across fields of practice and specialization.

The terms chosen by tech-centered artists also reiterate the common practice of collaboration. These artists often work with collaborators in different disciplines from project to project, resulting in works that take very different forms and make their overall careers difficult to neatly categorize or describe. These collaborations can involve equal contributions from individuals or groups, such as a collective, a cohort of skilled practitioners, or community co-creation. Furthermore, some artists prefer to work primarily in team-based environments for the production of new works, recognizing a wide range of skillsets and specialized expertise might be essential for executing complex artistic visions and building interactive experiences. These collaborative practices test traditional notions of a singular artist-visionary and challenge the practice of attributing the creation of an artwork to a single artist.

“Many of the artists who participated in research for this report used words such as inter-, multi-, trans- or post-disciplinary, trans- or multimedia, or even anti-disciplinary to describe their expansive arts practices.”

Emergent technology also allows practitioners to further explore relationships between creators and audiences by designing intentional opportunities for contributions through community co-creation.³⁹ Participatory works can involve sourcing audience

contributions through a number of methods, from in-person workshops to online crowd-sourcing through digital platforms. Such works can engage participation from large audiences and deliver unprecedented outcomes. During an interview as part of this study, Lance Weiler, director of the Digital Storytelling Lab at Columbia University's School of the Arts, referred to a participatory project, *Sherlock Holmes and the Internet of Things*, which had more than 2,600 collaborators in 60 countries and 180 self-organized events. The university describes such projects as a “massive online/offline collaboration.”⁴⁰

Given the complexities outlined above, grantmakers and entities organized around established artistic disciplines often struggle to fit these practices into grant categories, to assist jurors who feel ill-equipped to assess proposals, and to support projects in need of research and

³⁹ For information about contemporary models of co-creation processes from within communities, across disciplines, and with living systems and artificial intelligence, see Cizek, Uricchio, et al., “Collective Wisdom.”

⁴⁰ “Sherlock Holmes and the Internet of Things.” *Columbia University School of the Arts Digital Storytelling Lab*. Accessed April 6, 2021. <http://www.digitalstorytellinglab.com/projects/sherlock-holmes-the-internet-of-things/>.

See case study on **Lance Weiler**

development funds. As digital technologies become more accessible, the numbers of artists working collaboratively in tech-centered artistic forms is likely to increase, as will the pressure on funders and arts organizations to find a footing in the field.

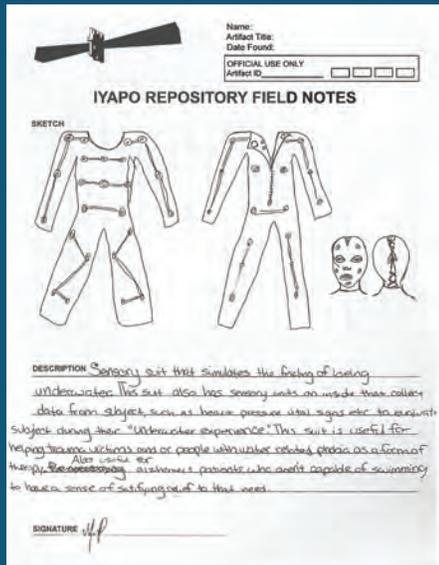


Iyapo Repository

The Iyapo Repository, co-founded by artists Ayodamola Okunseinde and Salome Asega, pays homage to an Octavia Butler novel by creating an Afrofuturist museum featuring digital and physical artifacts. Objects are co-created with community members during a process of speculative design, which are then fabricated into actual prototypes and archived as artifacts in the Iyapo Repository collection to imagine fantastical ways Black histories can be told to future generations.

Above: Iyapo Repository workshop at Rhizome DC, Washington, DC, 2016. Image courtesy of the artist

Below: *Artifact_012* (2016). Water Suit, Spandex fabric, EVA foam, tubing, motors, Raspberry Pi. All images courtesy of the artist



Artists create projects within and between virtual and physical spaces.

Artworks that incorporate digital technologies exist across a spectrum of physical, virtual, and hybrid forms. Through these forms, artists are able to reach new audiences outside traditional arts institutions via film festivals, public spaces, branded marketing events, commercial social media platforms, and online communities:⁴¹

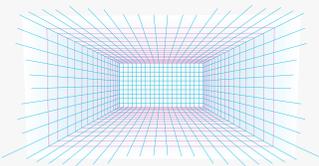
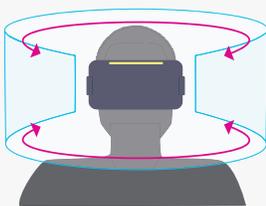
- **Virtual forms** can include works that exist within the internet or social media platforms, video game environments, or virtual reality (VR) and immersive 360° media.
- **Physical forms** can include works that exist as interactive sculptures, site-specific experiences, live performances, screen-based works or projections, or ephemeral public art projects.
- **Hybrid forms** can include works that blend the physical and virtual, such as augmented reality (AR), mixed reality (MR), or mobile or smartphone projects.

WHAT IS EXTENDED REALITY (XR)?

XR is the umbrella category that covers the various forms of immersive computer-generated reality, including: Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR).

VIRTUAL REALITY (VR)

Users experience a fully immersive digital environment constructed with varying levels of interactivity. VR experiences can be multi-sensory and interactive, using haptic devices and olfactory components, and even mapped to a physical location with live actors for a mixed reality experience. VR projects can be experienced using a variety of head-mounted devices.



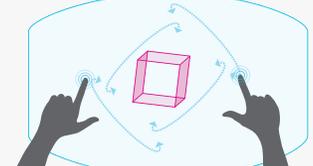
AUGMENTED REALITY (AR)

Users engage with digital information or graphics that are virtually overlaid onto physical surroundings, augmenting a live feed captured from a camera. AR projects can be experienced using tablets or mobile devices with a camera, AR glasses, or MR headsets.



MIXED REALITY (MR)

Users can seamlessly interact with virtual elements integrated within a physical environment, including the capability to interact with physical objects or other participants. MR can be experienced using head-mounted devices that have external cameras, and may involve complex immersive installations with multi-sensory components for users to navigate.



⁴¹ Mentioning these platforms is not to suggest that gaining audience attention outside of traditional channels is easy. For an in-depth discussion of the challenges that artists face attempting to gain traction through tools such as social media platforms, see Deresiewicz, *The Death of the Artist*.

Art in the Palm of Your Hand

The widespread adoption of smartphones⁴² has also opened up significant new avenues of experimentation to artists. Artistic interventions that until recently would have required expensive software and hardware are now delivered to users' own smartphones at a fraction of the cost and effort. Works created by artists using mobile devices overlay physical and virtual elements—disrupting, augmenting, or interrogating users' physical environments.

Location

The ability of a smartphone to tap into the Global Positioning System (GPS) has enabled artists to use location as a component of their works. Location enables find-and-see experiences as well as more complex narratives that unfold in space as well as time. Blast Theory's 2007 [Rider Spoke](#) combined GPS with participatory media, prompting bike riders to seek out locations where others had recorded a story and to record one themselves for later discovery.

Augmentation

The capability of AR allows artists to overlay digital information onto the physical world through mobile devices such as smartphones and tablets. A growing set of tools exist for artists to experiment and discover new potential for this technology, such as software development kits for Android ([ARCore](#)) and iOS developers ([ARKit](#))⁴³. Launched in 2016, Marjan Moghaddam's [AR activations and #arthacks](#) display 3D computer-generated animations of undulating "glitch goddesses" within galleries, museums, and public spaces. In August 2020, artist Vince Fraser, in partnership with ARTECHOUSE, launched *We Rise Above*, an Afrosurrealist AR project geographically linked to Black Lives Matter Plazas across the country. Through such projects, artists are centering underrepresented communities by overlaying imagery onto established venues and shared public spaces. AR also presents artists with opportunities to fill gaps in historical narratives, responding to centuries of injustices and omissions, and circumventing slow-moving wheels of curriculum development, through the nimble capabilities of digital technologies. For example, the artist-activist collective Movers and Shakers, co-founded by idris brewster and Glenn Cantave, launched the Monuments Project during Black History Month in February 2021. The project includes the release of the Kinfolk App, a catalog of AR monuments featuring women, people of color, and LGBTQIA+ icons with a purpose to "merge these icons with culturally responsive pedagogy so that students of color can see themselves in their history" and "empower anyone with a smartphone to be able to see digital monuments of black and brown icons in their homes."



An AR monument of Shirley Chisholm, the first Black woman in Congress. Image courtesy of the artist



Glenn Cantave (right) and idris brewster (center) demonstrate their augmented reality monuments at a teach-in at Columbus Circle, 2018. Photo by Zoe Pappis, courtesy of Movers and Shakers

42 Pew Research Center, "Mobile Fact Sheet."

43 Visit the Experiments with Google website to see projects by coders experimenting with the software development kit ARCore: <https://experiments.withgoogle.com/collection/ar>

Mobile Applications

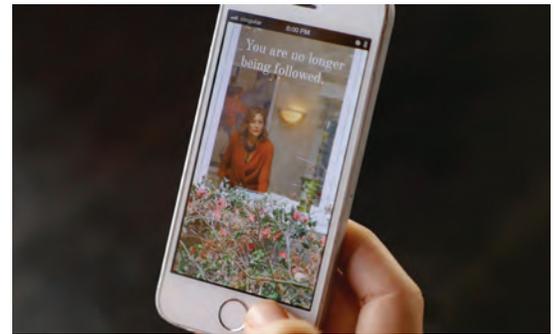
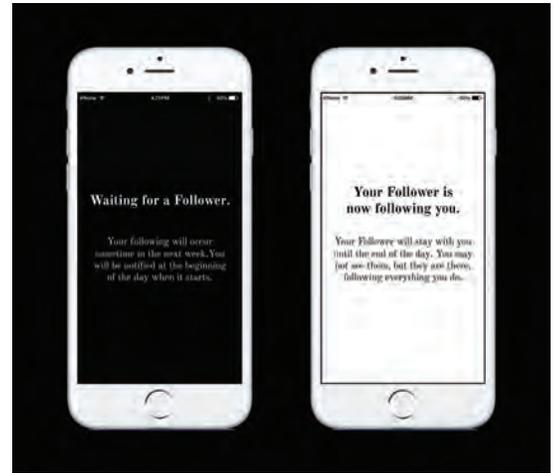
Some artists develop mobile apps as critical components to their art projects, with concepts ranging from explorations in polyrhythmic sound composition⁴⁴ to thought-provoking social experiments. An example of the latter is **Follower**,⁴⁵ a service offered by artist Lauren McCarthy that provides a “real-life follower” for the day. While app users will never see their “follower,” they receive notification on the morning of their following and are provided a photo upon conclusion. The project examines the relationship between social media “followers” and modern surveillance.

Viral Campaigns

In addition, artists can use their digital skills to launch elaborate online marketing campaigns, which can garner critical attention and leave audiences questioning the reality of their existence. **Hello Velocity** specializes in designing “internet experiences,” from practical, client-based products to speculative marketing campaigns that use social media to gain viral attention. An example of the latter is Bitelabs, a satirical biotech startup that “grows meat from celebrity tissue samples and uses it to make artisanal salami,” and it used the hashtag #EatCelebrityMeat to mobilize audiences.⁴⁶ In a similar vein, collaborators Tega Brain and Sam Lavigne launched a website for **Smell Dating**, a product that claims to be the “first mail odor dating service”; the project raised eyebrows from global news outlets, including *Time* magazine.⁴⁷

Virtual Realities

Artists are actively experimenting with VR technology, which often requires dedicated headsets and peripheral devices, such as haptic gloves and vests equipped with motors or sensors to create lifelike sensations. Users can experience virtual immersion in a variety of forms, and in some cases they can roam freely within mixed reality experiences created as room-scale installations that allow for seamless interaction within a virtual world mapped to physical objects and locations. Key venues in which audiences can experience VR artworks and



Top: Image from the Follower App. Bottom: Film still from documentation of Follower. Photos by Lauren Lee McCarthy

Bitelabs poster by Hello Velocity. Image courtesy of Hello Velocity

44 Rhythm Necklace is an iOS app, created by artist Meara O’Reilly in collaboration with Sam Tarakajian. For more information, see “Rhythm Necklace.” Accessed April 6, 2021. <http://rhythmnecklace.com/>

45 “Follower,” *Lauren Lee McCarthy*. Accessed April 6, 2021. <https://lauren-mccarthy.com/Follower>

46 B. Merchant, “The Guy Who Want to Sell Lab-Grown Salami Made of Kanye West is “100% Serious,” *Vice*, February 26, 2014, <https://www.vice.com/en/article/kbz8ky/the-guy-who-want-to-sell-you-salami-made-out-of-james-franco-are-100-serious>. For more information about how Hello Velocity have used Twitter to gain viral attention, see: <https://www.behance.net/gallery/43950965/Bitelabs-by-Hello-Velocity>

47 Oaklander, “Love in the Stenches.”

immersive storytelling content include festivals, museums, and ticketed entertainment spaces. For example, Laurie Anderson's *Chalkroom*, a VR installation created in collaboration with new media artist Hsin-Chien Huang, has been featured at festivals and museums, including the Venice International Film Festival, Tribeca Film Festival, and MASS MoCA. The piece invites users to float through a library of hidden stories and explore a virtual world filled with playful interactive experiments in audio, poetry, and sound produced by the artist and generated by participating museum visitors.

Even in VR worlds, user experiences are rooted in the physical body, and tech-centered artists are using VR to explore novel methods of embodiment and multisensory interaction. Pierre Friquet's 2019 project *Spaced Out* used a

waterproof VR headset designed by Ballast Technologies to give audiences immersed in a swimming pool the experience of floating on the surface of the moon. Jordan Tannahill's co-production between the National Film Board of Canada and National Theatre's Immersive Storytelling Studio *Draw Me Close* combined one-on-one interactive theater with VR for an intimate, embodied hybrid experience that blends the physical and virtual.

Immersive storytelling in VR is another means for artists to emotionally connect with users through engagement with the narrative form. Experiences can take place as 360° content viewed via web-based browsers or headsets and can offer variable modes of interactivity, from passive observation to

active engagement. A number of mobile apps also exist that allows users to convert their own smartphones into a "head-mounted display" capable of viewing 360° content ranging from journalistic to nonfiction and fictional narratives.⁴⁸ Notably, the growth of immersive storytelling content in recent years has spurred growing speculation over the future of virtual reality as an "empathy machine" capable of influencing social behaviors and instigating change.⁴⁹

Given physical hardware and limited access points, there are a number of barriers to experiencing VR works; however, artists are working to expand opportunities for experiencing these projects.⁵⁰ Alfredo Salazar-Caro's Digital Museum of Digital Art ([DiMoDA](#)), "dedicated to commissioning,



Laurie Anderson, *The Chalkroom*, 2017, virtual reality installation with Hsin-Chien Huang. Photo by Christin DeFord, courtesy of MASS MoCA

48 The University of Southern California's website includes Immersive Storytelling Resources to assist users with navigating options for consuming 360° content using their own smartphone devices. The list is available at: <https://uscpublicdiplomacy.org/story/immersive-storytelling-resources>

49 Farmer, "Can virtual reality increase prosocial behavior and reduce prejudice?"

50 Mobile devices do allow for some access to VR artworks using simple and inexpensive Google Cardboard-style headsets; however, such pieces may be less accessible than pieces created for the web, social media, or even AR. For more on VR and accessibility, see Ugolik Phillips, "Virtual Reality Has an Accessibility Problem."

preserving, and exhibiting cutting-edge VR artworks,” allows visitors to download virtual exhibitions and also partners with exhibition venues around the world. Aaron Koblin’s company [Within](#) both produces VR and AR experiences and distributes the work of other artists across an assortment of commercial headsets. In addition, Lauren Ruffin’s founding of [Crux](#), an Albuquerque-based XR company, aims to amplify underrepresented voices and reduce inequities facing Black XR creators in areas of funding, production support, and distribution.⁵¹

Another form of “virtual space” exists online, where artists craft self-contained worlds that either present fully fledged artworks or invite audience participation. Online projects rely on bespoke websites, commercial social media platforms, networked devices, and other methods for experimentation and user interaction. Cao Fei’s [RMB City](#) (2008-2011) used the online world Second Life to construct a fictional Chinese city where she hosted art projects, contests, and other events. Taking its name from the Chinese currency the *renminbi*, the project experimented with building an online community, both socially and structurally, as a virtual urban space. RMB City also provides an example of how “virtual” and “physical” worlds blend together. The project included both online and in-person events, as well as video artworks.

Digital Art in Public Spaces

Projects involving digital technologies as creative materials enliven public spaces through myriad means beyond mobile devices, including installations, light- and screen-based works, motion responsive projects, data visualizations, projection projects, community-engaged works, educational initiatives, and place-based interventions. Despite the fast turnover of technologies, artists are developing permanent and quasi-permanent installations that incorporate digital technologies into architectural structures, outdoor spaces, renovations, and new constructions.

Creative placemaking projects focused on community revitalization have a history of technology-infused public artworks that engage full body in play or immersive environments; provide focused, intimate encounters; or invite audiences to see and experience shared spaces in a new light. In 2010, Meejin Yoon’s interactive installation of [Light Drift](#) employed sensors and radio signals to encourage interactions between visitors along the waterfront of the Schuylkill River in Philadelphia, Pennsylvania. Dan Corson’s 2013 [Rays](#) in Council Bluffs, Iowa, animated a five-acre riverside park overnight, incorporating digital technology into waterfront renewal by inviting visitors to enjoy light patterns cast across the lawn and play games directed by the lights, which respond to their actions using motion sensors.

Artists may create temporarily installed artworks aligned with public events, educational goals, or civic initiatives to create distinctive experiences. Rafael Lozano-Hemmer’s 2019 [Border Tuner / Sintonizador Fronterizo](#) provided one such opportunity for audience connection by using intersecting search lights to form “bridges of light” that open channels for audio communication across the border between El Paso, Texas, and Ciudad Juárez, Chihuahua, Mexico.

Outdoor festivals focused on arts and technology and nighttime light festivals transform public spaces and provide regional audiences with a chance to experience projects unavailable elsewhere, and offer local and visiting artists the opportunity to experiment with site-specific installations and showcase work. Festivals like [Aurora](#) (Dallas), [LUNA Fête](#) (New Orleans), [Dlectricity](#) (Detroit), [Northern Spark](#) (Minneapolis), [Light City](#) (Baltimore), and [the Paseo Project](#) (Taos, New Mexico) have expanded opportunities for light-based, multimedia, projection, and other digital artworks in public spaces. These public art projects and festivals provide models for supporting artists and engaging audiences with technology-rich projects, offering introductions as well as opportunities to expand local programming and partner across regions and organizations.

51 Gossett, “How art co-op, Crux, uses VR to amplify Black voices.”



Both left and bottom: Visitors interacting with Meejin Yoon's *Light Drift* (2010) on the waterfront of Schuylkill River in Philadelphia, Pennsylvania. Photos by Jeff Wolfram Photography, courtesy of Höweler + Yoon Architecture



(Left) Four people interacting with Dan Corson's *Rays* in Council Bluffs Iowa. Photo courtesy of the artist

(Right) Audiences of the AURORA Biennial 2018 experience Miguel Chevalier's *Digital Icons* (2018), a generative and interactive virtual-reality installation at City Hall, Dallas, Texas. Photo by Nicolas Gaudalet



Artists extend established arts disciplines through creative experiments with technology.

In 2008, Rocco Landesman, former National Endowment for the Arts chair, wrote:

“Many of us in the arts battle the technology invasion; performing our own version of the refrain that those who do not remember their own history are condemned to repeat it. The radio and the record album were once thought to herald the death of live music. The VHS tape and cable television were going to end film. Photography was going to replace painting, and color catalogues were going to obviate the need for museums. None of these innovations led to the death of the art form, but instead contributed to its spread and helped create new audiences. So now we are faced with the Internet, social media, and other new technologies, and I believe the arts field must embrace them and integrate them into our work. Not to replace it, but to extend it.”⁵²

As Landesman emphasized, although artists working with digital technologies seem “new,” their artistic journeys engage with questions and practices at the heart of established disciplines and offer relevant and meaningful experiences for arts audiences and supporters.

Sensorium

Sensorium is an experiential studio co-founded by Matthew Niederhauser and John Fitzgerald, both artists with backgrounds in film and media arts. Their immersive storytelling work has resulted in



numerous interdisciplinary collaborations experimenting with new and expanded forms of digital media across artistic fields. For example, *Hamlet 360: Thy Father's Spirit* is an adaptation of Shakespeare's iconic play merged with immersive storytelling and virtual reality, collaboratively produced by the Commonwealth Shakespeare Company, Chronotype, and Sensorium, which was released in partnership with Boston public media producer WGBH and Google.

Production image from *Hamlet 360: Thy Father's Spirit*. Photo by Matthew Niederhauser, courtesy of the artist

52 National Endowment for the Arts, *Audience 2.0: How Technology Influences Arts Participation*.

Established Disciplines and Continual Evolution

Working with advanced technologies does not divorce artists from traditional artistic disciplines or lineages. Similar to avant-garde artists of previous eras, artists working with digital technologies today are challenging divisions between “high art” and popular culture, acceptable venues for art experiences, and the boundaries and norms associated with particular disciplines.

Artists working with digital technologies within established disciplines also make different choices regarding how to describe themselves or their work. Roundtable artists working in a variety of formats, from filmmaking to photojournalism to dance, embraced the term “media artist” or “new media artist.” However, other artists working along similar lines described themselves in relation to particular roles or fields—as “designers,” “performers,” “musicians,” “choreographers,” “composers,” or “writers.” Therefore, while an artist may embrace the term “media arts,” it is important to understand their creative investigations may be rooted in, and informed by, traditional or established artistic disciplines.

Methods of Extending Forms

Established artistic disciplines are exponentially expanded through the application of technology and digital tools to these disciplines. Sculptors design imagined forms using modeling software, and manifest those forms with 3D printers. Musicians deploy artificial intelligence to craft generative compositions.⁵³ Architects embed LED- and screen-based projects into their constructions.⁵⁴ Below are a few examples of the directions that such work can take.

Process & Development

Artists have a long history of sparking creativity through mechanisms beyond the traditional tools of an artistic discipline—incorporating chance and task-based instructions, centering relationships and participation, focusing on concepts over objects, and collaborating across sectors and disciplines, to name just a few strategies. Digital technologies continue such experiments and provide artists with new methods for crafting artworks.

In the late 1980s, choreographer Merce Cunningham began working with LifeForms, a computer program that replaced dancers with tireless avatars, enabling him to repeatedly test out unconventional movement sequences that were then translated onto live bodies.⁵⁵ Choreographer [Wayne McGregor’s *Living Archive*](#), a collaboration with Google Arts & Culture, used machine intelligence to analyze thousands of videos from McGregor’s archives, resulting in an [online tool](#) for audiences to construct choreography and a [performance experiment](#). Mimi Yin’s [Dancing with Machines](#) drew on her backgrounds in dance and interactive design, using infrared depth-sensors and motion-tracking software to enable dancers to improvise with and respond to lights and visual projections in real-time.⁵⁶ These examples show just a few ways that digital tools have been used to generate movement, while pointing to ways that such processes become central components of performance.

Aesthetics & Audience Experience

Theater practitioners have been merging live performance with multimedia and digital components for decades. Experimental theater makers have long explored the edges of technological capabilities and have acquainted audiences with a spectrum of technology-infused encounters—visual, interactive, immersive, and more.

53 Musician Holly Herndon’s 2019 album titled *PROTO* was produced in collaboration with an AI named “Spawn” that she created with husband Mat Dryhurst.

54 Lau, “The Tech to Expect in Architecture in 2018.”

55 Jacobs, “When Merce Cunningham Took on a New Collaborator: The Computer.”

56 Center for Ballet and the Arts at New York University, “NYU IT Connect: Mimi Yin: Dancing With Machines.”

The cultural sector’s legacy institutions have also adopted digital technologies as core elements of current work and future plans. Projections have enabled Broadway set designers to mirror the elaborate special effects that audiences expect from big-budget Hollywood movies and have had ripple effects in the industry, as regional theaters work to upgrade their equipment to support touring productions.⁵⁷ The Royal Shakespeare Company’s [Audience of the Future](#) initiative brought together a consortium of technology, education, and arts entities to explore integrating VR, AR, mixed reality, mobile phones, and streaming into live performances.⁵⁸

On a more intimate and experimental scale, COVID-19 quarantines spurred performers to translate theater techniques to video conferencing platforms.⁵⁹ In addition, some artists were already experimenting with virtual performances prior to the COVID-19 lockdowns. For example, Los Angeles-based studio [Tender Claws](#) combines gameplay with storytelling and immersive theater performance, allowing live actors to interact with audience members during remote performances taking place within a networked VR environment.

Many artists also remain deeply connected to particular disciplines—dance, music, visual art—and do not want to replace disciplinary associations with new media terminology.

Format & Content

Digital technologies have also offered new platforms and formats for artists working within established disciplines. Literary arts have been informed by the proliferation of digital text and publishing environments over the past two decades—tablets, e-readers, mobile phones, social media platforms, and game design tools like [Twine](#). These devices have provided writers with platforms for experimenting with literary conventions, crafting nonlinear narratives, and granting unprecedented agency to readers. Additionally, digital texts such as emails and Wikipedia pages have provided authors with raw materials to mine as part of the creative process. As new generations who have grown up using digital devices and platforms begin to develop their own work, creative writing instructors are finding ways to rethink their curricula.⁶⁰

Preserving “New” Forms

As artists working with digital technologies as creative materials extend disciplines in unanticipated directions, they encounter challenges related to preserving their artistic legacies. The rapid

57 Lee, “Projection design is reinventing theater, and not just Broadway. National tours too.”

58 Royal Shakespeare Company, “Creative Industry Pioneers Come Together to Shape How Audiences Experience Live Performance.”

59 Fuchs, “Reverse-Engineering Zoom with Isadora: Site-Specific Performance for the Internet.”

60 Skains, “Teaching digital fiction: integrating experimental writing and current technologies.” Additionally, in his 2001 book *Digital Poetics: The Making of E-Poetries*, Loss Pequeño Glazier drew historical comparisons between avant-garde poetry and electronic writing, positing that the web of that moment, composed in the language of code and strung together through hyperlinks, was itself a “space of poesis.” On the commercial side, festivals such as [The Future of Storytelling](#) bring authors innovating in digital formats together with marketing professionals, game designers, YouTube stars, and data scientists for big-ticket gatherings to dissect how narratives are evolving and influencing companies and consumers.

obsolescence of technologies on which artworks rely presents concerns for both artists and institutions. Projects in older formats or for older devices lead to archival and preservation challenges, particularly for institutions without related expertise on staff.⁶¹ For artists, technology turnover requires extensive work to update past projects. Documentation, which can be time-consuming and costly, is key, both for recalling projects no longer able to be maintained and for properly remounting projects on new systems.

Terminology also poses a challenge. The terms used to describe works may shift as a work “ages,” and terms are not universally adopted. Phrases such as “media art,” “new media art,” “emerging technologies,” and “digital art” are regularly used by some and rejected by others. Such terms overlap, have been used interchangeably, and, by the nature of the innovation-infused practices they describe, quickly feel obsolete. Many artists also remain deeply connected to particular disciplines—dance, music, visual art—and do not want to replace disciplinary associations with new media terminology. These artists want their work to be considered in the context of specific disciplines even when the technology deployed is cutting-edge.

61 For an examination of archiving and preserving digital artworks, see Noordegraaf, Cosetta, Le Maître, and Heidiger, *Preserving and Exhibiting Media Art: Challenges and Perspectives*.

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CHAPTER 2

Navigating the Ecosystem

This chapter examines the ecology of networks, hubs, and resources that provide vital support to artists working with digital technologies as creative materials.⁶² The artists participating in this research repeatedly described themselves as self-taught, having pursued informal education offerings through physical hubs, makerspaces, and meet-ups as well as via virtual learning communities, online forums, and online networking with other artists. The chapter begins by introducing the types of formal and informal gathering spaces frequently referenced by roundtable participants and the programs and resources they offer. This examination of hubs is followed by an exploration of artists' career trajectories, from entry points to how artists make a living doing this work.

This chapter is divided into two sections:

- **Interconnected Communities, Hubs, and Gathering Spaces** provides an overview of the creative ecosystem that supports and surrounds tech-centered artistic practices.
- **Entry Points and Strategies for Making a Living** examines artists' career pathways, ways of earning a living, and interactions with organizations that artists both engage within and rely upon.

The first section explores programs and services offered by artists' hubs and tech-centered organizations, festivals, and conferences, spurred in large part by artist-founders. Online forums offer critical networking, training, and community-building resources where artists share ideas and tools and learn from one another. Such forums are distributed across the internet in places like Facebook groups, Slack channels, and other sites that support information-sharing and dialogue. Colleges and universities also are important players in the arts and technology ecosystem, as employers, resource-providers, and centers of research and critical dialogue. This report's research documents a robust and growing number of academic programs in arts and technology that are graduating creative artists with deep technical expertise. These artists are now entering the cultural sector with advanced computing training and abilities.

The second section explores how artists begin working at intersections of art and digital technologies, build professional connections, and pursue career pathways to sustain their creative work. Artists enter tech-centered practices both from arts disciplines and from computing backgrounds. A portfolio career approach—mixing income from various earnings as teachers, speakers, freelancers, and artistic work—is common in this realm, as it is across most artistic disciplines. Artists in this report have access to work in the tech industry where compensation may be relatively generous, but they face the same challenges as other artists when it comes to support for their creative practices.

⁶² While this report focuses on artists working with digital technologies as creative materials, many findings have parallels in other artistic communities. For example, in *The Death of the Artist*, essayist and critic William Deresiewicz describes the gravitational pull of geographic hubs: "People don't make art in isolation, and online interactions are incomparably impoverished relative to those that take place in real life. Artists move to centers to be in the thick of it: for education, motivation, inspiration, for the chance to find their tribe, join the discussion, and make their way where the making is good" (91).

INTERCONNECTED COMMUNITIES, HUBS, AND GATHERING SPACES

Roundtable participants and field interviewees reported key nodes of activity and learning that represent prominent pillars of support for tech-centered artistic practices:

- In-person gatherings, workshops, festivals, and conferences are core hubs for learning and community building.
- Online resources and communities expand access and enable participation.
- Colleges and universities are prominent employers, incubators, and resource providers.

In-person gatherings, workshops, festivals, and conferences are core hubs for learning and community building.

Nonprofit and community organizations, as well as arts and technology festivals and conferences, have grown up alongside arts and digital technology practices. Such convening spaces offer exhibition and performance venues, workshops, training, artists' services, and peer gathering and networking opportunities.

This loose network of entities has been spurred by need and opportunity. Artists and field advocates founded their own organizations to fill voids in the arts ecosystem, promote fellow artists and their work, spark dialogue, and connect with one another. Many artist founders were inspired by a community-building spirit—the desire to expand participation, collaborate, create opportunities for themselves and others, and pool resources and abilities to create ambitious projects.

Gathering Spaces

Organizations dedicated to tech-centered artistic practices host exhibitions, presentations, workshops, trainings, and other events that convene artists as well as supporters, and facilitate



Open Signal

In Portland, Oregon, Open Signal builds on a local history of community-driven media, offering classes, production studios and equipment, exhibitions, artists' talks, meetups, and fellowships in support of "creativity, technology, and social change."

Open Signal New Media Fellow Laura Medina (center) looks on as an attendee views her VR project *Recordar es Construir* through an HTC Vive headset, 2020. Photo by Sam Gehrke

formal and informal networking. Presence in such communities helps artists to build familiarity with their work and to develop relationships—with peers, collaborators, funders, and potential employers. Physical presence also fuels community vibrancy: artists and enthusiasts can meet to engage with ideas and artworks in settings where social and professional relationships overlap.⁶³

Tech-centered arts organizations offer varied programming. Workshops and classes often focus on technical skill-building. Such educational and event-based program offerings, open to a broad array of participants, serve core community-building needs. Residency programs, generally longer and often more focused on particular projects and activities, provide artists with extended time and space to develop ideas and experiment. Incubator programs also offer concentrated creation time, sometimes including a cohort model or a focus on specific goals, from business planning to project milestones. In addition to such program offerings, hubs also contribute to artists' income streams by commissioning projects or hiring artists as speakers or instructors.

Makerspaces, another form of hub open to wider communities of tinkerers, inventors, and hobbyists—from beginners to experts—offer shared tools, the space to create independently, and often, interaction with other makers. These communities of makers welcome different perspectives and knowledge bases from arts-oriented contexts. Artists such as Darcy Neal credit these communities with helping them to adopt new techniques and production models and learn directly from other makers. Makerspaces are a cousin to “fab labs”—digital fabrication laboratories that offer a similar combination of space, tools, and community, with an emphasis on digital technologies.

See case study on Darcy Neal

New York City Hubs

New York City is a center of activity for artists working with digital technologies. The numerous programs, events, residencies, and classes contribute to a flourishing environment for artists to cultivate community and grow their practice. For example, [NEW INC](#), an incubator lab affiliated with the New Museum, convenes creatives working at the intersection of art, design, and technology. [Harvestworks](#) hosts the biennial New York Electronic Art Festival and leads a three-month Online Technology Immersion Program. [Babycastles](#)' weekly Coworking sessions give artists the opportunity to work independently alongside peers. [Rhizome's Seven on Seven](#) program pairs seven artists with seven technologists, challenging them to make a new artwork or prototype, which is premiered at an annual event. The [School for Poetic Computation](#) provides a mix of practical and thought-provoking classes, such as “Code Movement” which focused on the intersection of coding and dance practice. [Pioneer Works](#)' Technology Department includes residencies, labs, workshops, and public programs connecting artists and creative technologists to explore emerging technologies such as robotics, AI, and XR. In addition to such ongoing efforts, special initiatives contribute timely perspectives that foster inquiry and dialogue. For example, [Eyebeam](#) has dispatched a series of multilayered initiatives such as the [Center for Future of Journalism](#), [Rapid Response for a Better Digital Future](#), and [Refiguring the Future](#), each focused on positioning artists in roles to “re-imagine what technology can be and who it is for” and build a more just future for all.⁶⁴

HIGHLIGHT

63 While this report focuses on artists working with digital technologies as creative materials, many findings have parallels in other artistic communities. For example, in *The Death of the Artist*, essayist and critic William Deresiewicz describes the gravitational pull of geographic hubs: “People don’t make art in isolation, and online interactions are incomparably impoverished relative to those that take place in real life. Artists move to centers to be in the thick of it: for education, motivation, inspiration, for the chance to find their tribe, join the discussion, and make their way where the making is good” (91).

64 “Eyebeam Reveals New Paths Toward a More Just Future for All.” Accessed April 7, 2021. <https://www.eyebeam.org/about-us/>

Professional Development & Technical Training

Artists working with digital technologies face dual learning needs, comparable to other arts disciplines—skills training and professional development. The fast turnover in technologies necessitates continuous learning and sometimes requires rebuilding older works so that they function properly with upgraded software and hardware. This challenge is exacerbated for artists who face disparities in access to equipment and resources, part of larger digital divides that cut along lines of race, socioeconomic status, gender, and geography. In addition, inequities across arts and technology sectors impacting creatives of color and other marginalized communities have spurred the development of organizations and hubs, such as [Color Coded](#) (Los Angeles), [Code Liberation](#) (New York City), and [Afrotectopia](#) (New York City), which go beyond technical training to foster a sense of community that seeks to support and amplify underrepresented voices. In addition, in-person venues may exist specifically to reduce digital divides, such as [PowrPInt](#) which describes itself as “a network of artists committed to providing digital arts education and access for all” and states on their website “access to technology is a right, not a privilege.”

Professional development programs at organizations variously focused on arts, design, or media help artists cultivate their career paths through services like business workshops, grantwriting feedback, input on “elevator pitches,” artwork critiques, and employment programs. Examples include [NEW INC’s](#) focus on sustainable business models through workshops, panel discussions, mentorship, social events, and peer review of project and business ideas; [Arts2Work](#), the first federally registered national apprenticeship program and workforce development program for Media Arts and Creative Technology; [Allied Media Projects](#) (Detroit), which provides services like fiscal sponsorship and evaluation planning; and [Scope of Work](#) (New York City), which focuses on early-career artists, supporting 17- to 24-year-old creatives of color through classes, office hours, professional residencies, and employment recruitment.

Like their peers in other disciplines, artists working with digital technologies require support systems in order to meet their artistic and professional goals. They also pursue and receive services from core arts services providers in local communities and nationally. As will be seen in the “Challenges” section in this report, these existing service organizations are not always prepared or able to tailor or expand their offerings to support the needs that artists working with digital technologies encounter.

Festivals and Conferences

Festivals and conferences focused on arts and technology provide concentrated opportunities for both artistic and professional growth. These gatherings enable artists to meet one another, connect with field supporters, show work, learn about technological innovations, and engage in reflection and debate. Artists also have been instrumental in instigating and developing conferences and festivals, building career pathways as artist-administrators while supporting their own and peers’ artistic growth and advancement. Such activities also bring together cross-disciplinary practitioners working across multiple fields. For example, the Conference for Research on Choreographic Interfaces founded by choreographer Sydney Skybetter convenes expertise in dance, performance, computer science, kinesiology, anthropology, social justice, and design to discuss the relationship between bodies and movement and emerging technologies.⁶⁵

The geographic spread of festivals offers numerous opportunities for artists, as well as access points for audiences and supporters new to the intersection of arts and digital technologies. For some artists, festivals function as career stepping-stones that provide commissioning support, advantageous visibility, prestigious awards, or monetary prizes. Film festivals, for example,

65 “CRCI.” *CRCI*. Accessed April 6, 2021. <https://www.choreotech.com/>

See case study on [Design I/O](#)

serve as incubators and meeting grounds for artists, filmmakers, animators, and technologists using digital tools to reimagine storytelling and expression. Entities such as the [Sundance Institute](#), Tribeca Film Festival's [Immersive](#) showcase, and [imagineNATIVE](#) are also resources for supporters seeking to understand these new formats. For those who cannot attend in-person, many festivals maintain online archives featuring past events:

- In Montreal, Canada, and Mexico City, Mexico, [Mutek](#) organizes annual electronic music and digital arts festivals, with related festivals regularly hosted internationally.
- In Minneapolis, Minnesota, the creative technology-oriented [EYEO Festival](#) gathers artists, creative coders, storytellers, researchers, and technologists for presentations and discussions.
- In Santa Fe, New Mexico, the [Currents New Media](#) festival welcomes both practitioners and the public for installations, performances, and exhibitions. The 2020 conference, presented online, focused on extended reality (XR) and artificial intelligence.
- In San Francisco, California, the [Gray Area Festival](#) combines conference presentations, performances, workshops, and exhibitions. A 2020 theme of “Radical Simulation” focused on immersive worldbuilding informed by “embodiment, social justice, identity, decolonialism, and regenerative ecology.”

Some long-standing convenings, such as ACM [SIGGRAPH](#) (Special Interest Group on Computer Graphics and Interactive Techniques), founded in 1974, and [Ars Electronica](#), started in 1979 in Linz, Austria, have developed numerous branches and activities over the years. SIGGRAPH, part of the Association for Computing Machinery (ACM), hosts multiple annual conferences, sponsors student and professional chapters, offers workshops, and organizes an international Digital Arts Collaborative. Ars Electronica launched an annual Prix Ars Electronica in 1987 and opened a physical center in 1996 that houses a FutureLab research space and think tank.

Online resources provide integral support to artists outside major urban centers, which is of particular value for artists who may not have access to regular in-person training or community-building at physical hubs.

Online resources and communities expand access and enable participation.

Given the quickly evolving nature of digital technologies, artists refine, acquire, and update their skill sets through continuous self-teaching. Roundtable artists repeatedly described themselves as “self-taught” despite higher-than-average advanced degree attainment (*see below*). Independent learning can involve classes and tutorials, such as computer programming tutorials posted by Daniel Shiffman on his YouTube channel [The Coding Train](#). Continuous learning also entails “learning by doing” through exploratory or project-based activities designed to foster creative approaches to digital tools.

Artists emphasized a common reliance on specialized online communities and forums for project development, technical troubleshooting, and continued learning. For example, [Cycling '74](#) offers in-depth tutorials; troubleshooting forums; and [Made with Max](#), a dedicated section featuring contemporary artists and musicians using its tools for sound, graphics, and interactivity. Similarly, [Isadora](#), a customizable software programming environment used for live performance and theater, offers free video tutorials for beginners to advanced users, a technical forum, and special features on artists and production designers using the software. For communities using the [openFrameworks](#) creative-coding toolkit, there are a [forum](#) for asking questions and meeting and assisting other users and a [Github repository](#) where accomplished users identify bugs, propose new features, and contribute directly to code development. These forums are also subdivided by different platforms and experience levels, with discussion areas focused on gear, technical advice, and opportunities such as job postings.

Online activities have also led to in-person forums. The University of Denver's [Clinic for Open Source Arts](#) (COSA) supports open-source tool development, hosts gatherings, and helps creators learn how to encourage the communities that grow around their tools. Processing Foundation launched [Processing Community Day](#) in 2017, and the in-person event quickly spread to hundreds of cities around the world.⁶⁶ During the COVID-19 pandemic, these gatherings were transformed into six-hour virtual hangouts and offered community members across the globe the opportunity to network and share projects and ideas.

Discord, a group chatting platform, is another form of social engagement used by artists to build online communities around modes of artistic practice. For example, [LiveCode.NYC](#)'s community on Discord features channels for discussing real-time music creation and live-coded visuals, promoting events, and sharing recordings of work. While the collective regularly hosts in-person workshops, performances, and festivals, the use of online forums (such as Discord, Instagram, and Twitter) further bolster community engagement. In addition, their website connects regional practitioners to global live code networks and forums, provides local member listings, and brings visibility to the various tools for live coding developed by artists around the world.

These many online resources help expand participation and foster the creativity of others. Online resources provide integral support to artists outside major urban centers, which is of particular value for artists who may not have access to regular in-person training or community-building at physical hubs. Online trainings also provide pathways into the field, expanding access through free and approachable virtual settings. Open-source software furthers this access, giving artists the tools to create with the skills they have developed, often without the barrier of the high costs of commercial software.⁶⁷

Critical Discourse and Discovery

In addition to skill-building, artists have long used their technology skills to build information networks and create forums for discussion and debate. Prior to the launch and popularization of the internet, artists were already connecting via bulletin boards that linked terminals and configured televisions through phone lines. Communities such as the internet mailing list [nettime](#), founded in 1995, and Rhizome, founded as a listserv in 1996, established early spaces for critical discourse.

66 The Processing Foundation shared video from their first Processing Community Day in 2017 on YouTube: [youtube.com/watch?v=0tzc6DbKJOo&feature=emb_logo](https://www.youtube.com/watch?v=0tzc6DbKJOo&feature=emb_logo).

67 For more information on the distinctions between open-source software, free software, and low- or no-cost options, see Stallman, "Why Open Source Misses the Point of Free Software" and Peterson, "What's the difference between open-source software and free software?"

See case study on the Processing Foundation

Nodes for technology news, digital arts criticism, and other relevant topics have multiplied with the rise of social media platforms, online publications, and podcasts. Artists may follow the [Voices of VR](#) podcast or the [No Proscenium](#) podcast or Facebook page; visit [aiartists.org](#) to learn about other artists or dive into their list of [Top 25 AI Newsletters](#); read publications such as [Leonardo](#), [Immerse](#) or [e-flux](#); and more, depending on their particular areas of practice and inquiry.

In addition, artists help each other by aggregating resources and recommendations for like-minded audiences. Everest Pipkin's "Open-source, experimental, and tiny tools roundup" includes "standards" and "artful tools and toys that are as fun to use as they are functional;" and Martha Hipley's *Artist's Guide to Computation*, which originally started as a Facebook group, is a weekly newsletter and website serving as a comprehensive guide to current events, opportunities, and resources, filling the need to expressly serve artists "who don't feel well-represented by neither the art world nor the tech industry."⁶⁸

These many publications and outlets build awareness and appreciation among core arts and digital technology communities, as well as broader audiences. However, the dispersed nature of the arts and technology ecosystem, along with the rapid turnover of digital technologies, means that there is a large quantity of information to sift through and track. This situation places artists in a position of constantly working to stay current—to keep their skills in line with new technologies, update the systems that their artworks rely upon, and stay up-to-speed on developments in the specific creative and technological communities that their work touches.

Colleges and universities are prominent employers, incubators, and resource providers.

"There's the challenge of how to be truly interdisciplinary with both students and faculty. How do our students talk and interact and create projects with mechanical engineers or material scientists, biologists? How do non-tenured or junior faculty co-teach with people outside of their discipline and be recognized and rewarded for it, as opposed to simply teaching 'an average'? These are the challenges. We do currently have a VR course which is a collaboration between our students and computer scientists, and it's working really, really well—but how do we begin these kinds of collaborations in the first year so that they can continue them over time, as opposed to limiting it to a one-off experience in their junior year?"

—Megan Elliot, Founding Director of the Johnny Carson Center for Emerging Media Arts

Colleges and universities across the United States play multifaceted roles as employers, physical hubs for the creation and presentation of new work, sites for cross-disciplinary collaboration, and stepping-stones for artists across career phases. As employers, colleges and universities support artists as full-time and adjunct faculty, guest lecturers, and artists-in-residence.

In their roles as faculty in these programs, artists are actively engaged in teaching the next generation of arts and technology creatives. They are helping to craft curricula, develop degree programs, and inform departmental purchasing decisions about ideal space and equipment. Artist-faculty also learn from their incoming students, who now come to higher education as digital natives.

68 Pipkin, "Open Source, Experimental, and Tiny Tools Roundup"; Hipley, *Artist's Guide to Computation*.

Increasing Degree Programs

While it is not possible to discern whether degree programs primarily enroll students who will become future artists versus students who go on to work in technology-related business and industry, [data published by the College Board in 2020](#)⁶⁹ show that 444 two- and four-year colleges in the U.S. offer degrees in the arts-and-technology field. Among these, common majors include digital arts, intermedia/multimedia arts, animation, video graphics, artificial intelligence, music technology, and game design. More than 500 colleges also offer related degree programs in graphic design, computer graphics, web design, and digital communications.

Digital Technologies Are Changing Traditional Arts Training

Traditional arts degrees are incorporating digital skills training in core curricula. Technology platforms are now embedded in arts disciplines as disparate as music composition and performance, photography, dance, and sculpture. Many faculty consider computation as a core skill for the next generation of artists; colleges are adding basic coding across arts curricula.

Many arts and technology programs focus on entrepreneurship. One example is the relatively new [Johnny Carson Center for Emerging Media Arts](#) at the University of Nebraska-Lincoln. The center strives to be a destination for “pioneers who use technology to innovate, to solve human-scale problems, to entertain audiences, and to tell breathtaking stories.” Megan Elliott, the center’s director, said, “In my mind, our students will find jobs...[and] in my mind, our students will create jobs. They’ll actually create their own companies.”

Colleges and Universities as Resource Centers

College and university facilities are often far better equipped than community hubs or individuals’ studios and can provide artists with access to space, tools, software programs, powerful computers, and other assets. Higher educational institutions also frequently establish relationships with technology companies in order to equip students and faculty with the latest gear. Artists report losing such access when they earn their degrees, and some said they enter graduate school or accept low-paying teaching positions to regain access to premier facilities for their own artistic work.

Challenges and Opportunities to Working Within Academia

Artists reported on the complexity of working within university systems that focus deeply on specific disciplines, given the interdisciplinary nature of art and technology practice. Students and faculty benefit from the depth of expertise across campuses, but are hampered by departmental curricula and budget structures, the lack of interdisciplinary scholarly journals, and the promotion requirements for tenure that are frequently tied to achievement within disciplinary constraints.

In their roles as faculty in these programs, artists are actively engaged in teaching the next generation of arts and technology creatives.

Artists described the ways they are working within academia to break down barriers and embrace new collaborative approaches beyond arts and technology to include the humanities, sciences, and social sciences. Artists also have been able to apply and receive funding for nontraditional collaborations within university departments, citing grants from the National Science Foundation and the Department of Defense, among others.

⁶⁹ College Board, “Major and Career Search.”

High Levels of Advanced Degree Attainment

Of the artists who participated in this field scan's roundtables, 71 percent hold graduate degrees, which is higher than the percent of working artists in the BFAMFAPhD longitudinal study on education and workforce participation of artists in the United States (60 percent) and the U.S. population over 25. According to the U.S. Census Bureau, more than one-third of the population over 25 had a college degree as of 2016.⁷⁰ About half of the field scan's participating artists hold graduate degrees with a specific arts-and-technology focus, such as dance/multimedia, digital arts and experimental media, and new media/art and technology. About 25 percent hold degrees in more traditional arts disciplines such as sculpture, theater, and visual arts. Furthermore, all artists in the research scan named "teaching and training gigs" as high on their list of income sources.

College and University Centers

[ITP \(Interactive Telecommunications Program\)](#) at Tisch School of the Arts at NYU is a 40-year-old department described as an "art school for engineers or an engineering school for artists." Its two-year graduate program explores "imaginative uses of communications technologies and how they might augment, improve, and bring delight and art into people's lives."

The School of the Art Institute of Chicago (SAIC)'s graduate program in [Art and Technology Studies](#) is focused on the use of technology as an art medium. Faculty and student works are often "time-based, interactive, immersive, multi-sensory or hybrids of retro and cutting-edge technologies." Students can study creative coding, machine-learning, game design, light, audio, VR, AR, AI, and other concentrations.

The University of California - Los Angeles [Design Media Arts](#) program offers a comprehensive, multidisciplinary approach to media creation in undergraduate (BA) and graduate degrees (MFA), which engage students in the design of objects, spaces, and experiences, such as publications, gallery installations, films, performances, public interventions, and multimedia websites. This [highly selective program](#) annually receives more than 20 times more applicants than can be admitted.

[Frank-Ratchye STUDIO for Creative Inquiry](#), associated with the College of Fine Arts at Carnegie Mellon University, is a laboratory for atypical, anti-disciplinary, and interinstitutional research at the intersections of arts, science, technology, and culture. The STUDIO provides grants for arts research, invites innovative artists-in-residence to stimulate dialogue, and helps to develop innovative public venues for new work. The STUDIO functions at the cross-section of multiple academic areas and provides space for nontraditional research that influences curricula in the arts, architecture, engineering, computer science, and other academic departments.

HIGHLIGHT

⁷⁰ U.S. Census Bureau, "Educational Attainment in the United States: 2016," last modified March 31, 2017, <https://www.census.gov/data/tables/2016/demo/education-attainment/cps-detailed-tables.html>

ENTRY POINTS AND STRATEGIES FOR MAKING A LIVING

The prior section described key elements of the ecosystem that sustain tech-centered artistic practices. This section focuses on career paths, exploring how artists begin working at intersections of art and digital technologies, build professional connections, and harness income streams to make a living.

- Routes into tech-centered artistic practices follow many paths, including informal experimentation, formal degrees, arts training, and technology careers.
- Artists cultivate multiple income streams to make a living.
- Artists collaborate across sectors and establish businesses that build on their creative and digital skills.
- Corporate and commercial work are prominent income streams that present artists with both opportunities and challenges.

Routes into tech-centered artistic practices follow many paths, including informal experimentation, formal degrees, arts training, and technology careers.

Many artists develop an interest in technology as children, through self-directed, exploratory learning, as well as through available programs and tools. In addition to video games, computer camps, and child-friendly computer programs such as [KidPix](#),⁷¹ Acid Pro, and Fruity Loops, artists described informal “tinkering” such as disassembling and reassembling their families’ consumer electronics. This fascination with digital technologies can begin early, with some artists recalling their first programming experiences between the ages of five and eight.

Youth Technology Training

Younger generations of artists are now exposed to routinized technology education, as computer science and technology courses increasingly become part of K-12 education standards. For example, New York City Department of Education, through their [Computer Science for All](#) program, are working to incorporate computer science education into elementary, middle, and high schools by 2025. Given the expense of digital technologies, free and early access is key to closing divides surrounding hardware and software, digital literacy, and broadband access.

Children can also gain early exposure to computation training, digital arts, and digital technologies through school and afterschool programs, day care centers, and summer camps, such as programs offered by organizations like [Black Girls Code](#) and [Girls Who Code](#). Youth arts education providers have also incorporated coding and computational training into their program offerings, such as the West Park Cultural Center in Philadelphia, which integrated dance and computer programming into [danceLogic](#), a program for 13- to 18-year-old girls. Likewise, artists-run organizations host youth workshops taught by new media practitioners, such as Rodolfo Peraza’s [Mud Foundation](#), which offers tech-focused arts programming in VR, AR, and Net Art in partnership with cultural institutions. In addition, community-based media arts organizations incorporate artist-led workshops for youth,

71 ComputerCloset, “KidPix: The Early Years.”

such as [Squeaky Wheel Film & Media Arts Center](#) in Buffalo, New York, which offers a range of technology-focused [education programs](#) for youth digital creators, including a program for young individuals on the autism spectrum.

Professional Pathways

“As I left school, I started to see these two sides of myself that were always there: the theater side and the technology side. I’m the kind of guy who watches every Apple keynote. It’s a part of my calendar and I was kept up to date on tech news, so I wanted to bring those two sides closer together. I went to a lot of events in New York just to try and understand what it could mean for my career to be connected to tech-driven work. Then I fell into collaboration with the Columbia University Digital Storytelling Lab and that was the real turning point where I saw a lot of possibility and did a ton of learning around how I can grow as an artist.”

—Brandon Powers, Creative Director and Choreographer

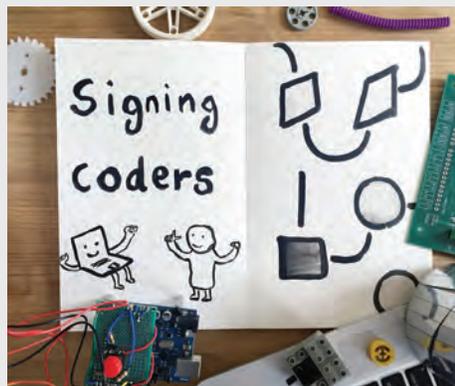
Roundtable artists and interviewees described pathways to working with digital technologies from many artistic disciplines, as well as from backgrounds in technology. Artists may begin in one artistic discipline and expand to include other artistic practices as they incorporate digital technologies into their work; they may be drawn to social media as a mode of expression or gaming as a creative outlet; or they may start out as computer scientists and develop cultural interests. A number of artists began in the performing arts, building on interests in experience design, movement-responsive technologies, collaborative creation, and immersive worlds. For example, theater, dance, and choreography can lead artists into experience design, user interfaces, development of immersive events and live performances, physical navigation in VR, and choreorobotics (the design of robot movement).

Ethical concerns also provide an avenue into arts and digital technologies, with artists creating artwork and engaging in dialogues that examine digital surveillance, representation in the technology sector, access to information, or the influence of technologies on daily life. Diving into these debates can fundamentally alter the course of an artist’s practice or career, what artist Stephanie Dinkins described as “turning my life over to this process.” In addition to grappling with challenges of today, artists also use their work to imagine alternative futures, drawing inspiration from science fiction, Afrofuturism, cyberfeminism, or social justice movements.

These many pathways lead to an array of journeys within the ecosystem supporting tech-centered artistic practices. The findings that follow highlight a few commonalities within wide-ranging careers and practices carved out by artists.

Artists Provide Accessible Entry-Points

Artists use their technology skills to conduct digital trainings and workshops reaching a diverse range of ages, abilities, and skill levels. Taeyoon Choi’s workshop series [Signing Coders](#) is designed for deaf and hard of hearing youth, but open to individuals of all ages and abilities. The program provides real-time transcription and American Sign Language interpretation for sessions on cultivating creative expression through computer programming, art, and poetry.



Signing Coders drawing and electronic circuits, 2016. Drawing and photo by Taeyoon Choi

HIGHLIGHT

See case study on [Stephanie Dinkins](#)

Artists cultivate multiple income streams to make a living.

“People should be able to follow their talents and build a life with a living wage-based income by working hard. There are a lot of people in the art world working very, very hard now with no path forward and that’s not sustainable.”

—Kevin Cunningham, Founder and Executive Artistic Director of 3-Legged Dog

Many of the artists who informed this research report rely on multiple income streams, a common scenario that takes many forms.⁷² Despite the range of artists’ multifaceted careers, awareness of this employment pattern can assist funders and advocates in supporting artists whose professional careers often involve uncertainty and instability. In addition, artists participating in the research listed sweat equity as one of the top sources of support for their creative work. While a significant amount of work for their own creative projects may go unpaid, artists felt ethically challenged and reluctant to rely on the unpaid labor of peers.



Hyphen-Labs

Hyphen-Labs, co-founded by Carmen Aguilar y Wedge and Ece Tankal, is an international collective of more than a dozen artists, engineers, designers, architects, and technologists. Hyphen-Labs collaborated with Ashley Baccus-Clark and Nitzan Bartov to create *NeuroSpeculative AfroFeminism*, a possible future told through installation design, speculative products, virtual reality, and cognitive research. Hyphen-Labs places

us in a “neurocosmetology lab” in a future where Black women are the pioneers of brain optimization fitting customers with transcranial electrodes that allow access to a surreal digital temple blending the physical with the digital.

An image from *NeuroSpeculative AfroFeminism* featuring the Techno Africanum Culturist, an ancient transhuman neuronaut existing within the immersive experience. Lead Artists: Ashley Baccus-Clark, Ece Tankal, Carmen Aguilar y Wedge, Nitzan Bartov. Image courtesy of Hyphen-Labs

⁷² For further analysis of the changing dynamics and strategies related to artists’ employment in the context of 21st century technologies and social media platforms, see Deresiewicz, *The Death of the Artist*.

Portfolio Careers

Artists frequently described portfolio careers—consisting of numerous part-time or freelance jobs—rather than reliance on a single full-time employer. This phenomenon is readily observable among other types of artists in the U.S. workforce. For example, artists are 3.6 times as likely as other workers to be self-employed.⁷³ In the case of artists working with technology, their portfolio careers mix artistic production with research, field-building, client work, teaching, unpaid promotional work, and other gigs and partnerships. Some artists are economically based in one primary arena, such as entrepreneurship, or have salaried positions that serve as anchors, such as professorships. Many are independent creatives who juggle cultivated skill sets and initiatives with serendipitous opportunities.

Some artists, such as Amelia Winger-Bearskin, seek out employment that allows them to give back to the field by bringing their artist expertise to cross-sector projects and administrative roles. Alongside income-generating work, projects such as tool-building, cultivating hubs, or activism also function as through-lines within wide-ranging careers.

In addition to salaried employment, work for hire, and self-employment, artists experiment with methods for added income such as crowdfunding ([Patreon](#), [Go Fund Me](#), and others), digital tip jars, merchandise, and licensing. Many artists also apply for grants, fellowships, and residencies.

While the sheer number of avenues for possible income can give the impression of ample opportunities, the majority of these income streams are inconsistent. Artists need persistence and ingenuity to find ways to make a living and to continue to create work. They also described anxiety and exhaustion from the never-ending process of balancing one-off client work and speaking engagements, applying for grants and residencies, holding down an anchor job, and carving out time for creative work.

See case study on [Amelia Winger-Bearskin](#)

Side Hustle Culture

Artists participating in the research described a “side hustle” culture of creatively making ends meet that coincides with significant challenges—lack of healthcare, debt, obstacles to dedicating time to artistic endeavors.

- Artists are experimenting with strategies for making a living, such as crowdfunding and digital tip jars. One artist in the Detroit roundtable described his practice as akin to “digital busking”—making it easy for people to pay him online in the same way that street performers make it clear their labor should be compensated by putting out a hat.
- Training and teaching gigs ranked high as a source of income support, with paid activities ranging from university employment, workshops and classes offered by nonprofits or other organizations, and speaker fees.
- Artists’ descriptions of their situations included: “currently in crisis mode: no job security, no healthcare,” “massive debt to make my work,” and “living in a place I don’t want to live.”
- Miami artists in particular noted the scarcity of opportunities for artist funding, describing juggling full-time jobs, personal projects, residencies, and commissions. In reviewing roundtable worksheets outlining sources of funding, one Miami artist called out the privilege of family wealth, stating, “In general, y’all should have family wealth [as a funding category].”

HIGHLIGHT

73 National Endowment for the Arts, *Artists and Other Cultural Workers: A Statistical Portrait*, iii.

Overlaps with Other Arts Practices

Because of the deep technological expertise of artists featured in this report, their portfolio careers can take distinctive forms. However, building livelihoods from multiple income streams is also characteristic of other arts disciplines. The Arts Endowment's 2019 research study, [Artists and Other Cultural Workers: A Statistical Portrait](#) noted that roughly 34 percent of all artists were self-employed (compared to nine percent of all workers),⁷⁴ a category of employment that encompasses activities from portfolio careers to running a full-time artist studio.

In his 2018 study, *'Positive Economy': Towards New Business Models for Artists*, researcher Frédéric Martel described similar phenomena, based on interviews with 125 artists under the age of 40 from 18 countries. Martel dubbed creatives whose artistic practices or income streams involve a combination of types of work “slash/artists,” referencing shorthand and colloquialisms for their unique combinations of activities. Examples include “poet/writer/visual/video artist” and “artist/start-upper/web graphic designer/community manager.”⁷⁵

Sweat equity was listed as one of the top sources of support by artists participating in the research. While a significant amount of work for their projects may go unpaid, artists felt ethically challenged and reluctant to rely on the unpaid labor of peers.

Unfortunately, multiple interviewees for this report commented on a steep drop in freelance work during the COVID-19 pandemic. With many offices shuttered and arts, nonprofit, and for-profit entities struggling, the short- and long-term impact on artist-in-residence programs, partnerships, and client work is uncertain. As of February 2021, an Americans for the Arts survey had reported that 96 percent of arts organizations have cancelled events; nearly 120,000 positions had been laid off, furloughed, or left unfilled; and in-person attendance had been reduced by more than 113 million.⁷⁶

Artists collaborate across sectors and establish businesses that build on creative and digital skills.

Artists' combination of creative thinking and digital skills puts them in demand outside the arts sector, particularly in corporate and commercial settings. The opportunities opened up by these skills also inform how universities approach their role in training a 21st-century workforce, seeking to develop students ready to innovate, participate in cross-sector teams, and establish their own businesses. Although many professional opportunities are concentrated on the coasts, attracting and developing this talent is an economic growth strategy for other parts of the country.

⁷⁴ National Endowment for the Arts' *Artists and Other Cultural Workers* further notes that 12.3 percent of artists pursued artistic careers as a second job. Compared with other workers, artists were less likely to work “full-year/full-time,” defined in the report as 50-52 weeks at a minimum of 35 hours per week. Note that both these data and roundtable data were gathered prior to the COVID-19 pandemic. For an additional perspective on this topic, see Woronkowitz and Noonan, *Who Goes Freelance?: The Determinants of Self-Employment for Artists*.

⁷⁵ Martel, “Positive Economy,” 11.

⁷⁶ Americans for the Arts, “The Economic Impact of Coronavirus on the Arts and Culture Sector.” February 21, 2021.

Grants and Fellowships

Grants and fellowships offer income and recognition, with awards from renowned entities bolstering artists' resumes and potentially leading to future opportunities.

Programs often target career stages or geographies, such as the Jerome Foundation's [New Media Jerome Hill Artist Fellowships](#) for early-career artists in Minnesota and New York, or the New York State Council for the Arts' grants in [Electronic Media and Film](#).

Programs may supplement funding with professional development, such as [Creative Capital's](#) combination of project funding for digital media, data visualization, and augmented reality (AR), coupled with advisory services and networking.

While beneficial on many levels, grants and fellowships involve time-consuming applications and inconsistent outcomes, representing both promising opportunities and only sporadic income.

Collaboration, Translation, and Thought Leadership Across Sectors

Collaboration across specializations is a foundational capability that enables artists to further their own projects and enterprises while working with partners across sectors. Artists cut their teeth for such collaborative work within artistic pursuits that depend on a creative team or on artistic or technical expertise beyond their own skill sets. Artists' core collaborators often consist of peers who serve as sounding-boards, technical troubleshooters, tutors, creative partners, and a generally supportive community. Roundtable artists frequently described a "family" of reliable supporters (both biological and chosen) as central to their practices. Core collaborators can also include academics, practitioners with specific technical knowledge, specialists in external fields of study (such as neuroscience, biology, or mechanical engineering), community members, funders, issue-focused nonprofits, and students. Extended processes of research, development, user testing, and revision are common, and artists may even employ co-creation strategies that hinge on community involvement in the creative process.

Collaboration often requires translation—of concepts, terms, and technologies—to ensure that all contributors are on the same page. The ability to communicate with non-specialist audiences is its own skill, and opens up roles for artists as liaisons and connectors between arts and non-arts disciplines. This ability can lead to opportunities in K-12 education, libraries, science centers, public spaces, corporations, and other settings that require artists' combination of creative, technical, and communication skills.

Working across sectors gives artists a unique vantage-point. These artists are simultaneously fluent with technological capabilities and capable of viewing contexts and systems from an outsider perspective as they traverse sectors. Artists have built on their insider/outsider positions to identify perceptual limitations surrounding technologies. They question practices that otherwise might be taken for granted, and they foster larger conversations about artificial intelligence, surveillance and privacy, and representation within the arts and technology sectors. Beyond critiquing current and emergent practices, such artists may construct alternative futures—by using technology as a lens for proposing more ethical or humane directions, or on a practical level, by envisioning new technologies.

Joy Boulamwini Testifying before Congress

Artist and activist [Joy Buolamwini](#) founded the [Algorithmic Justice League](#), developed techniques at the MIT Media Lab to improve transparency in the use of facial recognition programs, and testified before Congress in 2019 on algorithmic bias.⁷⁷ Through such work, artists bring a creative and humane lens toward influencing or rerouting technology developments and practices, addressing areas of concern relevant to large populations affected by these technologies and related policy decisions.

Future Worlds and Storytelling

Alex McDowell, director of the [World Building Institute](#), champions storytelling and narrative media as powerful forms to advance human capabilities. His belief is that the imaginative worlds developed in the creative storytelling process are capable of influencing future realities, as these imaginations can be brought into existence through new technologies. His work on the 2002 film *Minority Report*, which included designs for wearable technologies, gestural interfaces, and driverless cars, provides one example of how artists, when given support to craft a future world, can imagine technologies with potential for widespread interest for years to come.⁷⁸

Imagination, Computation, and Expression

Artist and researcher Fox Harrell explores the interdisciplinary relationships between computer science, cognitive science, and digital media arts. He is co-founder of the [MIT Center for Advanced Virtuality](#) and the [Imagination, Computation, and Expression Laboratory \(ICE Lab\)](#), both initiatives that connect arts and humanities scholars and practitioners with leading technologists to examine the social, cultural, and ethical impacts of computational technology.

Artists as Entrepreneurs

Many of the artists who informed this report are self-employed, producing both artworks and work for clients, particularly in the media, entertainment, and technology industries. Independent corporate, commercial, and freelance work can include coding, web design, corporate installations, designs for trade shows, and motion capture. Artists also use their creative and technological skills in positions within the private sector, which can open doors to for-profit work that is balanced with non-commercial artistic projects.

Artists also launch organizations to pursue client work or to carve their own paths. Participants from among the 66 artists who attended this study's roundtable events had founded at least 34 entities, including artist studios, nonprofits, software companies, businesses, and other organizations. Through such endeavors, artists contribute to creative economies as employers,

⁷⁷ Visit Buolamwini's website www.poetofcode.com for further information on her research as well as videos of past presentations and links to articles. Her full spoken testimony is available on *Medium*, "Face: The Final Frontier of Privacy—Full Spoken Congressional Testimony, May 22, 2019."

⁷⁸ For more information, see Fairs, "Minority Report made today's technology possible, says production designer Alex McDowell"; Roy, "CarDesigning the Future with Creative Director Alex McDowell"; and Wardrip-Fruin, "An Introduction to Alex McDowell's 'World Building.'"

ambassadors for the creative potential of emerging technologies, and managers of hubs that provide resources and physical gathering spaces while also turning their creative pursuits into income-generating businesses.

Launching ambitious startups can also lead to tensions between pursuing profit versus creative projects for their own sake and can place artists in direct competition with deeper-pocketed tech companies. Artist-founded companies such as Scatter, creators of the volumetric filmmaking software Depthkit, produce innovative creative tools that, once released, must compete in technology marketplaces.

See case study on Scatter

Corporate and commercial work are prominent income streams that present artists with both opportunities and challenges.

The ability to merge out-of-the-box thinking with detailed, technical prowess makes artists enticing to corporations seeking to introduce new products into consumer and cultural arenas or to participate in trends of enlivening business with innovation and creativity.⁷⁹

This momentum has a long history, stemming in part from late 1960s arts, science, and technology collaborations such as the involvement of Bell Labs engineers in Experiments in Art & Technology (E.A.T.), Arts and Technology (A&T) at the Los Angeles County Museum of Art (LACMA), and the Center for Advanced Visual Studies (CAVS) at the Massachusetts Institute of Technology. Such precedents provide a foundation as well as a point of comparison for the opportunities and challenges faced by artists working with industry today.

Opportunities for Artists and Industry

For artists, corporate partnerships and artist-in-residence programs enable them to try out technologies in development; work with cross-disciplinary collaborators at the top of their fields; push the boundaries of new tools, materials, or software; create new work; or access workspace and expensive equipment and software. Projects for residencies or corporate clients also give artists the opportunity to build and test code or systems that they can redeploy in art projects, thereby diminishing unpaid development time.

For industry, artists can provide an external perspective that helps researchers see new possibilities and troubleshoot solutions. Artists can also reveal uses for technologies not previously imagined, find clear methods of conveying complex ideas, engage and inspire potential users, and generate positive media attention.⁸⁰

The knowledge and abilities that artists bring to client work are forged in experimental arts contexts, making intersections of arts and digital technologies an early testing-ground for what may later become more widespread cultural and technological practices. Kevin Cunningham, executive artistic director of the arts and technology-based theater company [3-Legged Dog](#),

Participants from among the 66 artists who attended this study's roundtable events had founded at least 34 entities, including artist studios, nonprofits, software companies, businesses, and other organizations.

See case study on 3-Legged Dog

79 Beck and Bishop, "The Return of the Art and Technology Lab," 228.

80 Diamond, "Degrees of Freedom: Models of Corporate Relationships," 409-413.

active from 1996-2020, cited immersive event design as one such example that went from “purely experimental up until a few years ago” to “commercially essential” prior to the COVID-19 pandemic.

AI and Architecture

From 2017-2019, architectural designer Jenny Sabin participated in the [Microsoft Research Artist in Residence Program](#), which connects artists with scientists, engineers, and new technologies to “expand public perception of computer science.”⁸¹ During her residency, she created *Ada*—a giant architectural installation that lights up different colors depending on people’s expressions, driven by AI.

Obstacles Confronted by Artists

When accepting industry opportunities, artists may find themselves steering around concerns over complicity with practices such as consumer surveillance and data-gathering. They may also grapple with the uncertainty of their long-term impact on corporate cultures, the risk of valuable work being co-opted, participation in smoothing over a company’s negative image, and judgments that such affiliations amount to “selling out.”

Corporate investment can stimulate work with particular technologies, such as specific hardware or new software applications, but this support ebbs and flows based on industry trends and demands.⁸² Through residencies, donations, or organizational mediators, corporations may offer artists the opportunity to experiment with technologies that would normally be out of reach financially, but there is no guarantee for how such technologies will take hold. This market-driven element can lead to both sudden opportunities and distracting career disruptions for artists responding to changing industry trends.

Partnerships in industry can also lead artists into a thicket of intellectual property and licensing concerns, particularly when artists want to retain control of and access to tools they build while working in corporate settings.⁸³ Serpentine Gallery’s [Legal Lab](#), devoted to examining “how the law can better support collaborations across art, science, and technology,” is one model for responding to this need, through both researching legal challenges and prototyping solutions.

Fostering Industry Relationships on an Individual Level

While artists working in digital technologies are often asked to produce a work or tangible item for industry, the long-term benefit of industry collaboration can be intangible. Asta Roseway, principal design researcher in the [Urban Innovation Initiative at Microsoft](#), commented on the value of

81 “Collaborations.” *Microsoft*. Accessed April 6, 2021. <https://www.microsoft.com/artist-in-residence/collaborations/>

82 For example, for examinations of shifting investment in VR, see Lee, “VR gets reality check with significant decline in investment” and Jenkins, “The fall and rise of VR: The struggle to make virtual reality get real.”

83 Licensing concerns may vary by geography; for example, for this study, Los Angeles-based artists mentioned corporate relationships and commissions as an income source at a higher rate than did artists in other roundtable cities (Miami, Detroit, and New York). They also reported, at a higher rate, specialized needs such as affordable lawyers and advisors, and education on contracts and intellectual property rights.

artists' perspectives and mindsets, explaining that by interrupting and expanding habitual ways of thinking, artists help her company's researchers reassess their assumptions about what particular technologies can do and what they can be used for.

While such impact is not guaranteed, it can be an authentic goal for individuals working to foster connections between artists and industry through advocating for programs and managing collaborations. Edward Shanken, associate professor of digital art and new media at the University of California, Santa Cruz, noted the significance of individuals in driving arts and industry partnerships, writing that "although corporate artist residencies and project sponsorship require broad support from within an institutional framework, often it is the vision, talent, and work of individuals that generate such programs."⁸⁴

As distinct sectors manage the course of the COVID-19 pandemic, such individuals may well be key for maintaining or encouraging the return of collaborations between artists and commercial industries.

Ada, an architectural installation project by Jenny Sabin Studio in collaboration with Microsoft Research. The 3D printed structure is driven by artificial intelligence and responds to facial reactions and tone of voice using light and color. Photo by Jake Knapp for Microsoft



84 Shanken, "Artists in Industry and the Academy: Collaborative Research, Interdisciplinary Scholarship and the Creation and Interpretation of Hybrid Forms," 416.

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CHAPTER 3

Next Steps for Supporters

This chapter is divided into two sections:

- **Understanding Challenges** highlights resource and infrastructure gaps for artists, organizations, and the broader arts and cultural field.
- **Recommendations** identifies near-term opportunities and actionable items to address challenges and deepen support for the field.

UNDERSTANDING CHALLENGES

Artists working with technology as a creative medium face numerous gaps, obstacles, and speed bumps. The chapter encompasses not only individual artists' hurdles in accessing tools, equipment, space, and money for projects, but also the complexities that arts organizations face in learning about and presenting the work. Many physical spaces in the arts sector were not built with technology capacity in mind, and do not have the infrastructure necessary to accommodate the kinds of works these artists are creating today, nor the ways that artists imagine audience participation. Furthermore, the technical knowledge of staff at cultural organizations is often not sufficient to support tech-centered artistic practices.

Artists repeatedly noted structural barriers that limit participation in the arts and technology ecosystem by race, gender, and other forms of privilege embedded in both the technology sector and the arts sector. Class, race, and family wealth, in particular, were recurring themes. Artists frequently commented on the prohibitive costs of electronics, software, and hardware; the lack of access to broadband in both rural and urban areas that limits connections; and the need for educational on-ramps that provide all school-aged children with computer training.

Artist Challenges

“Independent creators are actively creating experiences that are driving the future of technology. We need more artists to be funded to see what the potential of this medium is. We need to get the technology into the hands of people who don't have the resources to get it.”

—Kent Bye, Host, *Voices of VR* podcast

Given this report's deliberate inclusion of a wide range of artistic practices, specific challenges vary based on an artist's realm, career phase, and proximity to physical resources. While tech-centered artists cultivate exceptional skill sets that can lead to opportunities not available to artists working in other disciplines, a number of common challenges arose from the research.

Artists face difficulties accessing training and equipment, a challenge that is exacerbated by the quick evolution of technologies. Keeping up with digital tools and platforms requires continuous learning. Furthermore, while artists often described their academic arts training as useful for theory,

context, and art histories, many found that their education did not fulfill their technology-related needs. Even so, when university programs did provide foundational technology training, artists emerging from these programs are abruptly cut off from access to expensive equipment, software, space, and knowledgeable colleagues. While physical and online hubs exist to provide free and low-cost educational resources and forums, which are often founded by artists to fill the need for accessing affordable training and equipment, such organizations are hard-pressed to fulfill the extent of the ongoing need.

Artists who shared their experiences at roundtables in fall 2019 outlined a number of pathways to supporting the field. In terms of training and equipment, artists will benefit from access to spaces with shared resources, tools, and equipment outside university settings.

Artists often rely on commercial software, which can be expensive, or on open-source tools, which can be built on the unpaid labor from the artists who produce and maintain them.

Commercial software can be costly and, with the rapid turnover of both hardware and software, artists who rely on such tools alone may not be able to sustain their practices. Free resources such as open-source software play an indispensable role, both by providing established artists with the tools needed to create work and by providing pathways into these practices for new generations of creators. Yet these vital tools rely on degrees of goodwill and donated time that can be unsustainable for artists struggling to make a living.

Despite the value of free and open-source tools for the field, lack of financial support for this work leads to a burden of uncompensated labor demanded of those who make the effort to create these resources. The ongoing nature of upkeep can lead to burnout—a hardship for individuals and a potential loss for the field when the challenge becomes too big for artists to sustain. Open-source tools are also at risk of being exploited by profit-driven companies, leading to a question of how to protect a vital arena of low-cost, easily accessible resources.

Artists often describe gaps in resources for project development.

Arts and digital technology projects can have long incubation and development timelines, requiring extended time for experimentation, collaboration, and customized coding and debugging. Processes and projects may, by their nature, be iterative, exploratory, and open-ended. Projects often require maintenance while software and hardware are updated.

Artists working at the intersection of technology and performance spoke of the need for creative space and time to interweave multiple forms of expression and technology. They also noted the difficulty of working within the timelines and expectations of standard venues, with limited tech rehearsal time and quick load-in and load-out schedules. In particular, works can require further time to remount and troubleshoot as they travel to new venues that have differing technology infrastructures or staff expertise.

Research-and-development time often comes with restrictions. Academic spaces may require end-of-semester culminations or otherwise adhere to semester-based timelines. Corporate residencies can come with expectations and priorities related to a company's market-based goals. Arts organizations or arts and technology residencies may not be able to provide adequate time, with artists stringing together multiple opportunities to support continued project development.

Cultural institutions that commission work also may not be able to accommodate the lead time necessary for building software, troubleshooting with collaborators, or otherwise constructing artworks. As a result, the fees, commissioning dollars, and development times allotted to projects can be unrealistically low.

Financial difficulties create a number of obstacles for artists working in the field.

“Many creatives I had seen who were working with new technology didn’t squarely fit into the art market or other traditional markets in industries like film, architecture, or design. As a result, they didn’t fit into the parameters for funding that was available. They were in this in-between space that fell through existing funding streams and market opportunities.”

—Julia Kaganskiy, Independent Curator and Cultural Strategist

Like other artists, and as documented in the 2016 *Creativity Connects: Trends and Conditions Affecting U.S. Artists*,⁸⁵ income instability is prevalent for individual artists of all disciplines. Portfolio careers are a workaround for aggregating income, yet this type of patchwork employment comes with its own challenges. Artists often lack healthcare, carry debt, and deal with stress in attempting to piece together paying work that they juggle with artistic endeavors. “Gig” work is inconsistent, requiring an unpaid output of time in seeking new clients. Family wealth helps some artists, but those without this type of support struggle with the high cost of basic tools such as hardware and licenses.

One factor that may be different for the artists profiled by this research is that artists with significant digital technology skills may have greater opportunities in the commercial tech sector and thus greater employment prospects overall than may artists in other disciplines. As artists, nevertheless, their income patterns and prospects are similarly challenged. Recruitment into the commercial sector can also be a loss for the field, as artists shift careers to accept more sustainable and lucrative full-time employment.

Artists may pour time, energy, and funding into projects with limited distribution and presentation options.

Artists variously described the infrastructure for the creation and distribution of their work as “nonexistent,” a “unicorn,” and “spotty.” While arts organizations have been organizing special exhibitions related to artists working with digital technologies since the mid-1960s, more work is needed to develop a foothold in arts institutions which play a critical role in reinforcing canons, setting trends, and elevating artists and artistic practices to a respected status. Such effort is related to opportunities—co-commissions, touring, and other cost-sharing measures common for both the visual and performing arts—as well as the legitimacy and visibility that cultural institutions lend to the artists and projects they support.

Visual arts organizations frequently cultivate reciprocal relationships with collectors, who serve as advisors, board members, donors, and sources for exhibition pieces. Artwork donors and lenders enjoy tax benefits or increases in the value and prestige of their collections, with institutional choices also informing their collecting practices. Given this relationship between arts institutions and private collectors, interviewees reported that the lack of collectors for digital artworks poses a challenge to integrating the work into museums. Patron education may be one solution, detailed by [TRANSFER](#) gallery-owner Kelani Nichole, who is cultivating a new generation of collectors by helping them to understand the installation and care of such pieces. While collectors may be promising supporters, the relationship between wealth and artistic renown is worth questioning, particularly in an artistic arena with large segments inspired by social movements and the democratization of creativity.

Meanwhile, film and festival circuits for VR/XR/AR provide artists with a number of opportunities for showing their work. However, the nature of such festivals requires that work is displayed in particular

85 Center for Cultural Innovation for National Endowment for the Arts, *Creativity Connects*.

locations for short periods of time and primarily reaches audiences rooted in the film or tech industry. This factor limits the ability of curators, arts leaders, producers, and mainstream audiences to experience new work, a scenario that both lessens the artist's immediate return on investment and limits the networking that may result in future opportunities.

Funders can have a significant impact on expanding distribution channels for artists and providing valuable opportunities to intersect with technology-centered works. In 2019, [Knight Foundation](#) set aside \$750,000 and issued an open call for “innovative ideas to engage audiences through immersive technology,” which received more than 500 submissions.⁸⁶ This investment enabled five arts institutions to experiment with using immersive technology for audience engagement and provided models for other institutions seeking to engage audiences with arts and technology.

The decentralized nature of the expansive arts-and-technology field poses challenges related to a lack of shared language, information, and critical coverage of artists' work.

As discussed throughout this report, both artists' language and the terms chosen by field-related programs can vary. Both the divergence and changeability of field language can pose challenges for individuals who may need to periodically shift their terminology to align themselves with the latest buzzwords. The sheer multitude of terms also challenges individuals new to arts and digital technology who are interested in learning about the field but who may not know which terms can retrieve the information they need.

This lack of agreed-upon terminology in turn reflects the large array of practices that the broader arts-and-technology field encompasses. The number and variety of areas involved in cross-disciplinary work means there is no central resource to gather the information needed for staying apprised of distinct intersections.

Interviewees noted reliance on Slack channels and social media feeds/groups (such as the [Everything Immersive](#) Facebook group), and select publications (such as [Leonardo](#), [Immerse](#), and [e-flux](#)). They also mentioned following specific individuals to stay current with emerging trends or news—naming sources such as Kent Bye, the journalist behind the [Voices of VR](#) podcast, or Jesse Damiani, curator, writer for *Wired* and *Forbes*, host of *TECH TOCK*, and deputy director of emerging technology & insight at Southern New Hampshire University.

Organization Challenges

Philanthropic funding sources can find it challenging to provide avenues of support tailored to the unique working requirements of arts-and-technology practice.

“[Thoma Foundation] decided not to call it new media, we decided not to call it computer art, and really only use those terms when we're talking about historic eras, and to sum it all up as digital art. I'm sure, in a few years, even that term will be contested...as some artists reject the term digital now. Is it a monolithic field or the two fields or the four? It's a question we often return to, because just creating a name for something is how you identify it, right?”

—Jason Fournberg, curator and funder, Thoma Foundation

⁸⁶ For more information, see Knight Foundation, “Shaping the Future of Technology in Museums: Knight Invests \$750,000 in Five Experiments Using Immersive Technology in the Arts.”

The commercial marketplaces and philanthropic pipelines supporting tech-centered artistic practices are immature. They lack shared resources for collaborating and for comparing notes. Interviewees cited challenges at every phase of arts-and-digital-technology work, from research and development to public presentation to archiving.

Online communities and virtual networks are critical support systems, but funding these resources can prove difficult for grantmakers that are locally or geographically based. Local and place-based funders may have difficulty learning about work in their own backyards, especially when it is accessed mainly online.

Many arts funding programs are designed and evaluated on the basis of support for traditional arts disciplines, whereas tech-centered artists and projects often do not neatly fit the norms of arts funding. Grantmakers additionally noted changing program names and inconsistencies regarding categorizations for artists working with technology. Multidisciplinary funding categories are one solution presented by artists, with an emphasis on the complementary need for jurors who understand cross-disciplinary collaboration and tech-centered artistic practices. This finding is corroborated in the Arts Endowment's Creativity Connects report, which documents artists' views that the guidelines for artists' support programs are not keeping pace with artists' working practices.⁸⁷

Art institutions often lack staff expertise to curate, present, interpret, and engage audiences with artists who use digital technology as a creative medium.

Artists expressed concern over the relatively small number of curators familiar with the field. In practice, this means a lack of capacity in areas that mirror the typical lead-up to an artwork being selected and produced or presented (in museums this could mean the art historical context, collection practices, exhibition requirements, and distribution channels). Few museums employ curators with knowledge of creative practice in technology, instead relying on guest curators, and thus learnings do not accumulate into an institutional knowledge base.

Maintaining and archiving digital work requires particular knowledge and technologies often not present in arts institutions. Projects that overlap with the field of public art may incorporate maintenance planning (near- and long-term) as part of contract negotiations. However, many other projects in the field lack necessary maintenance and preservation planning. Additionally, challenges arise related to certain types of platforms. Artworks that use proprietary platforms such as iPhones or VR headsets, which are difficult to emulate, are difficult to conserve. Social media forms like Instagram present challenges related to preservation, given that artworks can be lost with platform redesigns.

Institutions lacking in-house expertise call on artists to troubleshoot for tasks such as remounting older projects in advance of new exhibitions. Even digital preservationists may resort to using tools built for other industries, such as tools created for preserving information on a criminal's confiscated laptop, in the absence of tools intended for maintaining artworks. As artists and organizations work to find solutions on a case-by-case basis, learnings related to methods for file storage, acquisition, or condition assessment, etc., for similar pieces are not being shared. The greater field is not aggregating this type of knowledge.

Jason Foumberg, curator of digital art at [Thoma Foundation](#), emphasized a need for archiving and maintenance discussions during artwork acquisition, noting that artists working with technology must be empowered to make specific demands about the future maintenance of their work, from

87 Center for Cultural Innovation for National Endowment for the Arts, *Creativity Connects*.

periodic artist assessment of a work's condition to coverage of related costs in terms of artist time and technology upgrades. While maintenance plans could be created and followed for each artwork, cultural institutions will need to invest in new capabilities. The rapid evolution of software and hardware makes the maintenance factor both urgent and complex.

Lack of expertise can also affect visitor experiences. Institutions unaccustomed to working with technologies may not take the extra step to consider how to establish welcoming and streamlined environments for visitors who may be new to interacting with certain types of technology.

Even prior to the COVID-19 pandemic, artists commented that audiences may be concerned about germs when using exhibition VR masks, and institutions may need to develop strategies for educating audiences and facilitating interactions with projects. [TRANSFER](#) gallery's Kelani Nichole created one workaround for such situations by developing a visitor experience checklist that included someone testing interaction points in an exhibition on an hourly basis. Such solutions may lie outside the financial means of all but the largest organizations.

Arts institutions frequently lack the technological infrastructure to adequately support arts-and-technology projects.

Many arts institutions and venues were constructed in earlier eras and have not been renovated to accommodate emerging technologies. Additionally, the lack of knowledge of the field means that employees in charge of planning building upgrades may not know what is needed.

Artists recounted having to provide their own equipment for exhibitions and described venues lacking basic requirements (reliable internet, computers, and accessible electrical outlets). They drew a contrast between this situation and experiential or primary market venues designed for digital projects, such as [ARTEHOUSE](#), or venues with access to the infrastructure and staff to accommodate this work, as found in arts and technology hubs.

Solutions to these challenges require institutional investment. However, the rapid turnover of technologies can lead to a reluctance to invest in equipment that could quickly become obsolete. Workarounds could involve equipment that tours with an artwork, shared equipment that can be borrowed for exhibitions, and longer-term maintenance planning at the time of acquisition. Such commitments may require a change of habits not only for an individual institution but also for institutions that work in partnership to better position their venues to share this work with audiences.

Barriers & Regional Challenges

Through roundtable discussions and interviews, informants described obstacles they face and which they view as common in the field. Race, gender, access, and other forms of privilege at play in both the technology sector and the arts sector arose as key concerns.

Class, and family wealth in particular, was a recurring theme. Artists frequently commented on the prohibitive costs of electronics, software, and hardware. Costs, paired with the realities of making a living as an artist without accumulated wealth, shed additional light on the centrality of open-source software, examined elsewhere in this study. Financial privilege can also lead to a lack of awareness, which impacts financially strapped artists attempting to participate in activities organized by artists with disposable income. Events difficult to access with public transportation, or held at sites closed to those under 21, create barriers to participation. Event logistics point to a larger social call for "radical hospitality"—actively working to make participation streamlined and welcoming and to improve accessibility to all populations.

During regional roundtable discussions related to how artists self-identify in terms of artistic discipline, artists raised broader issues of intersectionality, such as junctions of race, gender identity, and class, underscoring that working in the field is informed by “not just disciplines but what communities you belong to.” Artists spoke of regularly code-switching to align oneself with the expectations of different communities and cultural subsets that intersect with the field and exist within it.

Artists’ needs, as well as available or unavailable resources, differ across geography, artistic practice, and career phase, and are subject to change both as technologies shift and as generations of digitally native artists create work. Insights in this field scan reflect some of the particular geographies of the artists who have participated in roundtables, based in New York City, Los Angeles, Detroit, and Miami. While there may be similarities and differences in building careers across artistic disciplines, informants revealed some differences across geographic regions.

New York City artists have comparatively more places to go in order to access technical training outside colleges and universities. Even there, however, hubs are concentrated in particular boroughs and can be challenging to access for artists relying on public transportation. Los Angeles artists cited relationships with commercial media and entertainment companies more frequently than did artists in other cities. They also more frequently raised the challenges of intellectual property and rights agreements.

Outside the four roundtable cities, artists in the Midwest and in rural areas face distinct challenges, from struggling to connect with presenters and galleries on the coasts who may provide important exposure and pay higher fees, to a lack of high-speed internet access. The latter poses a challenge not only to artists and audiences, but also to artist-entrepreneurs and future generations of technology-based artists living in rural areas.

The Federal Communications Commission estimated that at the end of 2019 14.5 million people in the U.S. lacked high-speed internet, including approximately 17 percent of people in rural areas.⁸⁸ An article in the *Washington Post* underscored the heightened impact of this disparity due to distance-learning during the COVID-19 pandemic, citing research from 2018 reporting that nearly 17 million children lacked high-speed internet at home and more than seven million did not have access to a computer.⁸⁹ Such disparities affect Black, Latino, and Native-American households at higher rates, so that nearly one-third of students from these communities did not have high-speed internet at home.

88 Federal Communications Commission, “Fourteenth Broadband Deployment Report,” FCC 21-18, January 19, 2021. Accessed April 7, 2021. <https://docs.fcc.gov/public/attachments/FCC-21-18A1.pdf>

89 Balingit, “A national crisis’: As coronavirus forces many schools online this fall, millions of disconnected students are being left behind.”

RECOMMENDATIONS

“It’s important that new media art and other emerging digital practices are represented and supported within major cultural institutions. While museums and other cultural gatekeepers might be hesitant to engage with this work, perhaps due to a lack of expertise or resources, there are artists working in these modes to deeply interrogate contemporary culture, aesthetics, and power structures. We need more pathways through the art system for these artists, because society and audiences benefit from the lens they put on our world. Philanthropic support can help institutions make this transformation and provide relevant digital offerings.”

—Chris Barr, former Director of Technology Innovation at Knight Foundation

This report characterizes a distinct field of creative practice at the intersection of the arts and digital technology. In doing so, the report explores promising avenues for supporting and engaging with tech-centered artists and organizations.

The featured artists, organizations, and case studies provide further insight on how these specialized digital skill sets can contribute to areas beyond the arts, such as computer science, community development, and to solutions around social and racial equity. Boundless opportunities exist for the arts and cultural sector to engage with tech-centered artists in uniting local communities, bridging digital divides, and supporting a more resilient arts and cultural ecosystem.

The use of technology as a creative medium has applications far beyond the arts and cultural sector alone. Even within the arts, however, this emergent field is rapidly gaining ascendancy—both economically and in the sheer volume of creators and consumers. From 2015 to 2017 alone, for example, the value to the economy from web streaming and web publishing services grew by 29.2 percent, compared with arts and culture in general (+4.5 percent) and the overall economy (+2.0 percent).

More than 74 percent of adults, or 176 million people, used media to consume art in 2017—far more than the number who attended in-person arts events that year. Arts participation via digital media is especially favored by younger adults. More recently, with COVID-19 pandemic causing arts organizations to close their doors across the nation, the need for artists and cultural institutions to engage with the public virtually has never been greater.

In the Community+Culture in a Time of Crisis survey published in July 2020, more than half of respondents said they had “participated in one or more digital cultural activity” since the pandemic began. Most had not physically visited the same cultural organization in the past year.⁹⁰ As organizations pivot to serve their existing audiences virtually, they are seeing broader participation from new audiences.

Such virtual participation will prove especially important as arts organizations reopen. Recent research published by the Arts Endowment shows that adults who used media to consume visual art or music, dance, or theater performances were at least five times as likely as other adults to attend in-person arts events. (This ratio holds after accounting for differences in race/ethnicity,

⁹⁰ LaPlaca Cohen, Culture+Community in a Time of Crisis, https://s28475.pcdn.co/wp-content/uploads/2020/09/CCTC-Key-Findings-from-Wave-1_9.29.pdf NOTE: This is from the first wave study. A second wave report is expected in autumn 2020 so the final report for the ATFS can be updated with the new data.

gender, age, and educational background⁹¹.)

Concurrent with trends within the arts sector, greater integration of the arts with computer science—in K-12 and higher education—offers more opportunities than ever before for tech-centered artists and organizations to partner with STEAM educators and networks involved with initiatives related to [Computer Science for All](#) (CS4ALL). Together, artists, designers, and educators can design tools and programs that engage children and youth from all backgrounds with computing skills that increasingly will be sought by job recruiters.

Examples of Initiatives Led by Funders:

Ford Foundation's [Creativity and Free Expression](#) portfolio supports underrepresented voices in technology by investing in projects such as [Making a New Reality](#), [Guild of Future Architects](#), and [NEW INC](#), as well as artists such as Stephanie Dinkins and Joy Buolamwini. In addition, Ford Foundation Tech Fellows are embedded within program areas and work at the intersection of social justice and technology. For example, Tech Fellow Salome Asega explores "[What happens when artists use tech to confront inequality?](#)"

[Knight Foundation](#) has seeded multiple [Arts + Technology](#) initiatives enabling institutions to create new ways to explore and make art; to express culture; and to reach, expand, and engage diverse audiences using technology. In 2021, they launched the [Knight Arts + Tech Fellowship](#), administered by United States Artists, which provides unrestricted grants of \$50,000 to artists using new and emerging technologies in thoughtful, creative, and poetic ways to expand the field.

National Endowment for the Arts' [Grants for Arts Projects](#) funding in the Media Arts discipline includes a focus on projects serving artists and audiences that contribute to the digital capacity-building efforts of organizations by hiring artists and creative expertise at the intersection of arts and technology. Projects funded by the Arts Endowment offer exemplary models supporting emerging practices in digital storytelling; performance, visual, and cinematic arts; and net art. They also include immersive and interactive media, open-source software toolkits, and other forms of data visualization or computation across all artistic disciplines, genres, and forms.

[Thoma Foundation](#)'s Digital Changemaker Grants support initiatives that reimagine the role and use of technology to achieve the organization's mission. The \$100,000 grant focuses on small and midsize cultural organizations in Arizona, Illinois, New Mexico, Oklahoma, and Texas and is open to a broad array of cultural organizations, including but not limited to museums, cultural heritage centers, tribal organizations, libraries, and local arts councils.

91 National Endowment for the Arts, *Paths to Participation*. For more information, see the 2017 SPPA technical documentation, available at the [National Archive of Data on Arts and Culture \(NADAC\)](#).

Overall, these six recommendations will provide support to tech-focused artistic practises:

- Expand Expertise and Technical Capacity
- Review Program Priorities and Outreach Plans
- Lift Barriers to Collaboration across Arts and Non-Arts Sector
- Strengthen Technological Infrastructure Serving Arts and Culture
- Offer Project Development, Creation, and Exhibition Opportunities
- Deepen Public Understanding of the Field's Value and Impact

The following recommendations are offered with the hope of inspiring readers to build a more resilient and equitable arts and cultural ecosystem for the 21st century.

Expand Expertise and Technical Capacity

Problem: Many artists reported that arts and cultural organizations are underprepared to adequately support the growing digital and virtual needs of artists and audiences, and that these organizations often lack expertise on staff to meet the needs of tech-centered artists and related practices. For example, institutions unaccustomed to working with technologies may be ill-equipped to properly present and install works—a deficiency that can result in unsatisfactory experiences for audiences and visitors. In addition, maintaining and archiving digital work requires special knowledge and technologies not always present in arts institutions.

Suggested Actions:

- Hire, partner, or consult with artists, arts collectives, curators, and arts workers who have experience working at the intersection of the arts and technology. These individuals or organizations can fill gaps in curatorial, installation, programmatic, or digital preservation expertise. Encourage your program staff to identify local and regional artists, organizations, and networks that may prove useful for strategic partnerships. These types of projects are encouraged in the [Grants for Arts Projects](#) opportunity within the Media Arts portfolio of the National Endowment for the Arts.
- Provide professional development opportunities for program staff to strengthen expertise by attending related conferences, events, workshops, and festivals.
- Consult knowledgeable practitioners with experience presenting tech-centered projects before you invest in technical facilities renovations or equipment upgrades. This way, you will avoid unnecessary or inefficient spending. The most useful exhibition spaces are often the most flexible ones, relying on rented equipment and less permanent infrastructure.
- Pursue strategic partnerships with local or global technology-based businesses such as software companies, commercial media firms, and corporate events specialists to provide cost-effective solutions, equipment, and technical resources for the installation, presentation, and exhibition of complex works. Nurturing these partnerships may help expand staff and technology expertise without your having to hire full-time staff.
- Tech-centered artists might need specialized assistance, installation timelines, and longer technical rehearsals for exhibiting works and troubleshooting, as they travel to new venues possessing differing technology infrastructures or staff expertise. Build in staff time to get on the same page with tech-centered artists and organizations about shared expectations and needs.
- Invest time and resources in documenting successes and failures. Share what you learn!

Review Program Priorities and Outreach Plans

Problem: Many artists and organizations featured in this report expressed having limited relationships, knowledge, and low comfort levels in approaching grantmakers, arts service or presenting organizations, and traditional arts institutions. Some artists and organizations asserted that their work was structurally excluded by arts funders, in particular due to disciplinary-based guidelines and standardized documentation requirements that often do not align with arts-and-technology outputs.

Suggested Actions:

- Arts agencies, service organizations, performing and visual arts organizations, residency programs, and funders can ensure that calls-for-work, open submissions, and program offerings have the potential to welcome artists, curators, and projects at the intersection of arts and technology.
- Disciplinary categories and program guidelines can be updated to explicitly reference arts projects and initiatives that incorporate new media, creative code, and emergent forms existing at the intersection of arts and technology.
- Public and private cultural funders can support grant funding and technical assistance for existing or new special initiatives that encourage arts and technology. Targeted outreach plans can promote grant opportunities and provide technical assistance for new applicants, possibly improving funding success rates.
- Funders can include appropriate field experts to review grant applications for projects involving technology. This report can be used to identify and engage networks as jurors or grant reviewers, and to boost outreach for prospective applicants.
- Arts funders and organizations should consider supporting the development, maintenance, and education of creative open-source tools, alongside related online forums, communities, and arts collectives. Artists repeatedly explained the foundational role of these entities in creating their work—yet the need for such funding is still not yet widely understood or embraced by cultural grantmakers.
- Service organizations should ensure that existing services for artists—e.g., legal advice, fiscal sponsorship services, and grant-writing clinics—extend to this emerging group of tech-centered workers.
- Grantmakers, arts service or presenting organizations, and traditional arts institutions can proactively identify and connect with regional hubs, networks, and artists working at the intersection of arts and technology to discover future opportunities for relevant constituencies.

Lift Barriers to Collaboration Across Arts and Non-Arts Sectors

Problem: While this report shows how practicing artists engage with technology to innovate across artistic disciplines, academic departments, and industry sectors, information silos exist and can result in missed opportunities and knowledge gaps. Tighter networks are needed to foster long-lasting, cross-sector relationships and make space for routine knowledge exchanges to share best practices, resources, and effective models in supporting tech-centered artistic practices. In addition, this infrastructure can seed technology-focused partnerships and strategic initiatives using the arts to advance shared goals and priorities.

Suggested Actions:

- Arts agencies, service organizations, and funders can build and nurture relationships within and across this field through activities regularly connecting with artistic disciplines such as film, performing arts, visual arts, and arts education. By doing so, they can rally arts and cultural organizations of all sizes and types, such as community arts spaces and collectives, arts presenting organizations, makerspaces and “fab labs,” universities, and legacy institutions.
- Academic institutions can help break down disciplinary and academic “silos” that hinder effective collaborations. Leaders in higher education should inspire students and faculty to engage with different departments, participate in cross-sector teams, and invent new creative opportunities. For concrete tips, academic leaders may wish to consult a previous report, also supported by the National Endowment for the Arts: [The Integration of the Humanities and Arts with Sciences, Engineering, and Medicine in Higher Education](#).
- Art department faculty can aid the artistic and professional development of students by incorporating basic coding and digital training into curricula across all disciplines.
- Educators seeking to prepare students with 21st-century skill sets through in-school and out-of-school learning activities can convene on a regular basis to strengthen relationships across intersecting networks such as Career and Technical Education (CTE) offices, CS4ALL, digital media arts and computer science educators, artists and educators in the creative code community, makerspace affiliates, and key networks such as the [Arts Education Partnership](#) and the [Alliance for Media Arts and Culture](#).
- Educational institutions and school districts can help higher-learning instructors and K-12 educators achieve student learning goals by partnering with or hiring artists and arts organizations with specialized expertise in conducting fun educational activities involving digital arts, technology, and computer science for youth and adults.
- Children and youth interested in computational thinking, creative code, and computer programming can benefit from learning about existing online forums led by artists and creative coders. Educators can inventory, and raise visibility of, these online educational resources for local schools and recreational programs. For example, [The Coding Train](#) has a series of fun coding tutorials that are popular on YouTube and can motivate aspiring programmers to learn new skills.
- Stakeholders across arts and non-arts sectors can explore ways to establish paid arts-and-technology fellowships or embed artists-in-residence to expand staff expertise, build connectivity between often-siloed grant portfolios or departments, or provide fresh insights by testing creative capabilities of new products or technologies.

Strengthen Technological Infrastructure Serving Arts and Culture

Problem: Regional hubs of arts and technology practitioners represent a field of practice that could be more embedded within the U.S. cultural infrastructure more broadly. At present, the lack of available funding to adequately support technical infrastructure or digital capacity-building initiatives for arts and cultural institutions is a barrier to widespread participation in the arts and technology ecosystem. These gaps exist alongside systemic inequities contributing to digital divides across geography, ethnicity, race, and gender. For example, artists in the Midwest and in rural areas face distinct challenges, from struggling to connect with tech-savvy presenters and galleries on the coasts, who may provide important exposure and pay higher fees, to a lack of high-

speed internet access. The latter poses a challenge not only to artists and audiences, but also to artist-entrepreneurs and future generations of technology-based artists living in rural areas.

Suggested Actions:

- Create pilot programs in cities across the nation to advance arts-and-technology initiatives. Targeted activities can be developed by mapping regional assets, opportunities, and needs to address resource gaps affecting local artists, cultural organizations, arts audiences, and communities.
- Federal and state agencies can facilitate local-level collaboration across sectors by establishing interagency working groups and partnerships to address digital infrastructure needs and support community-based arts programming designed to bridge digital divides, advance digital literacy, and build 21st-century skill sets.
- Policymakers can ensure that municipal governments are able to provide equitable access to reliable high-speed internet in communities across the U.S. This goal also can support local job and business growth to revitalize communities and attract and retain talent. For example, self-employed artists and designers would be able to establish businesses and reside in rural locations yet continue to serve clients in urban centers.
- Public and private dollars can be invested into digital inclusion initiatives that use the arts to reduce economic, educational, and social inequalities caused by the digital divide. In addition, these investments can support accessible on-ramps to the 21st-century workforce and the next generation of arts leaders. Decision-makers can also find pathways to develop and support affordable space, access to equipment, and opportunities for community-based arts programming, whether through public libraries, community colleges, or standalone nonprofits.
- Funders can help fill the gap in arts journalism and critical analysis by supporting writers and critics covering this area of practice. Both artists and arts organizations said the lack of critical discourse hinders field development and makes it more challenging for arts programmers, curators, and funders to understand and track field developments.
- Educators and policymakers can adopt national core arts standards for media arts and technology. The [National Coalition for Core Arts Standards](#) now include media arts standards to reflect a broader definition of arts-making, which encompasses contemporary art forms such as animation, film, gaming, or interactive- and computer-based art-making. To see the status of media arts policy in your state, use the [Education Commission of the States](#) as a resource.
- Educators and policymakers can support integration of the arts with STEM through educational initiatives inclusive of creative coding and other arts-based learning to bridge digital divides, promote digital literacy, and build essential 21st-century skill sets.
- Establish local, regional, and national partnerships to support equitable on-ramps to the 21st-century workforce. For example, [Arts2Work](#) is the first federally registered apprenticeship programs for media arts and creative technology, which includes a growing network of regional apprenticeship and training hubs led by grassroots media arts organizations. Businesses and tech companies similarly can provide valuable opportunities for workforce development and build talent pipelines through on-the-job-training, apprenticeships, and mentorships.
- Business and particularly tech firms can strengthen the local infrastructure for 21st-century arts and culture through corporate responsibility initiatives supporting equitable access to broadband internet, digital training and tools, and computer science initiatives at venues such as makerspaces and community arts organizations.

- Public and private organizations can develop research agendas that document and evaluate the impact of laws, regulations, and policies affecting independent artists, arts organizations, and the general public in the digital age, such as net neutrality, intellectual property laws, competition and consumer protection in the 21st century, technology mergers and acquisitions, corporate social responsibility, data ownership, and broadband internet and digital issues.

Offer Project Development, Presentation, and Exhibition Opportunities

Problem: Tech-centered artists experience challenges in securing adequate resources for project development. They may pour time, energy, and funding into projects with limited distribution and presentation options. Artists in this report also cited challenges with accessing technical facilities and equipment after receiving formal training.

Suggested Actions:

- Colleges and universities were repeatedly named as the best-equipped facilities available to technology-centered artists. These places offer access to experimentation with tools for developing immersive experiences, digital fabrication, game design, and other creative pursuits at the intersection of the arts and technology. Faculty and staff can develop visiting artist initiatives and residency programs to support the development and exhibition of new work, while providing stepping stones for practicing artists and valuable learning opportunities for students and community members.
- Creative placemaking strategies, cultural institutions, and community revitalization initiatives can commission technology-focused projects and artworks or hire artists to conduct technology-based public programming. Doing so can introduce audiences or residents to contemporary arts approaches to technology, such as new media storytelling projects, interactive art festivals, or temporary public art installations. Commissioned work should adequately compensate artists and accommodate their needs during project development and prototyping, installation, and maintenance.
- Arts service organizations can support program initiatives such as co-commissions, touring, and other cost-sharing measures common for both the visual and performing arts. These measures will introduce audiences to new artists and bring works to places that otherwise would not have access.
- Municipal government entities, such as an urban planning department or public library, can hire or partner with tech-savvy artists and organizations to develop digital content, creative data visualizations, social media, and technology-driven community solutions.
- Cultural and education-based organizations can seek new opportunities to boost funding for arts-and-technology-related initiatives with support from public or private sources. Potential sources include such as National Endowment for the Arts, National Endowment for the Humanities, state or regional arts and humanities agencies, the “Computer Science for All” initiative at National Science Foundation, U.S. Department of Education and state education agencies, local school districts, community-based or arts funders, digital inclusion funds, or corporate responsibility funds and sponsorships from the tech industry.
- Tech firms can provide artists with early access to tools and software. Artists such as those profiled in this report might be regarded as early adopters and could prove eager to test-drive new products and discover new applications. These connections are beneficial for tech companies looking to gain innovative perspectives from potential consumers and explore the creative potential of newly developed tools and software.

Deepen Public Understanding of the Field's Value and Impact

Problem: Several artists claimed that their role was overlooked by the broader arts and cultural field and by other actors in the creative economy. There is a need for greater public recognition of industry's reliance on artists' mindsets, in particular for their creative approaches, innovations, and contributions to the technology sector.

Suggested Actions:

- Field practitioners and arts researchers can promote ways that artists address issues around digital equity and inclusion; contribute to building pipelines for a more equitable and diverse tech industry; and examine ethical issues surrounding technology, such as data privacy and artificial intelligence. Elevating these contributions will help the field advocate for greater public and private investments in arts and culture, STEAM initiatives, the creative economy, and initiatives for digital inclusion and training.
- Researchers can develop agendas that can inform best practices, models, and support ways for the arts and cultural sector to bridge digital divides, train the 21st-century workforce, improve digital literacy, teach computer science education, build strong and resilient communities, and stimulate local economy.
- Researchers can conduct further studies documenting the value and impact of arts-and-technology training and related entrepreneurial activities, which can provide kindling for creative economy decision-makers. Many of the artists participating in this report are entrepreneurs, populating a wide range of businesses, governments, media, and nonprofits with their creative energy.⁹²

⁹² In addition, this report did not set out to research the role of digital arts programs for children and youth as pathways to working in arts and technology, but it is an area that should be studied.

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Case Studies

3-Legged Dog
Refik Anadol
Design I/O
Stephanie Dinkins
Darcy Neal
Processing Foundation
Scatter
Lance Weiler
Amelia Winger-Bearskin

Commissioned Essays

Agnes Chavez, STEMarts LAB
Vanessa Chang, CripTech Incubator, Leonardo/ISAST
Megan Elliott, Johnny Carson Center for Emerging Media Arts, University of Nebraska-Lincoln
Ari Melenciano, Afrotectopia
Stephanie Pereira, NEW INC
Omari Rush, CultureSource
Eleanor Savage, Jerome Foundation
Kamal Sinclair, Guild of Future Architects
Hrag Vartanian, Hyperallergic
S. Craig Watkins, Institute for Media Innovation, University of Texas at Austin

Roundtable Hosts

Wasserman Projects (Detroit)
CultureSource (Detroit)
Mana Contemporary Miami
UCLA Design Media Arts (Los Angeles)
Ford Foundation Center for Social Justice
(New York)

Roundtable Artists

DB Amorin
Onyx Ashanti
Jason Bernagozzi
Rafael Vargas Bernard
Tega Brain
Kayla Briët
Jessica Brillhart
Sophia Brueckner
Peter Burr
Leo Castaneda
Cezanne Charles
Linda Cheung
Sandy Cioffi
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Aaron Koblin
Wendy Levy
Zach Lieberman
Adelle Lin
Mikhail Mansion
Emily Martinez
Sharon McCaman
Lauren McCarthy
LaJune McMillian
Evan Meaney
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Cory Linn Metcalf
Marjan Moghaddam
Nick Montfort
Darcy Neal
Matthew Niederhauser
Diana Nucera
Ayodamola Tanimowo Okunseinde
Rodolfo Peraza
Althea Pergakis
Everest Pipkin
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Casey Reas
Kristin Sue Reeves
Benjamin Rosenthal
Alfredo Salazar-Caro
Kate Sicchio
Paisley Smith
Eric Souther
Jennifer Steinkamp
David Stout
Barry Threw
Lee Tusman
Amy Youngs

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APPENDIX A

Case Studies

CASE STUDY

3-Legged Dog



ONLINE VIDEO

ARTIST PROFILE

Founded in 1996, 3-Legged Dog developed original interdisciplinary work that merged performance, media, and technology. This creative work was supported by a distinctive business model, where artistic endeavors were funded in large part through work for clients. For 16 years, the company also managed the 3LD Art & Technology Center, a multiveneue space in Lower Manhattan, that provided artists with technical training, access to high-tech equipment, and extended 24/7 creative and performance residencies. 3-Legged Dog served an average of 700 artists a year and produced an average of 11 award-winning full-scale productions a year between 2006 and 2019.



3-Legged Dog (3LD) was an artist-run production company that developed experimental performances and installations incorporating technologies such as holographic projection, augmented reality, live-motion tracking, and mapped projections. Within this multifaceted creative practice, founder Kevin Cunningham explained that “the art is the boss,” with technology serving as a tool for making ambitious artistic visions come to life. 3LD

Marie Davis performing in 3-Legged Dog’s production of James Scruggs’ *3/Fifths: Supremacy Land*, an immersive theater experience exploring the history of violence against Black bodies. Photo by Skye Morse Hodgson



capitalized on the creative technology skills of its team of artists, and worked with an extensive roster of corporate and institutional clients to create and produce events, installations, and immersive experiences, with revenue supporting creative projects.

3LD’s commissioned work included sound and lighting design; architectural installation; app and software development; and creative direction and conception to incorporate holographic projections, mapped projections, virtual and augmented reality, live motion tracking, VR/MR/XR design, and more. The

3-Legged Dog control interface and installation view from control booth for a Vogue China Annual Event, Beijing, 2016. Photo by Fubbi Karlsson/House of North

organization created video designs for pop singer Lady Gaga, a custom designed projection system for the University of Maryland, immersive experience design for Vogue China, and projection mapping for the Metropolitan Museum of Art Gala Exhibition. For fashion designer Michael Kors, they “landed” a full-sized holographic jet.

Our job as artists is to try to bring our imagination into reality and share it with people. And technology can help do that in many different ways.

These projects were not standard work for hire. 3LD intentionally accepted client projects that enabled the organization to experiment and strategically advance its skill sets and capabilities. Technology was carefully selected to execute projects, with the 3LD team deliberately working with affordable systems and hardware so their learnings could inspire and benefit other artists, for

whom specialized commercial products would be financially out of reach. Through this approach, Cunningham explained how commission work is aligned with the mission of 3LD and “serves as a larger-scale research and development platform for ideas that we’re going to bring into our artistic projects.”

3LD’s earned-income provided a degree of artistic freedom. However, this choice was also motivated by a desire to address funding challenges that are commonplace for grant-supported nonprofits: shifting funding trends, declines in private and public philanthropic support for original art, the propensity for project-based funding rather than long-term support, the administrative burdens of applications and audits, and the disconnect between funding amounts and the actual costs of technology-infused projects.

3LD recently left its costly Lower Manhattan center and shifted to a virtual studio model. Amid the COVID-19 pandemic, 3LD was working on new artistic projects as well, bringing their blend of theatrical creativity and technological savvy to the new challenge of creating for socially distanced audiences.

In March 2020, because all projects scheduled for 2020-2022 had been cancelled or indefinitely delayed due to the COVID-19 pandemic, 3-Legged Dog was forced to file for Chapter 7 bankruptcy.

The bankruptcy was completed in December 2020 and Cunningham has created a new company that will be structured to facilitate international and cross-sector collaboration and for-profit/nonprofit cooperation focused on original interdisciplinary production and related technology development. The company 3LD, Inc. launched in January 2021.

NOTE: This case study reflects interviews conducted with 3-Legged Dog and its network between April and June 2020.



3-Legged Dog’s production of *Losing Something* (2007), the first fully holographic stage production in the United States and winner of the American Theater Wing Hewes Design Award for Notable Effects in 2007. Photo by Jeff Morey

CASE STUDY

Refik Anadol



ONLINE VIDEO

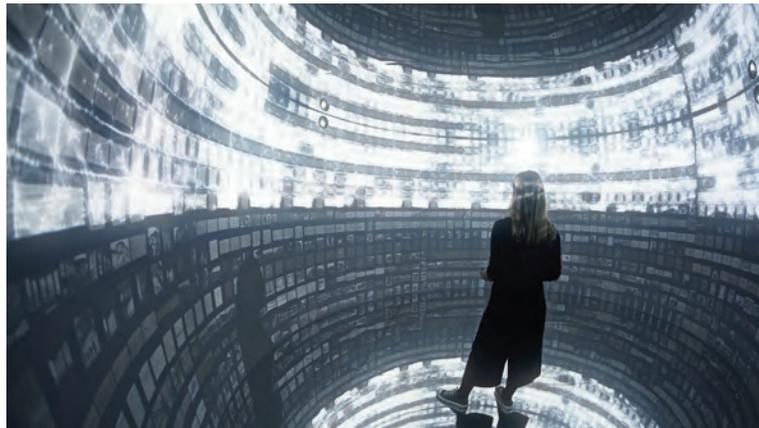
ARTIST PROFILE

Refik Anadol is a media artist working in the field of site-specific public art, parametric data sculptures, and live audio/visual performance with immersive installations. His works explore the space among digital and physical entities by creating a hybrid relationship between architecture and media arts with the help of artificial intelligence.

The [Refik Anadol Studio](#) harnesses the abilities of a collaborative team of 18, including data scientists, visual designers, generative designers, architectural designers, a software developer, a concept developer, a composer/sound designer, and more. Anadol is also the co-founder and creative director for the Istanbul-based design studio Antilop.

Artist Refik Anadol has gained international recognition for transforming massive datasets into multidimensional imagery. Coining the terms “data sculpture,” “data painting,” and “latent cinema,” Anadol likens data to pigment, with algorithms serving as brushes that he uses to create elaborate visuals for architecturally embedded screens, large scale projection-mapping projects, and immersive installations. Anadol’s work focuses on the ways in which machine intelligence allows for new aesthetic methods to create immersive environments that offer a dynamic perception of space,

as well as history. Anadol and his team train AI algorithms with vast data sets and offer radical parameters of artistic design based on digitized memories of individuals, societies, institutions, and nature. The fluid ease with which this data-driven imagery morphs and flows masks painstaking work behind the scenes.



Archive Dreaming, commissioned to work with SALT Research collections, employed machine learning algorithms to search and sort relationships among 1,700,000 documents and translate them into an immersive media installation. Photo by Refik Anadol

WDCH Dreams, commissioned in celebration of the Los Angeles Philharmonic’s centennial year, is one example of this richly detailed work. For the project, Anadol’s team drew on the philharmonic’s nearly 45 terabytes of archival data, including almost 588,000 images and 40,000 hours of audio from over 16,000 performances, to create an immersive exhibition and a week-long public art installation projected on the surface of the Frank Gehry-designed Walt Disney Concert Hall (WDCH).



Refik Anadol, *WDCH Dreams*, 2018, AI Audio/Visual Installation. Image courtesy of the artist

The project is a culmination of Anadol's research into generative machine learning, supported by a Google Artists & Machine Intelligence residency. Anadol's studio translated digital files from the L.A. Philharmonic's archives into millions of data points, categorized by hundreds of attributes. Using deep neural networks to create a machine learning algorithm that functioned as the "mind of a machine," Anadol trained the system to move through an evolutionary exploration in real time, projected onto the concert hall using 42 high-powered projectors. Machine learning also played a role in the score for the performance, compiling and categorizing hundreds of data points across thousands of hours of audio recordings, curated and arranged by sound designers.

"Data as a medium or as a material is beyond just ones and zeros. I don't look at data as just numbers. I look at them as memories...the meaning of that certain moment transformed into a digital entity and stored in the mind of a machine."

Each performance cycled through three phases. "Memory" began with processing the mass of collected data, highlighting moments from the orchestra's history. "Consciousness" mapped billions of data points, abstractly depicting networks of relationships, connections, and contrasts. "Dreams" combined past and present, with machine intelligence dreaming futuristic hallucinations; hence the project title—*WDCH Dreams*.

Such ambitious works reflect an ongoing fascination with the intersection of architecture and intangible elements—the data points that surround us, the flexibility of memory, and how an artist might "make the invisible visible."



Refik Anadol, *Machine Hallucination*, ARTECHOUSE NYC 2019-2020, 42 Channel Projection. Photo courtesy of Refik Anadol Studio

CASE STUDY

Design I/O



ONLINE VIDEO

ARTIST PROFILE

Founded in 2010, Design I/O is an award-winning creative studio led by Emily Gobeille and Theodore Watson. From studios in New York and California, the Design I/O team collaborates on developing immersive environments, interactive experiences, experimental forms of storytelling, and new prototypes that lead toward a more magical future. Combining artistry with technological innovation, they foster connections within digitally responsive worlds for clients such as the New York Hall of Science, Cleveland Museum of Art, Nokia Bells Labs, TELUS World of Science (Edmonton), digiPlaySpace (Toronto), and Cinekid (Amsterdam).

Design I/O immerses audiences in playful and quirky encounters, sparking a sense of wonder through the magic made possible by advanced technologies. Whether developing a curious robot, a mysterious nocturnal forest, or a world where participants control the weather, Design I/O's work blends technological experimentation with artistic imagination and design sensibilities to "make it feel seamless and magical."

The team has earned a reputation for large-scale installations with renowned institutions. However, their professional trajectory began with modest projects nurtured by a network of festivals in Europe willing to take a chance on promising emerging artists. Watson acknowledged that Design I/O "wouldn't be here today if they had stayed in the U.S."

After completing degrees at Parsons School of Design in New York, Watson and Gobeille moved to Amsterdam. They branched out regionally, with a steady stream of small commissions contributing to a burgeoning portfolio. They also actively hustled—printing project postcards, pitching ideas, and frequenting arts events to meet potential commissioners. These face-to-face efforts went hand-in-hand with an online presence, where they shared preliminary ideas, posted high quality project documentation, and contributed to open-source communities, with Watson participating in the core development team for openFrameworks.



Both top and bottom:
Connected Worlds, 2015,
interactive installation.
Photo courtesy of David
Handschuh

Puppet Parade (2011) is an interactive installation that allows visitors to use their arms to puppeteer larger-than-life creatures projected on the wall in front of them. The project is based on Design I/O's Kinect Puppet Prototype video and uses two Xbox Kinects to track the arms of the puppeteers. Photo courtesy of Design I/O



As their abilities and ideas grew, curators like Paulien Dresscher at [Cinekid](#) in Amsterdam and Nick Pagee at [TIFF digiPlaySpace](#) in Toronto took note and became repeat commissioners. Such supporters often go beyond funding projects—they also open professional doors, partner to commission and tour projects, provide mediation for publics new to the work, and champion technology-rooted artworks at their institutions. Building on this infrastructure of support from individuals, festivals, and venues, Gobeille and Watson scaled up their practice and gained traction for their careers.

Since then, Design I/O has become known for works such as *Connected Worlds*, where audiences enter a 3,000-square-foot interactive space and manage the flora and fauna of six interconnected digital ecosystems. They direct the flow from a 45-foot-tall waterfall, plant seeds, and learn concepts of environmental stewardship and cause and effect, all within an intricately crafted world of discovery and play.

Nick Pagee summed up the impact of the team's capabilities, explaining that "A Design I/O piece is the gateway experience to appreciating what interactive can do...Design I/O pieces take people out of the everyday and bring them into a new world that is incredibly rich, masterfully executed."

The bridge between when someone decides they're going to embark on a career in this direction and getting to that point of being established—that's an incredibly hard thing to overcome, but it doesn't take a lot. It takes having a platform and a little bit of funding for one or two compelling works and good exposure.

CASE STUDY

Stephanie Dinkins



ONLINE VIDEO

ARTIST PROFILE

Stephanie Dinkins is a transmedia artist and professor at Stony Brook University, where she holds the Kusama Endowed Chair in Art. She creates platforms for dialog about artificial intelligence (AI) as it intersects with race, gender, aging, and our future histories. She is particularly driven to work with communities of color to co-create more equitable, values-grounded artificial intelligent ecosystems. Dinkins' art practice employs lens-based practices, emerging technologies, and community engagement to confront questions of bias in AI, data sovereignty, and social equity.

While some artists begin dabbling with coding at a very young age, Stephanie Dinkins was already an established artist when she chose to pivot her practice to cutting edge technologies. Motivated by pressing questions of ethics and representation in artificial intelligence, she navigated the challenges of learning new skill sets and immersing herself in a new specialization. Artificial intelligence is now central to Dinkins' three-pronged practice of art making, community engagement, and public speaking—all grounded in a core ethos of “making space for blackness” within artistic, technological, and cultural domains.

Dinkins's artistic transformation was sparked by a YouTube video of Bina48, an advanced AI robot in the form of a Black woman. This encounter led Dinkins to create [Conversations with Bina48](#), a series of discussions with Bina48 on topics such as mortality, loneliness, racism, family, and faith. The project was a starting point, a shift described by Dinkins as “turning my life over to this process.”



Stephanie Dinkins & Bina48. Photo courtesy of Stephanie Dinkins

Stephanie Dinkins, *Not the Only One*, 2018, deep Learning AI, Computer, Arduino, Senors, sculpture 3d printed PLA, ~ 16" x 18", pedestal 30" x 18" x 18. Image courtesy of the artist



Her next step was to cultivate a new knowledge base, spending countless hours on independent learning; online coding tutorials and forums; and practical methods of trial, error, and troubleshooting. She workshopped ideas through residencies at Eyebeam, Pioneer Works, and NEW INC and connected with expert partners, such as her studio assistant Neta Bomani, an artist and technologist in her own right.

At an AI Story Circle as part of her Project al-Khwarizmi (PAK), Stephanie Dinkins uses her art as a vehicle to engage citizens in discussion to better understand how algorithms, the artificially intelligent systems they underpin, and big data impact their lives. Photo courtesy of the artist



Dinkins' current artwork, *Not the Only One* (*N'TOO*), combines oral history with AI to create an interactive family memoir. *N'TOO* is trained on interviews from three generations of Dinkins' family—her aunt, herself, and her niece—an intentionally small dataset that enables *N'TOO* to resist the cultural dilution that comes with training AI on massive datasets that reinforce biases or inadequately represent communities of color.

Gathering communities in conversations around race and technology is also core to Dinkins' practice, aimed at empowering individuals to take an informed, vocal, and active approach to influence both the present and future impacts of technology. In so doing, she advocates for Afro-now-ism, "a willful practice" overlaying technology and social justice that "imagines the world as one needs it to be...in the here and now."⁹³

“How does change get into a system?... How do we get folks that bring a different vision or way of seeing the world into institutions creating AI and keep them there?”

93 Dinkins, "Afro-now-ism."

CASE STUDY

Darcy Neal



ONLINE VIDEO

ARTIST PROFILE

Darcy Neal is a new media artist and co-founder of Trash Hackers Collective and Lady Brain Studios, where they develop interactive works and teach creative applications of electronics for artists. With a background in sculpture, electronics, and experimental sound, Neal's artistic practice and teaching explores circuit design, rapid prototyping, and experimental media that pushes the boundaries of traditional circuit applications.



Darcy Neal is an artist whose practice relies on physical hubs such as makerspaces and fabrication labs—both of which offer access to tools and space, and to frequent interactions with other makers. These community spaces and conversations can result in critical turning points for artists working with physical hardware, such as Neal, who was able to adopt new techniques and production models thanks to resources and learning opportunities offered by these spaces.

Darcy Neal experiments with the Trash Hackers Trashprinter, an open-source, large-format 3D printer originally designed by Sam Smith, which utilizes waste plastic that would otherwise be thrown into the landfill. Photo courtesy of the artist

Neal's experiences have led them to co-found their own maker-oriented entities, such as the Trash Hackers Collective, which trains community members to repurpose discarded plastics into everyday objects using accessible and open-source machinery, and Lady Brain Studios, an arts studio that develops interactive projects and provides workshops in electronics. While their earlier artistic practice involved traditional media, such as painting and sculpture, Neal credits the makerspace community, and a workshop in circuit-bending, as contributing factors to their trajectory in merging arts, science, and technology.

Currently, Neal is a teaching artist at Pacific Northwest College of Arts' Make+Think+Code program and serves as the STEAM coordinator for immersive technologies at Portland Community College's Cascade campus (PCC). Neal's role at PCC supports the creative coding program, VR/AR development, and 3D design applications.

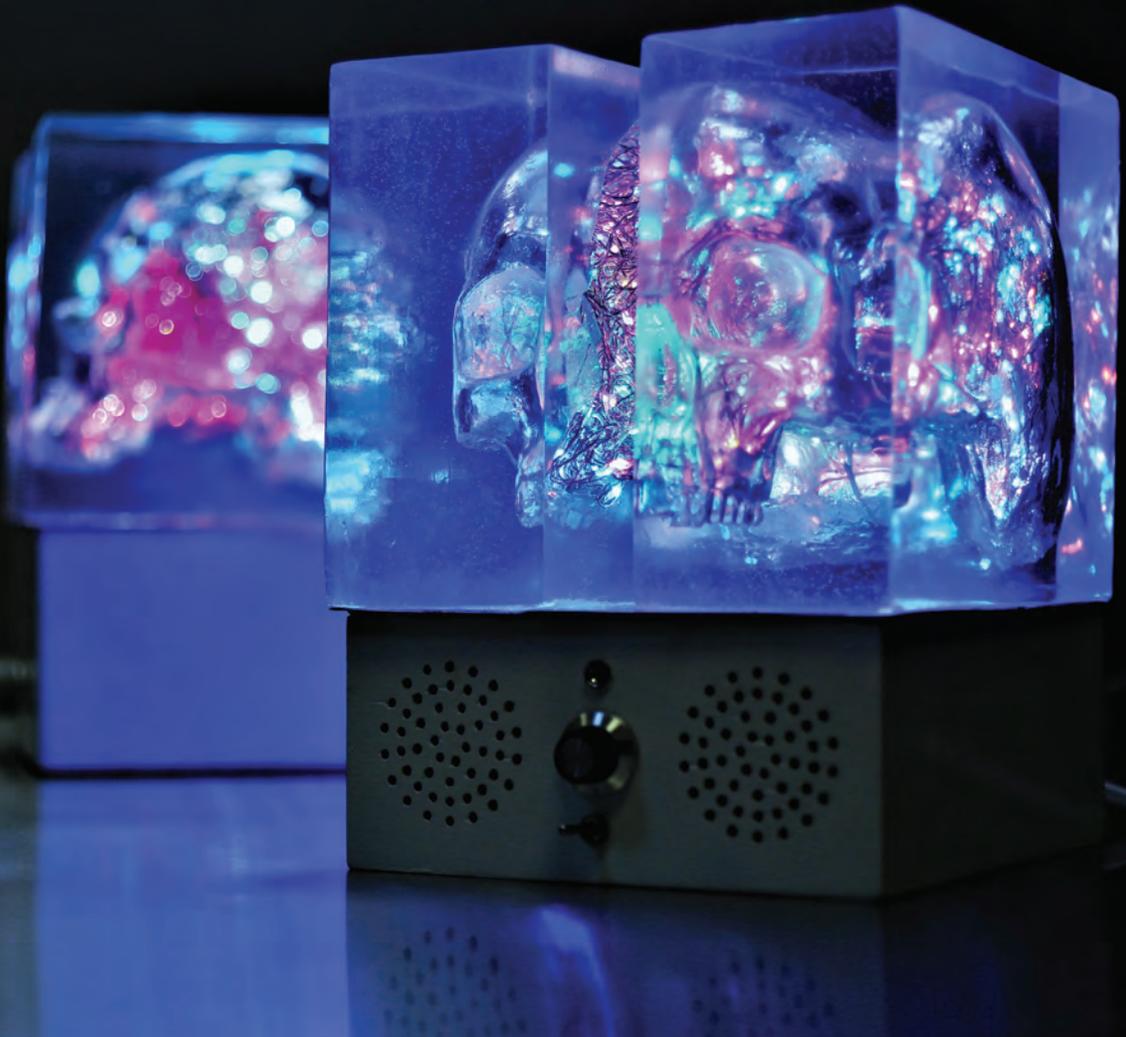


Lady Brain Studios, co-founded by Darcy Neal, actively conducts DIY art and technology workshops covering various topics relating to Arduino programming, DIY synthesizers, e-textiles, and printed circuit board design. Photo courtesy of the artist

“I got a lot of my support for learning from hanging out at makerspaces and hackerspaces, where people who were studying the subversive niches of technology could talk about their work and learn from one another. These spaces are a key breeding ground and meeting point for new ideas and new technologies.”

Darcy Neal, *The Brains of Sound and Light V2 & 3*, mixed media. Photo by Steve Rainwater

Since Neal began working at PCC, they have helped support new course offerings and degree programs centering on technology and the arts. PCC's associate's degree in music and sonic arts combines music, coding, and design; and the creative coding and immersive technologies degree, launched in 2019, is the first of its kind at a community college in the United States. Dan Wegner, dean of arts and professions at PCC, explained that these programs are growing quickly and reflect the robust arts and tech sectors in Portland.



CASE STUDY

Processing Foundation

ARTIST PROFILE

The Processing Foundation makes software tools available for free that support the use of code for self-expression. Their flagship project is [Processing](#), a flexible software sketchbook used by millions of artists, designers, students, and cultural workers around the world each year. Casey Reas, an artist and professor based in Los Angeles, and Ben Fry, a principal at Boston-based design and software consultancy Fathom, first started working on Processing in 2001 at the MIT Media Lab. They launched the foundation in 2012 with New York-based educator and programmer Daniel Shiffman.

The Processing Foundation provides free access to software projects tailor-made for creative coders. This artist-run nonprofit demonstrates the power of building generative tools that can support a wide variety of creative work and engage a dedicated community of users that continue to push boundaries.

Based on the programming language Java, [Processing](#) is their most popular project, with 2.6+ million site visitors over the past year. A Processing program is called a “sketch”— a coding sequence designed to perform a particular function, such as drawing a sphere. Users assemble sketches inside of the [Processing Development Environment](#), and build libraries for functions including animation, sound, and video. They participate through [online forums](#), local user groups, and the code-sharing site [GitHub](#).

After many years of development and community-building, Casey Reas, Ben Fry, and Daniel Shiffman started the foundation to ensure that Processing would continue to be maintained and shared. They now make up its board, along with LA-based artist and professor Lauren Lee McCarthy.



Participants at the Creative Code Fest in Los Angeles, California. Photo courtesy of Processing Foundation



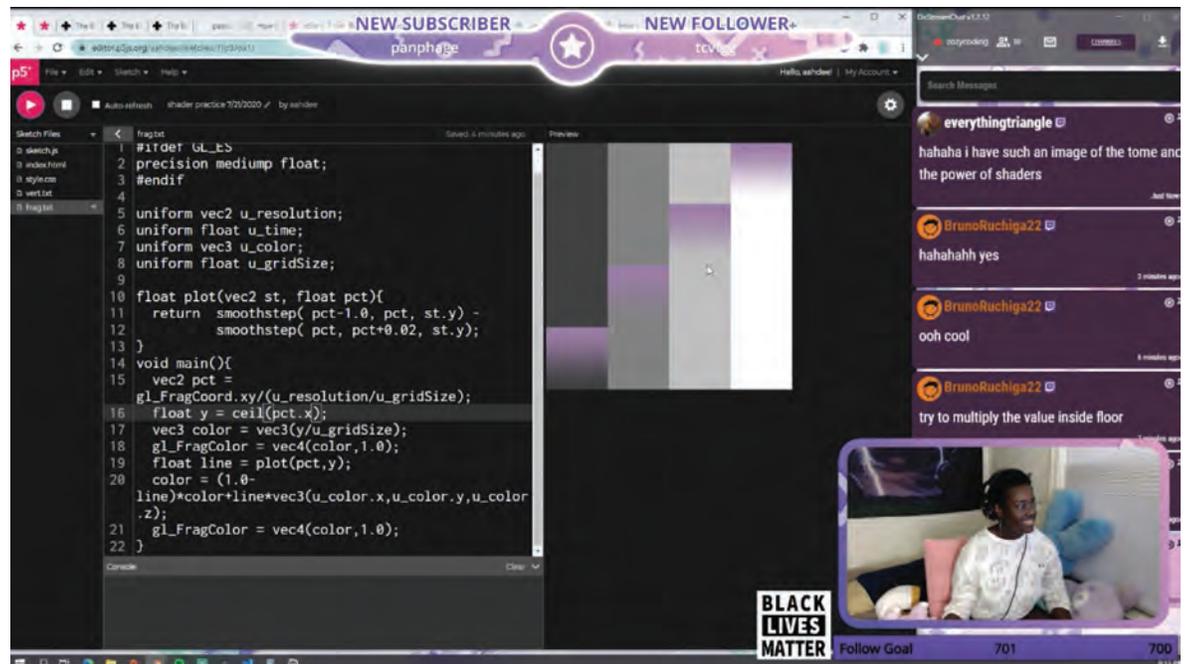
Ted Davis, *P5LIVE*, 2019. Photo by Ted Davis

Lowering barriers to access is central to the organization’s mission. McCarthy developed [p5.js](#), a JavaScript library for web-native creative coding that is more accessible to lay users than Processing. It has also gained broad adoption, with 1.6 million site visitors in the past year. During the pandemic, Pittsburgh-based developer and artist Aren Davey started hosting “Cozy Coding,” a series of p5.js tutorials on the popular live streaming platform Twitch.

I believe artists and communities of artists should be deeply engaged with making our own platforms and our own tools rather than relying on proprietary software that we can’t control.

Education is also integral to the project, said Reas, “and I think that’s where it’s had the most impact.” The site provides resources for teaching art and computer science, including a lively set of training videos by Shiffman called *The Coding Train*.

But Processing is not just for students. The Museum of Modern Art and the Centre Georges Pompidou have featured the work of artists and designers who use it. Processing drives stage designs and music videos for bands such as REM. Product designers from companies such as Google and the *New York Times* have used it for prototyping and data visualization. The project has become an everyday utility, providing makers and visual thinkers with a welcome alternative to expensive and proprietary commercial software.



Aren Davey’s Processing Foundation Fellowship (2020) allowed the artist to focus on breaking the stereotypes of programming by showing that it can be warm, playful, and spontaneous through her Twitch channel, Cozy Coding (pictured), which explores facets of P5.js live with viewers. Image courtesy of the artist

CASE STUDY

Scatter



ONLINE VIDEO

ARTIST PROFILE

Scatter is an immersive design studio based in Brooklyn, New York, co-founded by artists Yasmin Elayat, James George, and Alexander Porter in 2016. The artist-run studio produces original content in emerging media formats and also developed a creative software tool, Depthkit. Storytellers around the world use Depthkit to capture volumetric video for immersive events, virtual and augmented reality experiences, games, creative documentaries, visual effects, and art installations.



Still image from *Blackout* (2017), a volumetric film and roomscale VR installation produced by Scatter. Image courtesy of Scatter

The Scatter team is filling a key gap in the larger virtual and mixed-reality ecosystem by making it possible for independent creators to access the new creative medium of volumetric video, without needing to move production to fixed capture stages in limited locations. With Depthkit, makers can use accessible retail-standard hardware and have their own volumetric capture kit in-house. The philosophy underpinning the Depthkit code prioritizes the ability for creators to rapidly prototype ideas, and experiment with their own voice in this new medium.

Scatter's aim is to define the emerging language of "volumetric filmmaking," a term James George coined in a 2016 essay, "A New Dimension in Filmmaking," to describe 3D capture of moving images.⁹⁴ Volumetric capture is now widely used in Hollywood and by commercial game companies. Scatter fosters a creative community through workshops, maker meetups, and online forums to champion the artistic use of the technology too. They are unusual in connecting emerging artists with Silicon Valley. "We're able to play a bridge role between the Microsofts and the Intels to this community that we've been so close to," Yasmin Elayat noted.

94 George, "A New Dimension in Filmmaking."



Poster image for *The Changing Same* (2021), a volumetric film and roomscale VR installation co-produced by Rada Studio and Scatter. Image courtesy of Scatter and Rada Studio

In their original content production, rather than acting as a service provider for commercial clients the team establishes collaborative partnerships to produce immersive works by using Depthkit. For example, with Rada Film Group and the Co-Creation Studio at MIT Open Documentary Lab, Scatter used Depthkit to explore VR as a collective healing device for generational trauma caused from racial oppression. This immersive experience, debuting at Sundance Film Festival 2021, will accompany the documentary film, *The Changing Same*.

Fireflies: A Brownsville Story is an interactive VR experience, fueled by Depthkit, in collaboration with Peoples Culture Collective and Brownsville Community Justice Center of the Center for Court Innovation. “The team literally built the computers they used to make the project,” said Alexander Porter. “It’s a really special example where the outcomes of the project are really gorgeous and extraordinary, but the methodology very much matches our intentions with the tool.”

Now full-fledged artist-entrepreneurs, Scatter collects funding streams from product sales, venture capital backing, and grants for individual projects. Grants and in-kind support from PBS, Fledgling Fund, Tribeca Institute’s New Media Fund, and Knight Foundation have been invaluable contributions enabling the production of new works. Arts incubators and fellowships programs, such as EYEBEAM, Frank-Ratchye STUDIO for Creative Inquiry at Carnegie Mellon, and NEW INC, also have been critical resources needed to continually develop Depthkit’s capabilities, sharpen the team’s business acumen, and build creative partnerships with fellow artists and industry leaders. James George affirmed that such support helps Scatter stay “ beholden to the artistic intentions, not only the bottom line.”

“Our ultimate goal is to make sure that really surprising, generative, experimental work gets made with our tool. We really think of it as a community, not as a group of customers.”

CASE STUDY

Lance Weiler



ONLINE VIDEO

ARTIST PROFILE

Lance Weiler is a storyteller, entrepreneur, and thought leader in the entertainment industry, who creates unconventional experiences with an interdisciplinary cohort of collaborators and the participation of audiences around the world. He is a professor of practice and the director of the Digital Storytelling Lab at Columbia University's School of the Arts (Columbia DSL), a "next generation media lab harnessing the arts, humanities and emergent technology to tackle some of the world's impossible problems."



Adept at merging storytelling and technology, Lance Weiler has pioneered cinematic innovations that incorporate multiple genres and formats. Steeped in his film industry experience, Weiler's interdisciplinary, cross-platform, and collaborative process is part of a larger ecosystem of practice, with discrete projects feeding the whole.

Early in his career, Weiler established an experimental approach to his film productions, mixing elements of experience design, theatrical performance, and gaming into the work. For example, his 2006 feature, *Head Trauma*, toured to museums instead of movie theaters. Screenings incorporated elements of immersive theater and augmented-reality gaming—with a live band, costumed performers, and participatory elements that allowed audience members to interact with the film's characters through their mobile phones. Audience members also were invited into a tent to describe their greatest fears, which then were streamed online. This transmedia approach—[of building a "storyworld"](#)—has become common, but at the time was a breakthrough.

Building on his forward-thinking practice, Weiler launched the [Digital Storytelling Lab](#) at Columbia University's School of the Arts. The lab explores how "the mass democratization of creative tools—code, data and algorithms—have changed the relationship between creator and audiences" and serves as a catalyst for interdisciplinary collaboration among students, faculty, and industry innovators.

Much of Weiler's work is open source or "[copyleft](#)," developed through generative prototyping processes where participants are invited to carry the work forward.



Frankenstein AI: A Monster Made by Many is an interactive experience which premiered at the Sundance Film Festival 2018 as part of the New Frontier exhibition program. Top: Show poster. Bottom: A person interacts with the AI at the Sundance Film Festival. Images courtesy of the artist

Sherlock Holmes and the Internet of Things had about 2,600 collaborators in 60 countries and 180 self organized events, and we just loved the chaos and freedom of it—the excitement of combining learning and storytelling and challenging authorship and ownership of stories.

Sherlock Holmes and the Internet of Things involved roughly 2,600 collaborators in 60 countries and 180 self-organized events.

Frankenstein AI: A Monster Made by Many, which premiered at Sundance Film Festival, invited participants to teach an AI entity about human emotions through face-to-face interactions with other audience members. The project then evolved into a dance performance choreographed by the trained AI entity.

Game designer Nick Fortugno has worked with Weiler to co-create

these and other experiences, stating, “I only really work collaboratively. I don’t know how not to. What’s really, really fun about this collaboration [with Weiler] and being part of that world is that we’re all making brand new work, and that’s incredible.” He explained that the duo’s hybrid approach transcends discipline by focusing on goals and process, allowing them to jointly refine design principles for audience engagement across projects.

During the COVID-19 pandemic, Weiler has been co-designing From the Futures, a virtual community “dedicated to the exploration of better futures in a time of extreme change” that has provided an opportunity for more than 1,000 participants around the world to connect in a time of physical distancing.⁹⁵ From the Futures embraces speculative design, enabling participants to imagine possible futures through the co-creation of stories, games, and artifacts.



Sherlock Holmes and the Internet of Things is one of the largest projects from the Columbia University School of the Arts’ Digital Storytelling Lab. Left: Event poster. Right: Participants creating artifacts (VR, AR, IoT) and narratives that fit within the massive connected crime scene. Images courtesy of Lance Weiler

95 “From the Futures”

CASE STUDY

Amelia Winger-Bearskin



ONLINE VIDEO

ARTIST PROFILE

Amelia Winger-Bearskin is an artist, technologist, and community-builder. Working in immersive media such as VR, performance, and participatory events, Winger-Bearskin invites audiences to reflect on the social and emotional dimensions of life in a tech-saturated society.

Winger-Bearskin is Haudenosaunee (Iroquois) of the Seneca-Cayuga Nation of Oklahoma, Deer Clan. Her practice includes examining ways Native and Indigenous perspectives and values systems can inform foundational components of the tech industry.



Amelia Winger-Bearskin's multifaceted career creatively bridges the arts and technology sectors, encompassing technologies from VR to 3D modeling, billboard design, and more. This expansive practice is underpinned by a collaborative spirit, nurtured early on in opera companies where, as a singer, she developed an affinity for working as part of a team. Collaboration has since become a through-line in her approach, and she regularly develops forums and shares platforms with other artists.

Such collaborations range in tone and format, but frequently take on a playful character. *Your Hands Are Feet*, a VR collaboration with Sarah Rothberg, had audiences maneuvering through cartoonish metaphors. *Monsters*, a 360-degree video/installation with Wendy Red Star, explored Seneca and Crow mythologies of keepers of the land. Her Wampum.codes podcast sparked thought-provoking conversations with Native and Indigenous creatives and technologists. She also convenes technology enthusiasts through the Stupid Hackathon, a humorous one-day event co-founded with fellow artist Sam Lavigne, which has taken place annually since 2013.

Winger-Bearskin's ability to use these skills to reach across sectors led Ralph DiBart, executive director of the Business Improvement District for the city of New

Amelia Winger-Bearskin in an immersive art piece while a student at NYU ITP. Image courtesy of Amelia Winger-Bearskin



Artist Matthew Gantt showing the 2018 IDEA New Rochelle cohort and residents Barak Chamo and Bayete Ross Smith one of his VR projects in the IDEALab. Photo courtesy of Amelia Winger-Bearskin

Rochelle, New York, to reach out to her about his goal to develop a technology district, including an artist community. Just 25 minutes from Manhattan, New Rochelle had a lot to offer but lacked an understanding of how their assets could be transformed into a vibrant center for arts and technology.

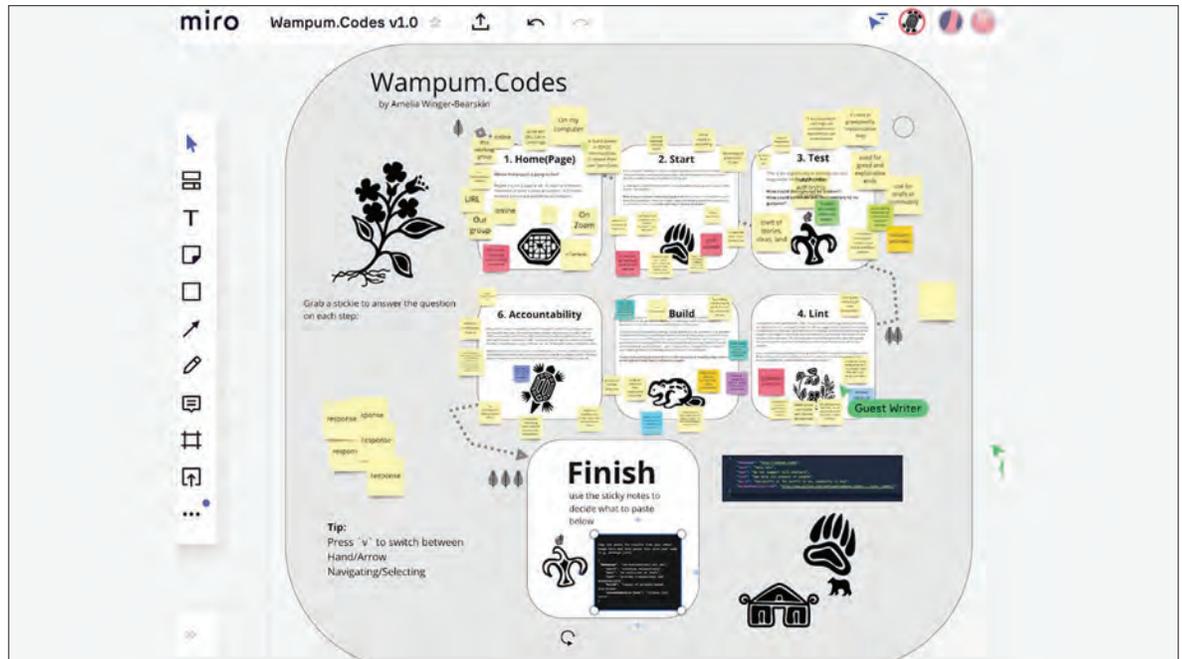


Image by Amelia Winger-Bearskin for her article, "Indigenous wisdom as a model for software design and development," 2020. Image courtesy of Amelia Winger-Bearskin

Stepping into a new role as director of IDEA New Rochelle (Interactive Digital Environments Alliance), Winger-Bearskin noted that the city's underutilized spaces would be a perfect setting for artists experimenting with augmented and virtual reality. IDEA New Rochelle's artist residency program, launched in 2018, provided an artist cohort with live-work space and access to development labs. The program soon expanded to include a day program in response to artist demand.

Building on IDEA, the city applied to the Bloomberg Mayors Challenge to engage residents in city planning through immersive technologies such as VR/MR/AR. After a yearlong test program, New Rochelle won \$1 million to expand these efforts, work that hinged on the abilities and expertise of IDEA artists.

Through such projects, Winger-Bearskin exemplifies the many creative and technological skills that artists bring to cross-sector work, as well as a distinctive ability to engage communities in imagining new possibilities together.

I know how to be an administrator and I know how to be a fundraiser and I know how to be a community organizer. And I think it's my responsibility to use those skills, in addition to my artistic skills, for my artistic community.

APPENDIX B

Glossary of Terms

360-degree (3D) video

Technology in which omnidirectional cameras grab a spherical video capture of a space. The perspectives are stitched together to generate an immersive experience that places the viewer within the context of a scene with the ability to control the orientation and direction of the experience.

3D Printing

The process of making a three-dimensional object, including sculptures, from digital sketches, drawings, or photographs.

Algoraves

Events where attendees dance to music and visuals generated through live coding, named through a combination of “algorithm” and “rave.”

Algorithms

Set of instructions designed to perform a specific task. This can be a simple process, such as multiplying two numbers, or a complex operation, such as the design and execution of an artwork.

Analog

In art, a reference to older, hand-crafted formats such as painting or sculpture as compared to those created using a computer or other digital device.

Anti-disciplinary

An approach in which work or research takes place outside of the boundaries of established academic or artistic disciplines.

Artificial Intelligence (AI)

The theory and development of computer systems able to perform tasks that normally require human intelligence.

Augmented Reality (AR)

The practice of layering digital information—usually sound, video, or graphics—onto the real, physical world through a screened interface like a phone, tablet, or specially designed headset.

Co-creation

An approach to creating art or media that sees subjects or audience members as collaborators, as opposed to an approach that sees the creator as having sole authority to define the work.

Code

The symbolic arrangement of data or instructions in a computer program or the set of such instructions.

Computation

The processing of information by digital devices or software.

Creative Coding

Both the practice of using code for expressive purposes—design, animation, music, visualization, robotics, games, and more—and a community dedicated to this practice.

Data

Quantifiable or characterizable inputs that serve as the material for computation.

Data Visualization

The graphical representation of information and data. By using visual elements like charts, graphs, and maps, data visualization tools provide an accessible way to see and understand trends, outliers, and patterns in data.

Digital

Electronic tools, systems, devices, and resources that generate, store, or process data.

Digital Art (see electronic art)

Art that is created or displayed through a computer or another digital device such as a smartphone, gaming console, or VR headset.

Disciplinary

Research or work relating to a particular field of study or creative output. Intradisciplinary work occurs within a single discipline; cross-disciplinary work uses one discipline to examine an aspect of another discipline; multidisciplinary work adds insights from two or more academic disciplines but remains grounded within the root discipline; interdisciplinary work integrates knowledge and methods from two or more disciplines; transdisciplinary work unifies intellectual frameworks that go beyond existing disciplinary perspectives.

DIY Electronics

A practice in which makers assemble and code their own electronic devices, wearables, gadgets, and interfaces using prefabricated circuit boards and components—a subset of the much larger DIY maker movement.

E-textiles

Fabrics that contain digital components and electronics such as microcontrollers and sensors. E-textiles can be wearable or found in other fields such as interior design.

Electronic Art (see digital art)

Art that makes use of electronic media or requires electricity to run. Broader than “digital art,” this term has expanded to cover many different formats over the past 40 years, including television, video, radio, projections, computers, games, interactive screens, and more.

Experiential art (see immersive art)

Installations, performances, and environments (both physical and digital) designed to engage the senses of audience members and transport them, often with the purpose of evoking a sense of wonder.

Extended Reality (XR)

An umbrella term for immersive technologies (augmented, mixed, and virtual) that superimpose digital information onto the physical world through the use of computer or wearable technologies.

Gaming

Gaming combines technology with traditional and digital art forms—3D modeling, illustration, writing, music, and animation—to create virtual worlds with which players interact using computers and other electronic devices.

Generative Art

Artistic projects and processes that are automatically generated by an algorithm that shapes the work. In earlier forms, they were generated through other autonomous or random input, such as the roll of a dice, a set of mathematical equations, or combinatorial systems.

Hackerspace

Community-operated physical spaces in which people with an interest in computing or technology can work individually or collaboratively on projects while sharing equipment and knowledge.

Haptics

Any form of interaction involving touch. Haptic technology uses a sense of touch (vibrations, motion, or force) to control and interact with computers and devices.

Hashtag

A word or phrase preceded by a hash sign (#) used on social media to identify a topic of interest and facilitate a search for it.

Immersive art (see experiential art)

Experiences, performances, and environments that surround and involve participants, engaging multiple senses and creating an alternate world or reality. Such projects can be fully digital, fully analog, or a mix of both.

Interactive Art

An approach to artmaking that invites users to manipulate the work or make structured choices in order for it to evolve to a new or finished state. Goals include making art more accessible, introducing play, creating personalized experiences, and exploring the dynamics of author and audience agency.

Interdisciplinary (see Anti-disciplinary)

An approach in which work or research takes place across the boundaries of two or more established academic or artistic disciplines.

Live Coding

A practice during live performances of projecting the code that is driving audio and visual effects, to reveal the creative process and celebrate coding itself as a virtuoso act.

Makerspace

A shared space—accessible for free or for a fee—which offers specialized equipment, training, and facilities for people to create various digital, electronic, scientific, and craft projects, and a way to connect with one another.

Media Arts

A term defined by the National Endowment for the Arts as follows: “Media arts is defined by all genres and forms that use electronic media, film and technology (analog & digital; old and new) as an artistic medium or a medium to broaden arts appreciation and awareness of any discipline. For example, this includes projects presented via film, television, radio, audio, video, the internet, interactive and mobile technologies, video games, immersive and multi-platform storytelling, and satellite streaming.”

Mixed Reality (MR; see extended reality, virtual reality, augmented reality)

An overlay of synthetic content that is anchored to and interacts in real time with objects in the real world.

Net Art or net.art

“Net art” is a general term for art in which the internet is the primary medium, which can only be encountered and engaged with online. The more specific term “net.art,” which has been attributed to Belgrade-based artist Vuk Ćosić in 1995, refers to a tongue-in-cheek art movement from the mid-1990s to the early 2000s.

Photogrammetry

A technology for capturing 360-degree still images based on a series of measurements scanned from various points around the subject, which are then “stitched” together to form a 3D digital model.

Post-internet art

Art created after the capabilities and dynamics of the internet had already become well-established. These capabilities include networked distribution well beyond the traditional art world, infinite replicability of artworks, collaborative authorship, cross-format experimentation, the dissolving of boundaries between the physical and the digital, and the presumption of audience participation. The term was coined by artist Marisa Olsen around 2009.

Robotics

Technology involving the design, construction, and operation of robots in automation.

Sensors

A device that detects and responds to input from the physical environment (i.e., heat, light, sound, pressure, or motion) and transmits information to other electronics.

Software

A set of instructions, data, or programs used to operate computers and execute specific tasks, procedures, and routines.

Time-based art

Art that unfolds over time and involves technology, including film, audio, computer games, slideshows, and more.

Transmedia

Art and media projects that expand across multiple formats, linking together a narrative or theme through different expressions or moments of engagement.

User experience design

Often abbreviated as “UX” (which stands for “user experience”). A cross-disciplinary practice that focuses on refining the ways in which people interact with digital interfaces, devices, processes, and environments.

Video mapping

Also known as projection mapping and spatial augmented reality, this projection technology maps images onto a non-flat or non-white surface, turning common objects—such as buildings, runways, stages and even water—into interactive displays.

Virtual Reality

An artificial reality accessible through either projections or head-mounted displays that completely surround the viewer.

Volumetric Filmmaking

The use of techniques and equipment to capture three-dimensional objects, spaces, performances, and people for use in immersive films, games, and interactive experiences; coined by the team from Scatter.

Wearables

Electronic devices that can be worn as accessories, embedded in clothing, implanted in the user’s body, or tattooed on the skin that detect, analyze, and transmit body signal data.

APPENDIX C

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APPENDIX D

Organizations Mentioned

Organization	Exhibitions, Festivals, Conferences	Resource hubs, workshops, and/or artist support orgs	Fellowships and funding	Sponsorships and commissions	Residencies
3-Legged Dog	X	X			
Abandon Normal Devices Festival	X				
Adafruit Industries		X			
Adobe Augmented Reality Residency					X
Adobe Creative Residency			X	X	X
Afrotectopia	X	X			
Alliance for Media Arts + Culture		X			
Allied Media Projects	X	X			
An Artist's Guide to Computation		X			
Ann Arbor Film Festival	X			X	
Apple AI/ML residency program					X
Ars Electronica	X	X	X	X	X
Art && Code	X	X			
ARTECHOUSE	X				
ArtFutura	X				
Arts2Work: National Apprenticeship Program in Media Arts and Creative Technology		X			
Association for Computing Machinery (ACM)		X	X		
Athens Digital Arts Festival	X				
Atlas V: Immersive Experiences		X			
Autodesk Technology Center Residency Program					X
Babycastles	X	X		X	
Before It's Too Late: Climate Change through VR	X	X		X	
bitforms gallery	X			X	
Black Girls Code		X			
Black Public Media	X	X	X		
Boston Cyberarts	X	X			
BRIC Arts Media	X	X			X
BUFU		X			

Organization	Exhibitions, Festivals, Conferences	Resource hubs, workshops, and/or artist support orgs	Fellowships and funding	Sponsorships and commissions	Residencies
Burning Man	X		X		
Cannes XR					
Carl & Marilyn Thoma Foundation and Art House	X		X		
Carl and Marilyn Thoma Art Foundation	X		X		
Center for Research in Open Source Software (CROSS)		X			
Centre for Indigenous Futures, Concordia		X			
Choreographic Coding Labs		X			
Chronus Art Center	X	X			X
Clinic for Open Source Arts (COSA), University of Denver	X	X	X		
Code Liberation		X			
Color <Coded>	X	X			
Conference for Research into Choreographic Interfaces	X	X			
Creative Applications Network		X			
Creative Capital		X	X		
Crux XR	X	X	X		
CultureHub	X	X			X
Currents New Media Festival	X	X			X
Cycling '74		X			
CYNETART Festival	X				
Dallas AURORA	X	X	X	X	
Dames Making Games		X			
Data & Society		X	X		
Derivative (TouchDesigner)		X			
Design Justice Network		X			
Detroit Narrative Agency	X	X	X		
Different Games Collective	X	X			
Digital Museum of Digital Art (DiMoDa)	X				
Digital Research in Humanities and Arts	X				
Digital Storytelling Lab at Columbia University		X			
DLECTRICITY	X	X			
Dynamicland		X			
E-Flux		X			
Electric Africa: VR Festival	X				
Electric South	X	X	X		

Organization	Exhibitions, Festivals, Conferences	Resource hubs, workshops, and/or artist support orgs	Fellowships and funding	Sponsorships and commissions	Residencies
Electrofringe Festival	X	X			
Emergence Media		X		X	
Experimental Media and Performing Arts Center (EMPAC)	X	X			X
Experiments with Google		X			
Eyebeam Art and Technology Center	X	X	X	X	X
EYEO Festival	X	X			
Fab Lab Network		X			
Facebook Connect Conference	X				
Fanguito eStudio		X			
fearless360°	X				
FEMMEBIT	X	X			
Flux Factory	X	X	X	X	X
Frank-Ratchye STUDIO for Creative Inquiry, Carnegie Mellon University	X	X	X		X
Future of StoryTelling	X	X			
Game Devs of Color Expo	X				
Games for Change	X	X			
Girls Who Code		X			
GLI.TC/H	X				
Glitch City LA	X	X			
Google AR/VR		X			X
Google Creative Labs		X	X	X	X
Google IO	X	X			
Google's Artists and Machine Intelligence		X	X	X	X
Gray Area Festival & Foundation for the Arts	X	X	X	X	X
Guild of Future Architects		X			
Hackster.io		X			
Harvestworks Digital Media Arts Center	X	X		X	X
HeK: House of Electronic Arts Basel	X	X			
HTC Vive			X		
Immerse: Creative discussion of emerging nonfiction storytelling		X			
IndieCade	X	X			

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Indigenous Matriarchs 4 Media Lab (IM4)		X			
Initiative for Indigenous Futures	X	X			X
Institute for Creativity, Arts and Technology, Virginia Tech	X	X	X		
Institute for Electronic Arts, Alfred University School of Art and Design	X	X			X
Institute of Network Cultures	X	X			
Intelligent Mischief		X			
International Conference on Motion and Computing	X				
International Symposium of Wearable Computers	X	X			
ISEA International	X	X			
Itch.io		X			
Journalism 360	X	X	X		
Kaleidoscope: Immersive Production Studio		X	X		
KIKK Festival	X				
Leonardo/ISAST		X			
LIKELIKE	X				
Los Angeles County Museum of Art (LACMA) Art + Technology Lab	X				X
Magic Leap			X		
Make+Think+Code, Pacific Northwest College of Art		X			
Maker Faire	X	X			
Mana Contemporary	X	X			X
Media + Emerging Technology Lab, University of North Carolina School of the Arts	X	X			X
Meta.Morf X: Trondheim International Biennale for Art and Technology	X				
Microscope Gallery	X				
Microsoft Garage		X	X		
Microsoft Research Artist in Residence Program					X
MIT Center for Advanced Virtuality		X			
MIT Media Lab		X	X		
MIT Open Doc Lab	X	X	X		X
Mobile & Environmental Media Lab (MEML), University of Southern California School of Cinematic Arts		X			X

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MocapLab		X			
MOCO: Movement and Computing Community	X	X			
Monira Foundation	X	X			X
MozFest	X	X			
Mozilla Foundation			X		
MUD Foundation ArtLab		X			
Museum Computer Network	X	X			
Museum of Other Realities	X				
MUTEK	X				
National Theater's Immersive Storytelling Studio	X	X			
NEW INC		X			X
New Media Caucus	X	X			
New York Electronic Art Festival	X			X	
Nokia Bell Labs: Experiments in Art and Technology (E.A.T.)	X	X			X
NYC Media Lab at NYU Tandon School of Engineering					
NYC Resistor		X			
NYU Tandon MakerSpace		X			
NYU Tisch ITP/IMA Project Residency	X	X			X
Oculus Launch Pad			X		X
Open Signal Portland Community Media Center		X			X
openFrameworks		X			
p5.js		X			
PaceX Gallery	X				
PHI Centre	X	X			X
Pioneer Works	X	X			X
Portland Community College Fab Lab		X			
POV Spark	X	X	X		X
POWERPLNT	X	X			X
Processing Foundation	X	X	X		
Radical Networks conference	X	X			
Rap Research Lab		X			
Recess Art	X	X			X

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REFRESH: Art and Tech Collaborative		X			
Research Centers, Arizona State University Herberger Institute School of Arts, Media and Engineering		X			
Research Labs, University of Southern California Cinematic Arts		X			
Rhizome.org	X	X	X	X	
Rlab NYC		X			X
Scatter/Depthkit		X			
School for Poetic Computation	X	X			
School of Machines, Making, and Make Believe		X			
Signal Culture		X			X
Simultan Festival	X				
Sonar+D	X	X		X	
South by Southwest (SXSW) Interactive	X				
Special Interest Group on Computer Graphics and Interactive Techniques (SIGGRAPH)	X	X			
Squeaky Wheel Film & Media Art Center	X	X			X
Stochastic Labs		X			X
Strange Foundation		X			X
Studio for Electro-Instrumental Music (STEIM)					X
Sundance Institute's New Frontier Lab Program	X	X	X		
Tata Innovation Center, Cornell University		X			
teamLab: Art Collective	X	X			
The Current Museum	X			X	
The Cybernetics Library					
The Leonardo Museum of Creativity and Innovation	X				
The Paseo Project	X	X			X
The Recalibrated Institution at ArtCenter/South Florida			X		X
The Wrong Biennale	X				
Times Square Arts		X		X	
TOPLAP: The Home of Live-Coding		X			
Transmediale	X		X		
TRANSMIT ³ residency project at The CUBE	X				X
Trash Hackers Collective		X			

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Tribeca Film Festival and Virtual Arcade	X	X			
Troika Ranch	X	X			
TroikaTronix/Isadora		X			
Trondheim Electronic Arts Centre	X	X			
Twitch		X			
UCLA Department of Design Media Arts	X	X			
UCLA REMAP: Center for Research in Engineering, Media, and Performance	X	X			
USC Annenberg Innovation Lab and Civic Media Fellowship		X	X		
V2_Lab for the Unstable Media	X				
Vancouver International Film Festival (VIFF) Immersed	X				
Venice International Film Festival - VR Expanded Program	X				
VR World		X			
Watershed Pervasive Media Studio					
Wave Farm	X		X		X
Wexner Center for the Arts' Film/Video Studio Residencies	X		X		X
Within	X	X			
World Building Media Lab, University of Southern California School of Cinematic Arts		X			
XR for Change Summit	X	X			
Yamaguchi Center for Arts and Media	X	X			X
Z.K.M. Center for Art and Media	X				
Zero1	X	X	X	X	



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