Interdisciplinary arts-charged creative processes as vehicles for knowledge production

Les processus créatifs interdisciplinaires centrés sur les arts comme vecteurs de productions de connaissances

Jiayi Young[1]

[1] Department of Design, University of California-Davis, Davis, USA, jdyoung@ucdavis.edu

ABSTRACT. Is Research-Creation a valid and legitimate mode of knowledge production? This was a question posed as the theme of a panel discussion at the 2023 de la mise en culture de la science à la recherche-création that took place at the École des Arts Décoratifs (ENSAD). This paper focuses on contemporary research-based creative practices. Rather than arguing the validity of such practice, or examining whether creative practice coupled with research methods equals knowledge production, the purpose of the paper is merely to share, from a practitioner's point of view, three case studies that speak to if, what, and how knowledge was produced in the creative process of these projects. Engaging with the critical perspectives of scholars, such as Loveless, Chapman, Gänschirt, and Groat and Wang, the discussion begins with insights from the 2016 ZKM exhibition on Frei Otto's architectural models and expands to share the authors' pursuits of two of their own creative projects. At the heart of these projects is the interdisciplinary arts-charged creative process, which propels the practice onward as a quest to know something we didn't know before. A key aspect of all these projects is their focus on questions of significant cultural and societal importance. The journey toward the answers intermittently intersects with science, engineering, and other fields beyond the arts.

RÉSUMÉ. La recherche-création est-elle un mode valide et légitime de production de connaissances ? Cette question a été posée lors d'un séminaire qui s'est déroulé en mai 2023 à l'ENSAD - Paris, intitulé "De la mise en culture de la science à la recherche-création". Le présent article examine cette question en se concentrant sur les pratiques créatives contemporaines relevant de la recherche-création. Plutôt que de débattre de la validité de ces pratiques, ou d'examiner si la pratique créative associée aux méthodes de recherche peut mener à la production de connaissances, il se contente de partager, du point de vue d'une praticienne, trois études de cas qui examinent si, quoi et comment des connaissances ont été produites durant les processus créatifs de ces projets. En s'appuyant sur les perspectives critiques de chercheurs tels que Loveless, Chapman, Gänschirt, Groat et Wang, la discussion débute par des considérations sur les maquettes architecturales de Frei Otto exposées au ZKM en 2016, et se poursuit par la présentation des travaux de l'auteure et de son équipe sur deux de ses propres projets. Au cœur de ceux-ci se trouve un processus créatif interdisciplinaire, essentiellement artistique, qui propulse la pratique vers une quête de nouvelles connaissances. Un aspect essentiel de tous ces projets réside dans leur focalisation sur des questions d'une importance culturelle et sociétale majeure. La démarche croise par intermittence les sciences, l'ingénierie et d'autres domaines au-delà des arts.

KEYWORDS. Research-Creation, Research-based Design, Research-Based Creative Practices, Knowledge Production, Interdisciplinary, Arts-Charged Creative Process, Research Methods.

MOTS-CLÉS. Recherche-Création, Conception basée sur la recherche, Pratiques créatives basées sur la recherche, Production de connaissances, Interdisciplinaire, Processus créatif chargé d'art, Méthodes de recherche.

1. Introduction

This paper discusses contemporary research-based creative practices that integrate art, design, science, and technology. It has resonance with what's been referred to as "research-based design" and the broader concept of Research-Creation, which encompasses design and other arts fields, even including the humanities when it integrates with the arts. The discussion begins with engagement with the critical perspectives of scholars, such as Loveless, Chapman, Gänschirt, and Groat and Wang. It is followed by insights from the renowned architect and practitioner Frei Otto's scientific experiments with soap bubbles to understand how gravity falls with fabric-based structures which challenged the heavy, cement-based Nazi architecture of his era. The discussion then unfolds through a personal journey of

research-based creative practice, presenting two distinct projects where the author assumed two different roles. In one role, as the artistic director collaborating with a small group of designers, computer engineers, and a political scientist, and in the other, as the principal investigator working with collaborating investigators to devise an engagement apparatus [BIS 10] for a large group of scientists and artists to enable a collective inquiry that navigates the intersections of artistic experimentation and scientific innovation. These projects serve as practical exemplars, shedding light on the ongoing dialogue of research-based creative practice and its relationship to producing knowledge at the nexus of art, design, science, and technology.

At the heart of these projects is the interdisciplinary arts-charged creative process, which propels the practice onward as a quest to know something we did not know before. A key aspect of all these projects featured is their focus on questions of significant cultural and societal importance as the end objective. The journey to realize the objective intermittently intersects with the sciences, engineering, and other fields beyond the arts. Throughout this interdisciplinary journey, driven by these critical inquiries, the projects necessitate leveraging existing expertise, known techniques, and established research methods or developing new ones to meet the demands of these critical inquiries.

The works discussed in this paper were originally presented in May 2023 at *De la mise en culture de la science à la recherche-création* at the *École des Arts Décoratifs* (ENSAD) and at the 28th International Symposium on Electronic Art (ISEA 2023 Symbiosis) in Paris, France. By invitation of *La revue Arts et Sciences* as part of a special edition, the expanded discussion here aims to contribute to the dialogue of contemporary research-based creative practices regarding knowledge production by illuminating the nature of the practice and contributing to the nuanced complexity of the discourse.

1.1. *Engagement in theoretical framework*

Interdisciplinary arts-charged creative practice that fuses artistic endeavor with scientific and engineering research to pursue questions, often of significant cultural and societal importance, is the discussion of the paper. Its emergence as a growing field of inquiry is evidenced in Roger F. Malina's annotated bibliography [MAL 16]. Theorists have postulated different terms to describe the interdisciplinary arts-charged creative practice as "practice-led research; practice-based research; art-based research (ABR); arts-based research; art practice as research; practice as research in the arts (PaRa); artistic research; research "into," "through," and "for" practice; research-led practice; research-informed; research by design; and art as research" [PRI 19]. Central to this dialogue are the contributions of professionals—artists, designers, architects, and scholars—who pursue and inquire collectively with a multi-disciplinary mindset to curiosity and generating new knowledge. An example of this type of creative work is *Aqua Forensic*, a project by Robertina Šebjanič and Gjino Šutić [ŠEB 18], which exemplifies the synthesis at the core of these interdisciplinary arts-charged initiatives. By focusing on the hidden contaminants in our aquatic environments, the project probes deep into questions of ecological and public health significance, bridging cultural and societal concerns with scientific inquiry. Through a creative integration of environmental science and digital art, Šebjanič and Šutić not only spotlight the pervasive, unseen toxins affecting both human and wildlife ecosystems, but also challenge the audience to reconsider their relationship with nature. In this way, this project embodies the quest for new knowledge by utilizing established scientific techniques alongside novel artistic expressions, forging a path that intersects various fields beyond the arts to engage with and respond to critical environmental issues. Similarly, *The Pollinator Pathmaker* by Alexandra Daisy Ginsberg [GIN 21-23] exemplifies another interdisciplinary arts-charged approach, blending digital technology with ecological science. Collaborating with horticulturists, pollinator experts, and an AI scientist, Ginsberg introduced an innovative algorithmic method for garden design. This technique uses a curated selection of plants to foster diverse pollinator species, enhancing biodiversity and tackling ecological challenges. Additionally, the project includes a digital tool hosted on pollinator.net, which allows users to design gardens from the perspective of a pollinator, prioritizing empathy over traditional human-centric designs. This virtual design can be transformed into a physical garden, where the selected plants are arranged according to the digital plan. Among Ginsberg's creations, *the Eden Project* in Cornwall, UK, is notable

as a 55-meter living, multispecies artwork. This project redefines human interaction with nature by promoting biodiversity and supporting crucial pollinator populations, thus addressing ecological issues like habitat loss, pesticide use, invasive species, and climate change. By integrating artistic creativity with scientific and engineering expertise, the project not only educates the public about environmental concerns but also actively reshapes our relationships with the natural environment in a meaningful way.

In addition to the above-mentioned theoretical terms to describe creative work that integrates with science and engineering, such as the two highlighted, the term "Research-Creation" has emerged in the ethos in recent years. Aligned with the general spirit of similar terms, Research-Creation has been used to refer to a methodology that creates knowledge through creative practice. As "a means to produce innovative scholarship" [LOV 19], the multifaceted nature of Research-Creation encompasses a broad spectrum of practices, where the creative process and scholarly research intersect and inform each other to address research questions, embody, provide theoretical context, and outline a well-considered methodology. Research-Creation as practiced in the social sciences and humanities, for example, shows the same pattern and has included engagement with contemporary media experiences as modes of knowing, and these projects "typically integrate a creative process, experimental aesthetic component, or an artistic work as an integral part of a study" [CHA 12].

This discussion of incorporating science and engineering in the arts can benefit from Christian Gänshirt's discussion on "research-based design" in his book *Tools for Ideas: An Introduction to Architectural Design* [GÄN 21]. Understanding how research works in architecture—a practice discipline known for its well-established processes, methodologies, and cultural contribution in solving problems with complex social and political components—helps us see how architecture, as an arts field, pushes forward its field-specific inquiries while integrating science and engineering; and, even when the creative process resembles a scientific process, it remains a subject of the arts at the same time making significant contributions to culture, society, the sciences, and engineering all at once. Gänshirt characterizes architectural practice as "a synthesis of creative, technical, and architectural skills coupled with academic research and reflection." This characterization presents a research-based hybrid model that blends competencies of various skills: creative skills that generate innovative ideas and concepts; technical skills that turn creative ideas into tangible outcomes; architectural skills that understand the relationship between space, structure, and the environment; academic research in various fields including outside fields such as science and engineering to incorporate and apply theoretical and empirical knowledge to the practice, and reflection as the process of critically analyzing one's own work in assessing the effectiveness of design solutions and methodologies leading to continual improvements (or iterations) toward the ultimate architectural goal. He describes the process of synthesis as a cyclic process that starts with defining a research question in architecture as a response to social, political, or environmental challenges, followed by data collection and observation to formulate an initial hypothesis. Subsequent experiments then test this hypothesis with systematic recording, analysis, and interpretation of data to validate experimental outcomes. The process emphasizes empiricism, rationality, reliance on scientific principles, and even transparency and reproducibility, much like the standard practice in science and engineering. This process points to a deep intertwining of scientific research and artistic design, with the two converging in practice. These descriptions of architectural practice articulate an active interdisciplinary space for the purpose of creative practice but with scientific rigor, positioning architecture design akin to a form of scientific inquiry; however, not only important for its own sake of the field of architecture but also for making significant cultural contributions including in the arts, science and engineering.

Following this thread, Gänshirt included discussions on Frei Otto's architecture as an exemplar of research-based design, particularly through the architectural models showcased in the 2016 ZKM exhibition *Thinking in Models*, curated by Georg Vrachliotis. In this paper, I have elected to expand on Gänshirt by further exploring Otto's use of models in his creative practice, focusing on how the freedom typical of arts-based explorations serves as a vital facilitator in Otto's approach to solving complex social and political problems. This freedom brings a fluid integration of scientific experimentation to the

creative process, which gives rise to finding solutions to his inquiries, particularly when it is against the status quo. In the case where novel solutions are imperative because the inquiry is new and has not been done before, I have chosen to explore Otto's path to lightweight structures based on research conducted with his soap bubble experiment. Otto's physics and engineering experiments led to the tension and membrane structures he is known for, and the experiments had a significant symbolic and technical impact on the post-war architecture he aimed for.

1.2. *Point of departure: Soap bubble experiment and Frei Otto's light-weight architecture*

Frei Otto, winner of the 2015 Pritzker Prize Laureate in architectural philosophy and practice, stood out for his integration of interdisciplinary methods combining arts, design, sciences, and engineering. His pioneering work on lightweight structures, particularly tension and membrane structures, revolutionized architectural form and function and embedded deeper societal significance into the designs [VRA 17]. His architectural ethos, shaped by an era coming out of the devastations of World War II, led to a distinct rejection of the Nazi era's heavy, monumental architecture. Or, as Irene Meissner points out, as "lightweight construction versus a display of prestige" and "to signal a turning away from monumental construction …" [MEI 17]. Accordingly, Otto championed designs that appeared light, seemed to defy gravity, and appeared almost to float as an embodiment of post-war aspirations for peace and social renewal [MEI 17]. This approach not only served as a visual manifestation of antiwar sentiments, but also expressed an integrated connection with the natural world. In 1964, he founded the Institute for Lightweight Structures at Stuttgart Technical University, which became a leading center for research in environmentally-conscious architecture and engineering sciences. The German Pavilion at the 1967 World Expo in Montreal is one such design, that symbolized a newly open and innovative Germany, and the iconic roofscape for the 1972 Olympic Games in Munich is another example. [VRA 17]

The 2016 ZKM exhibition *Thinking in Models* was a comprehensive showcase of Otto's work, running from November 5, 2016, to March 12, 2017, with a broad collection of his projects, including renowned and lesser-known works. The exhibition featured 200 models, with over 1,000 photos, drawings, sketches, plans, and films, along with a large-scale media projection, as a result of a collaboration between the Southwest German Archive for Architecture and Engineering (saai) of the Karlsruhe Institute of Technology (KIT), the Wüstenrot Foundation, and ZKM Karlsruhe [ZKM 16]. The extensive collection highlighted the breadth and depth of his creative approach to design and engineering through Otto's physical models, emphasizing modeling as a creative tool in his process. These models are made of conventional and unconventional experiments involving materials such as elastic fabrics, foils, rubber membranes, or even soap bubbles. The experiments Otto conducted utilized existing knowledge and methods and led to the creation of new tools and studies. These innovations enhanced his understanding of the geometries, physics, and engineering behind tented and air-supported frameworks and models suspended in mid-air. This advancement in knowledge and technology enabled him to develop complex architectural structures, such as branching constructions, vaults, and shells. [ARC 16, STE 16]

Otto's heavy reliance on empirical methods and material explorations can be seen as akin to practices commonly found in artistic creation, where hands-on interaction with materials and forms facilitates the evolution of ideas through discovery and not a predetermined design. This freedom allows practitioners to explore, innovate, and express themselves without constraints, fostering diverse expressions of ideas that feed into developments, not limited by preconceived conceptions. In the arts, such liberty is essential for personal growth and the advancement of the field as a whole. It encourages experimentation and pushing status quo boundaries, which can lead to new insights, techniques, tools, and the development of concepts. In the case of Otto's creative practice, as revealed in the ZKM exhibition, it is the freedom to pursue, particularly through the freedom to construct physical models, that enabled the architect to see, touch, and thus understand what material to use and how to support weight, from which to expand thinking to move the project forward. The articulation of this point is well expressed in the Preface of the *Thinking in Models* exhibition catalog:

"The central role that experiments played in this context becomes apparent in light of the huge number of models that figured in his thinking, research, and designs. Here he adopted an archetypal development method from the realm of engineering: the empirical process, according to which form is not created but rather determined heuristically via a material approach to the model—a logic that is not limited to single objects viewed in isolation, but rather [is] experimentally embedded in ingenious series of experiments and apparatuses" [HAN 17].

One of Otto's most astonishing experiments was his form-finding methods, used in the soap bubble experiments, which gave rise to the rooftop forms that inspired architecture designs like the stadium roofscapes for the 1972 Olympic Games in Munich [HER 76]. These experiments used a soap bubble apparatus that combined soap water and wires to investigate shapes that naturally conform to the forces of nature and the laws of physics. The apparatus was invented in collaboration with Larry Medlin. It functioned as a form-generating machine, referred to as the "minimal surface device" that provided a more precise geometrical analysis of the minimal surfaces created by the soap bubble shapes. This machine was also equipped with a humidifier and an air-cooling system, so that the surface tension of the bubbles remains balanced so as not to pop the bubbles. It also incorporated parallel lighting, a mesh grid, a projection screen, and a camera to enhance the precision and visibility of the experimental parts [VRA 17]. In addition, the study also contributed to understanding pneumatic buildings, which offer structural design alternatives in pneumatically stabilized membrane structures. They provide answers to structural forms based on the deformation of an originally flat soap membrane by means of individual supports [MIN 76].

This interdisciplinary experimental thinking and execution brought together expertise from engineering, physics, material science, and, of course, architecture. However, Otto's primary reason for bringing interdisciplinary experts together was to help solve problems central to an architectural quest of post-war ideology and associated functional requirements of new architecture, and the arts-charged freedom in thinking and practice is the vehicle that enables the emergence of groundbreaking architectural forms and concepts. When describing his encounter with Buckminster Fuller, another thinker and architect of a similar era, in the documentary film *Frei Otto: Spanning the Future*, Otto said, "We both did think free." [HAS 16]

If we were to consider the way in which Otto's architectural design makes use of interdisciplinary research, we would say that the process embodies an arts-charged freedom to create design integrated with scientific analysis. Circling back to Gänshirt, we can see that the nature of Ott's creative process is "… basically primarily synthesis; it is only secondarily scientific analysis. He [Otto] thus always remains an architect in his research." [BARTH 2005:6 cited in GÄNSHIRT, 2021] A way to further illuminate this idea can be found in Linda Groat and David Wang's 2001 book *Architectural Research Methods*. Groat and Wang conducted a detailed investigation on the effective mastering of the technical, aesthetic, and behavioral issues that arise in architectural work and concluded that,

"Design and research are neither polar opposites nor equivalent domains of activity; instead, subtle nuances and complementarities exist between the two. At their respective poles, yes, research tends to be more conceptually systematic, whereas design activity makes episodic uses of research." [GROAT & WANG, 2001:21-57]

2. Case studies: A practitioner's perspective

Practitioners of this approach to inquiry continue to shed light on how this integrative method provides a flexible framework to build a sophisticated adaptive investigation modality to harness knowledge and access complex research questions of societal importance, often embodying shared cultural conditions, human experiences and societal challenges. This section includes two projects with which I had direct involvement. Discussing one's own experience of practice in this paper is crucial, as it adds a layer of authenticity and intimacy to the otherwise theoretical discourse on others' work. A practitioner's account

of the development and evolution of a project, weaving together artistic experimentation and scientific explorations, provides a real-world perspective of the subject matter, offering readers a glimpse into the nuanced approaches of the practice. Moreover, incorporating personal experiences allows the author to demonstrate how theoretical frameworks manifest in real-life scenarios, bridging the gap between theory and practice. Ultimately, by intertwining personal narratives with scholarly analysis, the discussion becomes more relatable, engaging, and impactful, facilitating a more comprehensive exploration of the topic at hand. In the first project that is discussed, I served as the artist or creative director; in the second, I served as the principal investigator in a collective group inquiry with many colleagues.

2.1. *First case study: Direct creative engagement*
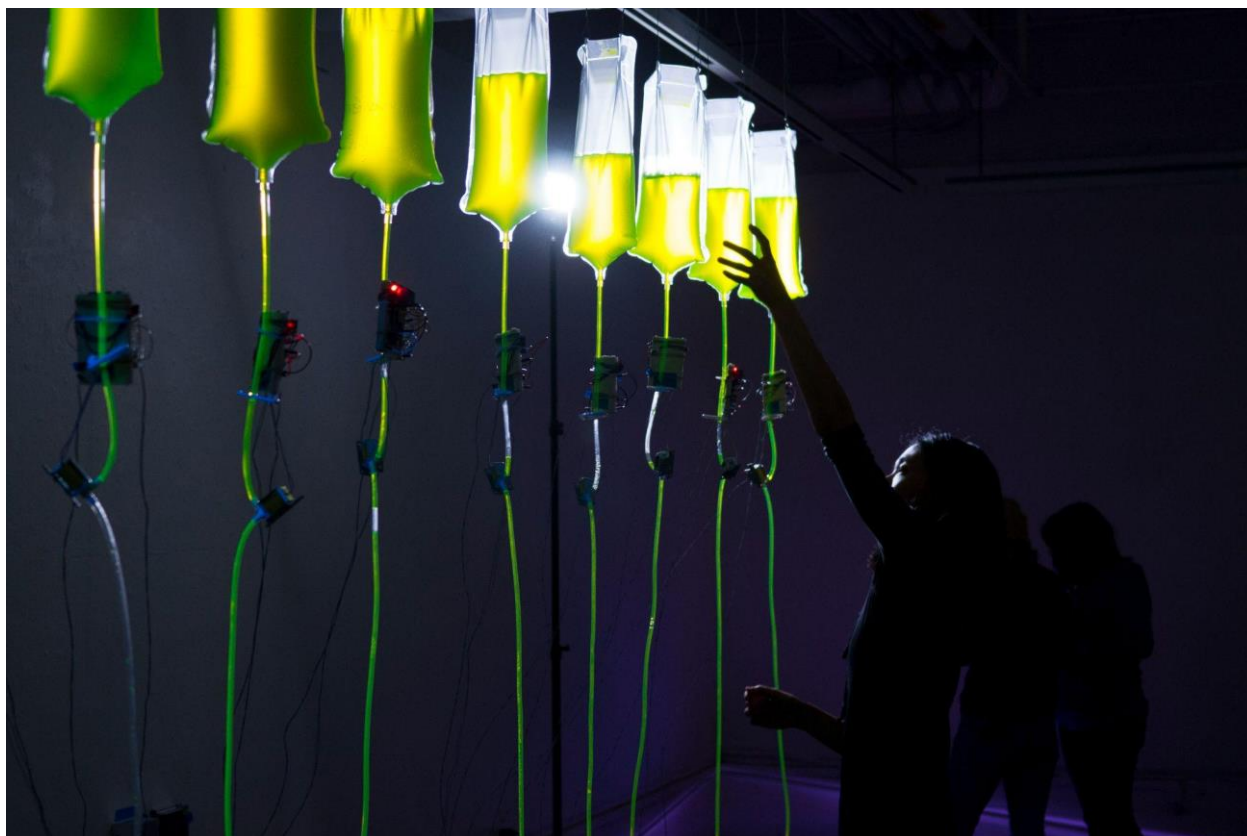
Figure 1. *What does the bot say to the human? Data Mapping of 2016 U.S. Presidential Election Twitter Activity 2016. Installation view, University of California, Davis, California. © Jiayi Young Studio.*

This first case study I include as a project in the discussion took on multiple shapes and forms with multiple phases of research spanning the last ten years, from 2014 to 2024, and is ongoing. The project focuses on examining social media data, particularly the social media platform Twitter (now named "X"), to understand the new social condition that underlies the way we interact with one another in the crucial decade of digital transformation involving social media. The project, first titled *What Does the Bot Say to the Human?* in 2016, was the manifestation of the research that took the form of a data-driven large-scale installation that exposed astroturfing efforts on Twitter related to the 2016 U.S. presidential election [YOU 17]. The term "bot" refers to Twitterbots, a type of software application that runs automated tasks over the Twitter social media platform, often used to post tweets automatically at programmed times to reply to tweets, retweet, follow users, and more; and the term "astroturfing" is the practice of creating the illusion of widespread grassroots support for an agenda, when in fact it is artificially orchestrated to influence public opinion or policy. During this period, as the artist leading the project, I worked with a data engineer to collect and analyze tweets and then embed the data findings in the installation as embodied knowledge. Post-2016, disinformation took center stage on Twitter. Later, during the 2020 U.S. presidential election, in collaboration with a political scientist and a computer engineer, I created an influencer visualization project titled *Project Echo* that tracked and visualized fake news dissemination on Twitter in real-time.

In extending *Project Echo* into a citizen humanities project, I am now working to build an Artificial Intelligence (AI) enabled tool called *Tracking X* that allows the public to track and visualize influencers on X with their chosen topic of interest. Equally as important—to apply the analogy of the importance of paints to a painter—just as a painter relies on unique paints to create art, developing this tool is like inventing new kinds of paint that enables entirely new forms of painting: I can use this tool and the data it collects at my fingertip and independently to create new visual and interactive installations and experiences providing insights into the dynamics of social media interactions. *Tracking X* would enable us to identify real-time patterns, shifts, and emerging behaviors, facilitating a deeper, data-driven comprehension of how information circulates and how narratives evolve on social media. This powerful analytical tool will democratize access to the typically opaque "black box" of social media, empowering individuals to participate and contribute to a more informed and inclusive digital ecosystem.

Below are more details on the different phases of the project, including *What Does the Bot Say to the Human?*, *Project Echo*, and *Tracking X*.

2.1.1. *What Does the Bot Say to the Human? (2014-2016): Data mapping of 2016 U.S. presidential election activity on Twitter*

What Does the Bot Say to the Human? (Figure 1) is an art installation that tracks and visualizes propagating hashtags from the 2016 U.S. presidential election, such as #trump2016, #trump, #tcot, #trumptrain, and #makeamericagreatagain. Transforming Twitter (X) data into a large-scale sensory experience with flickering lights, clicking sounds, and fluid exchanges between IV bags, the installation encapsulates Twitter activities from February 2016 up to the U.S. presidential election day on November 8, 2016. By distinguishing major Twitter influencers, mapping out propagation patterns in the data-driven campaign landscape, and differentiating between human and robotic tweets, the installation lays bare the mechanisms of a world where human and automated interactions blur and amplify each other's impact, fostering a combined propagation force. This installation not only explores the infiltration of machine-driven communication in shaping national discourse but also offers a tangible space to reflect on the profound challenges that social media poses to our understanding of social dynamics and the radical transformations in interpersonal relations.

The primary goal of the installation was to convey the proliferation of a pro-Trump sentiment as it spread on Twitter during the 2016 election. The project was designed to engage the public in critical social dialogue, highlighting how the manipulation of social media engagement significantly impacted contemporary American life, democracy, politics, and social interactions. By exposing how an illusion of popularity or consensus is manufactured, the artwork prompts a reevaluation of how public perceptions and discussions are shaped in the digital age. Designed to be versatile across different cultural and public settings, the installation leveraged insights from art, design, data science, and engineering to transcend traditional data visualization methods. The project employed provocative methods typical of the creative arts to draw viewers into a close encounter with data findings using lights, sound, and an immersive experience to prompt the public to critically consider the nuanced interplay of political power unfolding in the digital landscape as a new shared human experience.

The interdisciplinary, arts-charged creative process was central to the project and propelled the practice forward, embodying inquiries of substantial cultural and societal relevance. As the project navigated through development, it made strategic stops to engage with scientific and engineering disciplines, driven by the inquiries at hand and necessitating the employment or invention of various research methods and tools. This integrative approach enabled the installation's narrative in the chosen deliverable format and enhanced its ability to foster a dialogue that is both accessible and intellectually challenging, inviting a broad audience to engage with and reflect on these pivotal issues.

2.1.2. *Project Echo (2017-2021)*

Following the 2016 U.S. presidential election, responding to a surge in disinformation on social media [BAR 18], we initiated a transition into a new phase of the project that coupled a browser-based

visualization platform (Figure 3) designed to track disinformation with an activist campaign on billboards (Figure 2) in six swing counties[1] aimed at combating the spread of disinformation. Initially, in 2016, the public's awareness of the political influence of social media platforms like Twitter on public opinion was just beginning to surface [All 17], although terms like "fake news" were not yet part of the common vernacular. However, by 2022, the concept and impact of "fake news" had become widely recognized [BOV 19]. In response to this development, *Project Echo* was launched in 2020 to track and visualize disinformation on Twitter. It employed live tracking of virality, visualization of influence dynamics, and the identification of astroturfing campaigns during the 2020 U.S. presidential election. At the time, no other tool of this scale and capability existed. We were able to achieve it because we innovated a method to strategically utilize both the Twitter Premium and Standard Search APIs (Application Programming Interfaces) to balance cost-efficiency with high data fidelity. The tracking mechanism we developed was also crucial in identifying and visualizing the spread of disinformation, pinpointing top influencers, and detecting malicious Twitterbot campaigns. Ninety percent of our dataset preserved the original data fidelity of the Twitter landscape at that time. This is a remarkable statistic for a real-time Tweet tracking project.

Figure 2. *Project Echo. 2020. Live Webcam on a billboard in Philadelphia, PA, located on Interstate 95, with traffic heading toward Bucks County communities. © Jiayi Young Studio.*

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[1] Swing counties in the U.S. are those that alternate between supporting Democratic and Republican candidates in elections, significantly influencing outcomes in closely contested states due to their unpredictable voting patterns. These counties are crucial in the Electoral College system and are often the focus of intense campaign efforts.
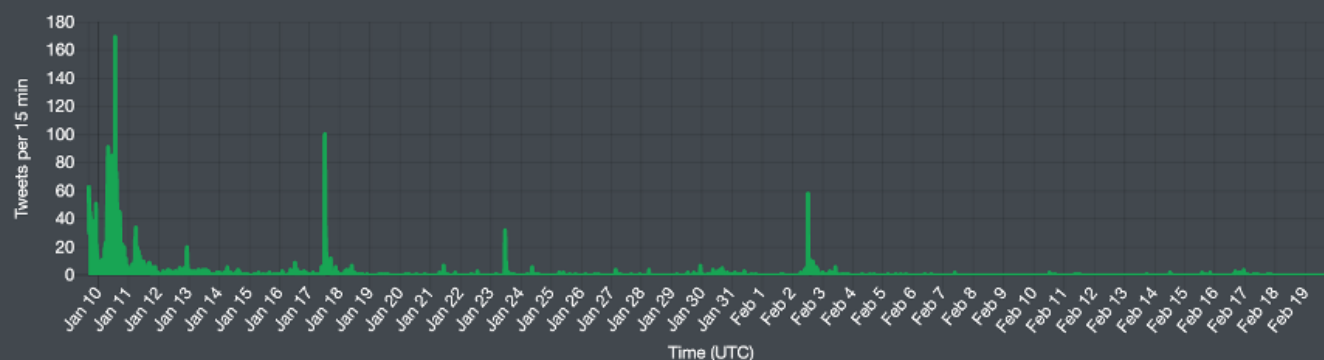
Figure 3. *Project Echo. 2020. This is an example of the interactive infographics showing a seismograph of disinformation topic 196. For each topic, the infographic shows the total number of Tweets and the time tracking started. The x-axis indicates the date, and the y-axis indicates Tweets per 15 minutes. The user interface is programmed to interact with pinch zoom to enlarge and hover to obtain the total number of Tweets in that period of 15 minutes. © Jiayi Young Studio.*
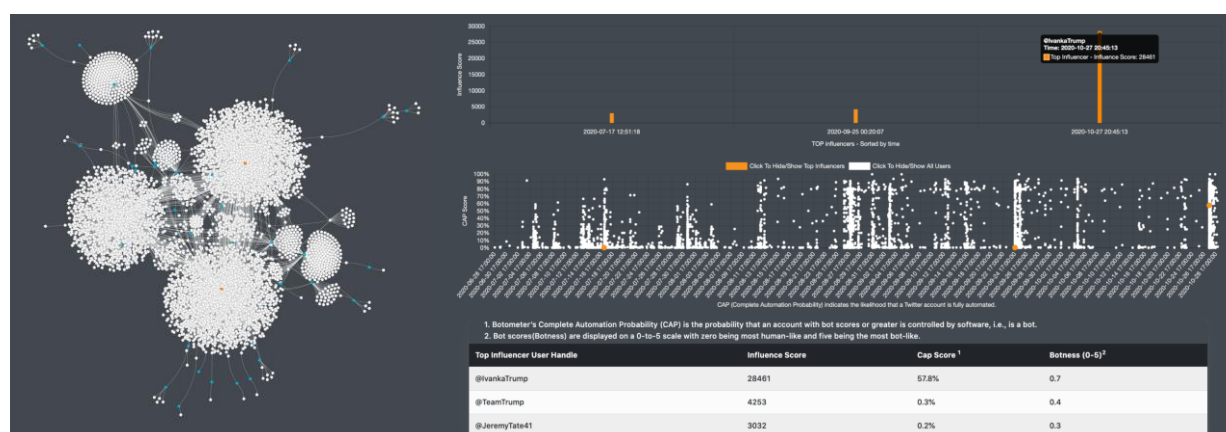

Figure 4. *Project Echo. 2020. This is an example of interactive infographics showing a social graph on the left and the identification of Top Influencers in the context of other users participating in the topic on the right. Each white dot indicates a user, and the orange indicates a Top Influencer, who is quantified as having influence scores above the 5% threshold in our project. The visualization is best viewed in color. © Jiayi Young Studio.*

The project workflow was also extensive. Each week during the project tracking duration, we manually curated election-related disinformation topics from articles published and verified by reputable nonpartisan fact-checking organizations like PolitiFact and Snopes. This step was followed by devising Twitter queries using keyword iteration methods and API-specific operators to gather Tweet data, such as user handles, messages, posting timestamps, and network reactions, including likes, retweets, favorites, etc. The real-time data analysis then focused on identifying major influencers for each topic, defined by those in the top five percentile of Influence Scores and calculated based on engagement metrics, such as retweets and favorites. Additionally, "botness" calculations were performed using the Botometer Pro API [BOT nd] to assess the likelihood of accounts being bots. Each disinformation topic

includes three sets of visualization charts: a seismograph to monitor live Twitter activities on the topic; a set of influencer bar charts that showed the timestamps when top influencers appeared on the network and the likelihood an influencer was or was not a Twitter bot; and an animated social diagram which mapped user interactions on the topic. Live data were downloaded from Twitter every 15 minutes to the backend database; analytics and visualizations were performed accordingly and then refreshed on the front end.

The project concluded with a significant dataset consisting of 204 disinformation topics generated between April 28, 2020, and February 20, 2021. The collected data included 2,623,792 Tweets, 1,030,066 users, and 2,365,660 incidences of user interactions. There were 103,879 accounts found that displayed a high probability of being fully automated social media bots carrying out astroturfing efforts that were designed to deceive and create the appearance of a grassroots movement. We also captured these Tweets before Twitter performed mass deletion of major disinformation spreaders in January 2021, after the January 6th Capitol Insurrection. The record contains the now-deleted @realdonaldtrump Tweets from the time and 70,000 QAnon (far right conspiracy theory) accounts and the Tweets that were posted through these accounts.

From 2016 to 2020, a transformative period in American politics culminated with the January 6th Capitol Insurrection following the 2020 Election. Originating from a nascent artistic exploration of Twitter data in 2014, this project evolved over a decade with its multiple phases, served both artistic and scholarly purposes, and, with a novel tool, empowered the public to access and interpret social media data more effectively. The dataset and visualizations from *Project Echo* have become a cultural artifact, reflecting shared cultural experiences of the time. This evolution of this project resonates with a discussion between two renowned physicists, Jean-Marc Lévy-Leblond and Roger Malina, that initially took place in a 2015 email correspondence (later published under the title, "Art-science: a dialogue on two world systems") about the importance of artists and scientists working together on joint projects to develop tools for both scientific and artistic purposes. Malina expressed, "Our hope is to create a context for scientific discoveries that would not otherwise have been made, and for impactful artistic works of our time." [BUR 16].

2.1.3. *Tracking X (2022 to Present)*

The project has now moved on to developing a standalone commercial-level web-based interface platform called *Tracking X*, which will feature tools that provide tracking and visualization of influencers and allow users to download data and related visualizations. The interface will enable real-time monitoring and analysis of user-specified topics and provide comprehensive insights into influencer dynamics and bot activities. This platform would be crucial for researchers and individuals who want to stay updated with the rapidly changing social media environment. One of the platform's key features will also incorporate AI capabilities to suggest query logic to facilitate the effective filtering of the relevant Tweets for continuous monitoring of selected topics. With the ability to discern patterns, shifts, and emergent behaviors in real-time, the aim of the interface is to foster a deeper understanding of how data-driven narrative spreads and how collective beliefs are formed, ultimately contributing to a more informed public via participatory access to the otherwise obscured but powerful digital landscape.

2.2. *Second case study: Useful Fictions, a collective inquiry*

The second case study is a project titled *Useful Fictions*, which emphasizes collective inquiry and explores how this project navigates the intersections of knowledge production and artistic innovation. The project began as a two-year collaboration between artists, designers, and scientists from the University of California, Davis, USA, and the *Chaire Arts et Sciences* of the *École Polytechnique & École Nationale Supérieure des Arts Décoratifs*, France. The project culminated in a week-long multidisciplinary symposium from Monday, September 9, 2019, to Friday, September 13, 2019. At the symposium, a coalition of artists, designers, and humanists worked with acclaimed climate scientists in their laboratories at *le École Polytechnique*. Accompanying the symposium, we also mounted a

temporary public art project titled *The Speed of Light (SOL) Expedition* that took place in Montmartre, Paris, engaging the public over the course of two days from Saturday, September 14, 2019, to Sunday, September 15, 2019.

The goal of the collaboration was to design and implement an experimental platform suitable for bringing artists and scientists together to exchange their shared concerns of critical ecological and societal importance. The vehicle that carried the discourse forward was the creative co-production of artwork by the artist-scientist teams. In pursuit of shared inquiries, the teams worked side-by-side with an attitude toward embracing the complexity of the problem and modeling radical openness to research, in which tools, laboratories, and studio work were shared between the team members (see Figure 5).

Figure 5. *Climate scientist explaining the purpose of a detector at SIRTA, France's national atmospheric research on climate and the environment. © Useful Fictions.*

2.2.1. *Useful Fictions symposium*

The project framework examined the *pars pro toto* correlation between measurements and their interpretations. For example, the concept of a meter, the speed of light, and a photographic record all inform our understanding of the world, with the assumption that they establish a truth that we can believe. However, measurements are often based on traces or indications of what is being investigated rather than the thing itself. They are often proxies or indices, representative substitutes, or indicators deemed able to represent the original subject of investigation. As such, measurements are fragile and prone to manipulation and misinterpretation. Thus, the context for the measurement is critical, but context is only sometimes known, disclosed, or disclosed adequately. Adding to this complexity are the tools used to make measurements, which are almost as malleable as the measurements themselves. In working with scientists, our project examines the idea of measurements and tools used in science as it relates to climate change in the Anthropocene, where the *pars pro toto* correlation between measurements and their interpretations has been increasingly exploited and politicized in the pursuit of varying human agendas. With an emphasis on examining the context and expanding concepts of ecological thinking through creative means, this project invites the rethinking of a human-centered narrative that dominates and defines contemporary cultural consciousness. We asked: "What controls the manufacturing of our systems of belief? What stories do we tell ourselves? Can we imagine differently?"

The five collaborative labs include: Lab 1, Climate Measurements, at the *Site Instrumental de Recherche par Télédétection Atmosphérique* (SIRTA) Observatory, *Institut Pierre Simon Laplace* (IPSL); Lab 2, A Microclimate of One, at the *Laboratoire d'hydrodynamique* (LadHyX); Lab 3, 4D Additive Manufacturing: From Print to Animation, at the *Laboratoire des Solides Irradiés* (LSI); Lab 4, *Data Materia*, at the X-Fab prototyping space; and, Lab 5, Making, Engagement, and Reflexivity, a migratory group threading between the other four labs.

2.2.2. *Climate measurements*

Building on the interdisciplinary approach highlighted earlier, the project was titled *Stardust* and took place at SIRTA, a prominent French national laboratory focused on atmospheric research related to climate and the environment (see Figure 6). At SIRTA, climate scientists study and track dust particles, contributing to a deeper understanding of atmospheric conditions. In line with the cultural and societal inquiry central to these creative projects, *Stardust* reimagined a vintage curiosity cabinet as an artistic installation showcasing ancient tools used in atmospheric science alongside visualizations of terrestrial and extraterrestrial dust studies. It served as an aesthetic display and a reflective medium, exploring how tiny dust particles have traveled across time and space. Engaging with the scientific discipline of climatology, the project incorporated a whimsical element with its *Dust Invasion* poster, humorously describing a fictional invasion of the U.S. in 2023 by foreign dust, linking environmental phenomena with geopolitical imagery. The final installation of *Stardust* was a testament to the integration of research and innovation in arts projects. It is presented in a light-hearted manner, complete with music and singing, illustrating how artistic creativity can intersect with scientific inquiry to produce engaging, thought-provoking, humorous, and poetic works. This project exemplified the synergy between the arts and sciences, driving forward the inquiry of significant cultural and societal themes.

2.2.3. *A Microclimate of One*

Continuing the interdisciplinary theme, the project, *A Microclimate of One*, exemplified the fusion of contemporary art with physics. This collaboration led to the creation of a participatory art installation, utilizing advanced synthetic Schlieren photography to produce real-time photographic portraits. This innovative technique captures the invisible atmospheric plumes emanating from the heat flux and convection generated by the human body (see Figure 6). Reflecting the key point of engaging with multiple disciplines, this project brought together artists and physicists to explore both the visible and the invisible aspects of human presence and environmental interaction. The choice of synthetic Schlieren photography, typically used in physics to visualize fluid flow and heat variance, was applied artistically to depict a unique "microclimate" created by each participant. The title *A Microclimate of One* deliberately plays on the ambiguity of "one," emphasizing individuality and the unseen thermal contributions each person makes to their immediate surroundings. By inventing a new process to visualize and capture these personal climates, the project not only furthered artistic and scientific methodologies, but also engaged deeply with the cultural and societal implications of individual impact on the environment. Overall, *A Microclimate of One* was a creative interpretation that weds technical and scientific tools with artistic exploration, driving the inquiry into how personal and environmental dynamics intersect, thus contributing to broader cultural dialogues.

Figure 6. *Synthetic Schlieren photography. © Useful Fictions*

2.2.4. *4D Additive manufacturing: From print to animation*

Furthering the exploration of interdisciplinary research-based creative practice, *4D Additive Manufacturing: From Print to Animation* at the *Laboratoire des Solides Irradiés* (LSI) also delves into the convergence of art, science, and technology at the nano level. This workshop pushes the boundaries of additive manufacturing by introducing the concept of "4D printing," a revolutionary approach that imbues inanimate objects with lifelike dynamics (see Figure 7). The lab leveraged advanced materials, such as magneto-responsive soft polymers, to explore the potential of programming printed objects to respond to environmental changes, employing a storytelling approach at the intersection of arts and engineering. Participants experimented with origami and kirigami folding processes to animate two-dimensional structures. This approach encourages speculation about future applications of 4D printing, prompting participants to consider how these responsive materials could react to real-life environmental shifts. Through this collaborative exploration, the explorations showcased the creative potential of additive manufacturing and prompted critical inquiry into the potential societal and environmental implications of such novel nanomaterial.

Figure 7. *Magneto-responsive soft polymers mimic nature's behavior. © Useful Fictions*

2.2.5. *Data Materia*

Data Materia was hosted at the X-Fab prototyping space, underscoring the transformative impact of representing data in physical forms. The workshop focused on perceiving data not just as numerical values but as tangible indicators that embody deeper truths about our relationships to more significant realities. Echoing the earlier focus on integrating various disciplines, *Data Materia* brought together participants from diverse academic backgrounds to reimagine data taking on physical form as a narrative tool. During the workshop, collaborators were challenged to envision and realize how data-driven

narratives could take physical form and occupy both indoor and outdoor spaces. This approach blends scientific insight with artistic expression, thus challenging the conventional usage of data as visualizations in charts and measurements in tables. Using data from varying sources, the collaborators made pasta out of data, printed creative visualization objects, laser-cut physical patterns based on data, made sound installations, and even invented data-driven machinery. This collaborative process showcases how data can transcend traditional analytical roles to inspire creative thinking. integration of research and innovation within the creative process, prompting participants and viewers to reconsider the role of measurements and data in shaping narratives. By transforming abstract quantitative information into tangible representations, the project enhanced our understanding of the dataset and fostered a deeper connection with our sensory experiences of seeing, touching, smelling, and interacting.

Figure 8. *Google Ngram was used to explore the relationship between domestic labor and climate from 1800 to 2000. Fresh pasta is made on-site and used as material to tell this story. © Useful Fictions*

2.2.6. *Making, engagement, and reflexivity*

Making, Engagement, and Reflexivity operated as a humanities lab focused on critiquing conventional modes of scientific knowledge production. This group studied the interactions between artists and scientists in the other four labs, offering insights and critiques on how scientific "truth" is an iterative construction shaped by epistemic, methodological, and technical queries. Emphasizing the role of cultural and societal impact, this lab functioned as a migratory group between the labs, challenging traditional scientific constructs and proposing alternative, fictional frameworks designed to navigate the complex interplay of knowledge construction processes, similar to how Hasok Chang (2007) described temperature as a construct that is measured by invented instruments. This perspective questions the arbitrary nature of scientific measurements and their role in defining "real" conditions. The participants of the group engaged deeply with the notion of overlooked constructs and instruments within the history of science, exploring what knowledge might be dismissed or marginalized by the dominance of the scientific method. It encourages the participation of experts, researchers, and storytellers who bring non-mainstream or fictional histories into the fold, including perspectives from queer and feminist theories. In essence, *Making, Engagement, and Reflexivity* fostered a reexamination of how scientific knowledge is constructed and perceived and championed the inclusion of under-represented narratives and theoretical frameworks in the discourse on knowledge production. This initiative aligns with the broader project goals of employing and inventing diverse research methods to explore significant cultural and societal themes.
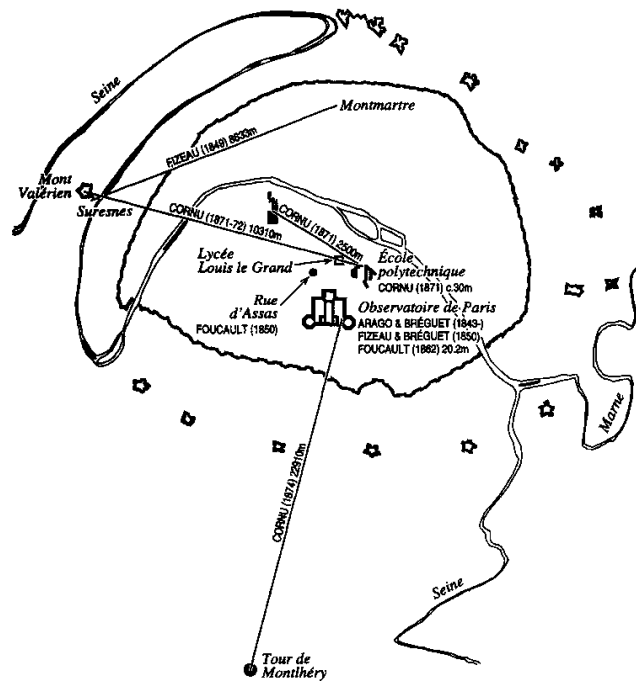
2.2.7. The Speed of Light (SOL) Expedition

Figure 9. *Light beams over Paris: a logarithmically-distorted map of the sites of the various mid-19th century speed-of-light experiments, including Fizeau's 1849 experiment.[2]*

Building on the themes of *Useful Fictions*, *The Speed of Light (SOL) Expedition* was designed as a dynamic public art project that began with an invitation to view Fizeau's original 1849 experimental device for measuring the speed of light, housed at the *Mus'X - Le Musée de l'École Polytechnique* in France. This device represents a pivotal moment in scientific history, contributing to breakthroughs that would eventually lead to Einstein's theory of relativity and subsequent shifts in scientific and artistic paradigms that have shaped the modern world.

The *SOL Expedition* leveraged this historical, scientific achievement and transformed it into a creative and collaborative journey of rethinking. Participants were invited to travel the same eight-kilometer path Fizeau defined for his experiment, from Mont-Valérien in Suresnes to Montmartre. This physical traversal was created to parallel the conceptual journey through time and ideas, stimulating cultural production and fostering a sense of agency among participants.

The project transcended traditional disciplinary boundaries by incorporating artists, designers, scientists, and the public in a collective creative process. It called on cultural and arts institutions to engage with this renewed historical inquiry, encouraging them to conduct research, create artworks, and design interventions that facilitate public participation.

A poignant example of this collaborative spirit was the response from *Galerie HUS* and the *Chambre d'embarquement* in Montmartre, which offered the *Speed of Shadows Expedition*. This public participatory performance was designed through the research of natural phenomena and integrated the concept of the passage of light with the three stages of twilight—civil, nautical, and astronomical—creating a multifaceted exploration of light and shadow. In this context, light and shadow transcend their ordinary roles and scientific interpretations to become a profound, multisensory experience where participants engage with light and shadow, not only visually, but through an immersive blend of poetry, participatory performance, precession, and even thematic elements like food and drink, creating an

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[2] Reprinted from Vistas in Astronomy, Vol. 36, 1993, William Tobin, Toothed wheels and rotating mirrors: Parisian astronomy and mid-nineteenth century experimental measurements of the speed of light, pp. 253–294, Copyright (1993), with permission from Elsevier.

intimate yet expansive interaction that feels both personal and planetary at once. This deep, experiential engagement is only possible through the use of a methodology deeply rooted in the arts with the ability to transform our perception to launch the imagination.

Conclusion

This paper does not intend to present a comprehensive list of terminologies that attempt to describe artists working with scientists and engineers (or their corresponding knowledge or methods). In fact, as Roger F. Malina points out, "Terminologies are unstable, as for example with the evolution of terms such as kinetic art, experimental film, video art, electronic art, digital art, computer art, interactive art, new media art, and so on" [MAL 16]. Regardless of the specific terminologies—whether 'Research-Creation,' 'research-based design,' or other variations—and their debatable validity and rationale, this paper shifts focus away from the terms themselves, acknowledging that we often use them interchangeably. Instead, I focus our discussion on the general spirit of the practice and how the interdisciplinary arts-charged creative process, in general, serves as a vehicle for knowledge production. This discussion has traversed the rich landscape of advancing arts inquiry by engaging with sciences, engineering, and other disciplines beyond the arts. It necessitates the use of established research methods or the development of new ones, thereby fostering a novel understanding of inquiries that bear greater cultural and societal significance.

The case studies presented underscore the versatility and efficacy of this approach, from Frei Otto's exploratory models, which transformed architectural norms and facilitated social innovation, to the decade-long, data-driven project on social media impact that starts with "*What Does the Bot Say to the Human?"* which initiates the unveiling of an invisible landscape that culminates in a substantial database of fake news influencers, thus acting as a cultural artifact that critically highlights their significant influence on public discourse. Additionally, the project "Useful Fictions" explores the limitations and fragility of using traditional scientific measurements and tools to represent complex phenomena in the world, such as climate change. It challenges the reliability and comprehensiveness of these methods, prompting a reevaluation of how we use science to understand and communicate about our environment. Each project articulated exemplifies how integrating artistic creativity with science and engineering can lead to novel insights and meaningful inquiries of societal value. This approach does not simply create knowledge or guarantee the production of new knowledge; it reshapes the way we perceive and interact with our world; in this way, it generates knowledge in a deep and profound manner that transforms our understanding and engagement with complex issues of the world.

In this sense, the pursuit of knowledge is referred to as the active endeavor to acquire information, understand phenomena, and develop insights through observation, study, experimentation, and reflection. This process involves questioning existing beliefs, exploring new ideas, and continuously seeking to expand one's understanding of the world. The endeavor cannot be limited to any one academic discipline or field; it must have the freedom to span what it needs to find answers that reflect a universal human desire to make sense of the environment and improve our interaction with it. This activity is fundamental to intellectual growth, innovation, and the advancement of society.

As we look forward to pursuing knowledge through the integration of arts, science, and technology, the landscape will undoubtedly continue to evolve and influence how we produce knowledge. The works discussed here advocate for a future where integrating creative practice is essential to the process of knowledge production. The nature of arts-charged creative practice inherently encourages experimentation. It is this freedom that allows it to fully engage with and navigate the complexities of the world. Such practices can pave the way for a future in which the integration of arts and research becomes commonplace and sets a standard for how we innovate and discover.

Acknowledgments

Bibliography

[ALL 17] ALLCOTT, H., & GENTZKOW, M., "Social media and fake news in the 2016 election", *Journal of Economic Perspectives*, 31(2), p. 211-236, 2017. https://doi.org/10.1257/jep.31.2.211.

[ARC 16] "Frei Otto's Drawings and Models Showcased With Exhibition Design by FAR frohn&rojas", *ArchDaily*, *29 Nov 2016*. Accessed 3 Apr 2024. https://www.archdaily.com/799988/frei-ottos-drawings-and-models-showcased-with-exhibition-design-by-far-frohn-and-rojas

[BAR 18] BARANIUK, C., "How Twitter bots help fuel political feuds", *Scientific American*, March 27, 2018. https://www.scientificamerican.com/article/how-twitter-bots-help-fuel-political-feuds/.

[BIS 10] BISHOP, C., "Is Everyone an Artist?", *Former West Research Seminars: Russian Avant-Garde Revisited*, Van Abbemuseum, Eindhoven (NL), 2010. Retrieved from https://www.youtube.com/watch?v=0sH3kMyqyVM.

[BOT ND] Botometer by OSoMe, "Frequently asked questions". Retrieved from https://botometer.osome.iu.edu/faq#how-does-it-works.

[BOV 19] BOVET, A., & MAKSE, H. A., "Influence of fake news in Twitter during the 2016 US presidential election", *Nature Communications*, 10, Article 7, 2019. https://doi.org/10.1038/s41467-018-07761-2.

[BUR 16] BUREAUD A., LEVY-LEBLOND J. M., MALINA R., "Un bref dialogue sur deux systèmes du monde", *MCD #81, "Arts & Sciences"*, March 5, 2016.

[CHA 12] CHAPMAN, O., & SAWCHUK, K., "Research-Creation: Intervention, Analysis and 'Family Resemblances'", *Canadian Journal of Communication*, 37(1), p. 5-26, 2012.

[GÄN 21] GÄNSHIRT, C., *Tools for Ideas: Introduction to Architectural Design, Expanded and Updated Edition*, Birkhäuser, 2021.

[GIN 21-23] GINSBERG, A. D., "Pollinator Pathmaker", no publication date, retrieved from https://www.daisyginsberg.com/work/pollinator-pathmaker.

[GRO 01] GROAT, L. N., & WANG, D., *Architectural Research Methods, 1st Edition*, Wiley, 2001.

[HAN 17] HANSELKA, H., et al., "Preface", in VRACHLIOTIS, G. (ed.), *Frei Otto: Thinking by Modeling*, Spector Books, p. 17, 2017.

[HAS 16] HASSEL, J. V., Director. (2016). *Frei Otto: Spanning the Future.* Documentary Film. Executive Producer: Simon K. Chiu; Written & Narrated by Michael Paglia. Full film available at https://www.freiottofilm.com/

[HER 76] HERZOG, T., et al., *Pneumatic Structures: A Handbook of Inflatable Architecture*, Oxford University Press, 1976.

[LOV 19] LOVELESS, N., *How to Make Art at the End of the World: A Manifesto for Research-Creation*, Duke University Press, 2019.

[MAL 16] MALINA, Roger F., "Art-Science: An Annotated Bibliography", CAA Advancing Art & Design, Art Journal Open, 27 Oct. 2016. Retrieved from http://artjournal.collegeart.org/?p=7855.

[MEI 17] MEISSNER, I., "Lightweight Construction Versus a Display of Prestige, from Montreal '67 to Munich '72", in VRACHLIOTIS, G. (ed.), *Frei Otto: Thinking by Modeling*, Spector Books, p. 41, 2017.

[MIN 76] MINKE, G., "Pneumatic buildings — structural design alternatives in pneumatically stabilised membrane structures", in HERZOG, T., *Pneumatic Structures: A Handbook of Inflatable Architecture*, Oxford University Press, p. 15, 1976.

[PRI 19] PRIOR, R. W., "Artistic Significance, Creativity, and Innovation Using Art as Research", in: PETERS, M., HERAUD, R. (eds), Encyclopedia of Educational Innovation, Springer, Singapore, 2019. https://doi.org/10.1007/978-981-13-2262-4_64-1

[ŠEB 18] ŠEBJANIČ, R., & ŠUTIĆ, G., "Aqua Forensic", posted on May 10, 2022 by roro, retrieved from https://robertina.net/aqua_forensic.

[STE 16] STEVENS, P., "Frei Otto's 'Thinking in Models' exhibition in Karlsruhe, Germany", *Designboom*, December 14, 2016. Retrieved from https://www.designboom.com/architecture/frei-otto-thinking-in-models-exhibition-karlsruhe-germany-12-14-2016/.

[VRA 17] VRACHLIOTIS, G., et al., *Frei Otto: Thinking by Modeling*, Translated by Simon Cowper and Ariane Kossack, 1st edition, Spector Books, 2017.

[YOU 17] YOUNG, J., et al., "Presently Untitled: Data Mapping of 2016 U.S. Presidential Election Twitter Activity, Phase III", in *Proceedings of the 2017 ACM on Multimedia Conference (MM '17)*, ACM, New York, NY, USA, p. 580-581, 2017. https://doi.org/10.1145/3123266.3129332

[ZKM 16] ZKM | Center for Art and Media, *Press Release: Exhibition "Frei Otto. Thinking in Models"*, issued October 2016, duration: November 5, 2016 - March 12, 2017, Exhibition held at ZKM_Lichthof 8+9, Karlsruhe, Germany. Retrieved from https://zkm.de/en/presskit/2016/exhibition-frei-otto-thinking-in-models.