# The Electronicists

## Techno-aesthetic Encounters for Nonlinear and Art-based Inquiry in HCI

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## ABSTRACT

This paper offers a theoretical and methodological framework of 'techno-aesthetic encounters' that supports nonlinear (situated, materially-driven, and multi-sensory) and art-based modes of inquiry in HCI and the broader STEM fields. We first investigate recent literatures in HCI and science and technology studies (STS) that explore nonlinear modes of practice and creativity in processes of technology design, and argue that better recognition of these dynamics may open space for art-based and nonlinear leaners and makers to more actively engage in HCI research and design. To meet this need, we study three renowned art-and-engineering practitioners (Klüver, Paik, Moog) and our own experimental project titled 'The Electronicists' in which participants from different disciplines collaborated to produce three hybrid works. Based on this work, we propose a framework of 'techno-aesthetic encounters' that pursues event-based creativity through the mediation of engineering, art, and humanistic engagements. We suggest trust-based experiments, error-engaged studio, and art-based ethnography as promising methodological tenets of this approach.

## CCS CONCEPTS

• **Human-centered computing**; • **Human computer interaction (HCI)**; • **HCI theory, concepts and models**;

## KEYWORDS

Techno-aesthetic, Art, Music, Nonlinear Engineering, Ethnography

**ACM Reference Format:**

Leo (Laewoo) Kang, Steven J. Jackson, and Trevor Pinch. 2022. The Electronicists: Techno-aesthetic Encounters for Nonlinear and Art-based Inquiry in HCI. In *CHI Conference on Human Factors in Computing Systems (CHI '22), April 29–May 05, 2022, New Orleans, LA, USA.* ACM, New York, NY, USA, 17 pages. https://doi.org/10.1145/3491102.3517506

## 1 INTRODUCTION

Over the last couple of decades, the understanding of human-computer-interaction has begun to expand to include notions of engineering and computing that involve constructivist, constructionist, and artistic modes of inquiry and design. By exploring how 'doing' and 'knowing' are interconnected to each other, recent researchers and designers have engaged HCI interests and problems through the reconstruction of their own technological learning and making experiences. This work has opened up diverse methodological approaches highlighting practices of inquiry that include critical, reflective and speculative design [12, 26, 43, 92, 110], materially-engaged and multisensory activities [32, 40, 48, 100], and experimental multidisciplinary collaborations [4, 10, 50, 61]. These approaches have helped HCI and other STEM fields to explore new creativities and tackle underrepresented problems less easily addressed under existing behavioral and engineering-driven approaches.

Following these lines of work, our research team has engaged in several ethnographic projects [49, 55, 61–64] over the past decade through which we met, studied, and worked with dozens of HCI and artistic practitioners who worked and collaborated in HCI and the STEM fields. As other art-related HCI work (see inter alia [10, 16, 31, 50, 71, 76, 78]) has shown, these encounters confirmed that there are numerous practitioners in the broad STEM fields eager to employ artistic skills, sensibilities, and modes of expression alongside more narrowly and traditionally 'academic' work in a conventional disciplinary sense. These participants have told us how practicing art is a crucial method not only for stimulating their creative thinking processes, but also for supporting the affective and psychological dimensions of their academic life and identity.

In recent HCI and design, the potential roles of artistic practice have been explored in several key dimensions, including how it helps us respond to situated and emerging technological problems in more nimble and intuitive ways [19, 38, 39], to support practitioners' self-confidence, motivation and investment in their inquiry spaces [17, 59, 97], and to push and refigure existing HCI notions of learning, creativity, and arguably interaction itself [22, 30, 44, 45, 56, 63, 79]. From the presence project [35] to design noir [27] to feral robotic dogs [57], the recent HCI and design fields have also shown abundant examples of modes of inquiry that have produced unique technological artifacts – and distinct technological practices – that could not be achieved by more linear and utilitarian engineering or behaviorist methods.

Yet, there is still a limited understanding of art practice and how it works as a mode of inquiry in technology-engaged fields, or the academic conditions that might better enable this mode of learning and creativity, especially in the context of HCI research. As recent literatures around alternative design approaches point out [40, 92], comparatively little theory and method exists for grasping and employing these growing artistic and alternative movements, and for explicating their relation to other modes of inquiry. As recent theories of 'somesthetic' design in HCI and design also argue [4, 48],


*CHI '22, April 29–May 05, 2022, New Orleans, LA, USA*

ACM ISBN 978-1-4503-9157-3/22/04…$15.00
https://doi.org/10.1145/3491102.3517506

the methods of inquiry available to artists in these fields, which usually involve interview-based qualitative approaches, are not sufficient, and need to be extended to more effectively consider and support practitioners' *situated*, *materially-driven*, and *multi-sensory* styles of inquiry. We will return to these modes later under the more general rubric of 'nonlinear' ways of learning and making.

The following sections seek to extend these lines of art-based HCI practice in two main directions. By presenting theoretical and empirical studies about crossover practices between art, engineering, and the humanities, our main goal is to explore how existing approaches to inquiry in HCI can be modified and extended to better support artistic and nonlinear practices and practitioners. To this end, the first and second sections investigate recent literatures in the fields of HCI, anthropology, and STS that both theoretically and methodologically explore nonlinear and aesthetic modes of human cognition and activity in technology design and use. Based on this, second, we argue the need for better frameworks capable of grasping theoretically the nature of art-based HCI practices (including in their relationship with other modes of inquiry) and supporting methodologically nonlinear practices and practitioners in the field.

To meet this need, we first study three renowned hybrid practitioners (Billy Klüver, Nam June Paik, Bob Moog) in the late 20th century who actively blended art and engineering practices in producing their work, often in rich multi-party collaborations with others (though this feature is partly obscured under the conventions of artistic fame and 'authorship'). We then present an empirical case of our own, a collaborative art project called 'The Electronicists (2019)', in which 11 participants from art, music, engineering, and academic research, including the authors of this paper, collaborated to produce three hybrid forms of work: an interactive art installation, an illustrated essay, and a live audio-visual performance. Based on these studies, we propose a theoretical and methodological framework of *techno-aesthetic encounters* that explores event-based creativity at the interface of engineering, art, and critical inquiries, including through the production of techno-aesthetic objects that, in concrete moments and places, can travel across and in some measure connect these worlds. We also suggest *trust-based experiments*, *error-engaged studios*, and *art-based ethnography* as promising (though not exclusive) methodological tenets of this approach. Finally, we explain how a focus on techno-aesthetic encounters can deepen and extend practices of creativity and interdisciplinary collaboration, as well as more diverse and inclusive modes of learning and learners, in HCI and the broader STEM fields.

## 2 NONLINEAR AND AESTHETIC ENGINEERING

Although now often regarded and practiced as separate domains, art and engineering historically have had deep and intimate connections. For example, the word 'art' is originally derived from the Latin word 'ars', translated from the ancient Greek 'techne' [42, 81]. Unlike the more complex and rarefied meanings attached to contemporary uses of 'art', techne in its Greek usage generally referred to skill or craftsmanship, especially as expressed through the making of physical things with hands and tools. The word 'technology' (techno-logia) shows similar etymological roots, combining with another Greek word 'logos' (word, myth) to mean in origin something like 'the story of human dexterity' [23, 121]. Given these common and modest origins, for many centuries the lines between art, craft, and engineering remained blurred. Leading figures in each, most famously perhaps Leonardo Da Vinci in the Renaissance, could not be easily sorted according to this typology. Indeed, many traits and tendencies used by later generations to distinguish *between* artists and engineers – for example, intuition vs. logic, creativity vs. practicality, freedom vs. discipline – were long viewed as common points *within* a shared program of human skill, labor, and technique [20, 23, 66, 75, 82].

What we would now commonly recognize as a boundary between them emerged only in the 18th century. At that time, Baumgarten and other theorists began for the first time to use the word 'aesthetic', derived from the ancient Greek 'αἰσθάνομαι' meaning 'I feel or perceive', to explain how artworks may differ from other more common or utilitarian objects [65, 106, 107]. These theorists suggested an absolutist and metaphysical idea of aesthetic universality 'disinterested' in either the taste of specific social groups or the practical benefits to be derived from the object in question. Meanwhile, the notions of technology and engineering evolved in their own separate disciplinary directions. Literally denoting those who know how to use and produce an 'engine' (from 'ingenium' in Latin, meaning 'clever invention'), 'engineers' became those who designed and produced artifacts with clear functions providing practical benefits to their users [69].

In early computer science and other fields that came out of this separation, the activity of making things was often understood as a kind of purposive and goal-directed action unfolding through linear, instrumental, and broadly predictable progressions [1, 70, 119]. Such traditions often defined 'making an artifact' as a 'design' activity that was supposed to follow clear procedures and blueprints drawn by specific authorities (e.g., designer, engineer) to solve specific problems identified by them (with more and less input from 'users') a priori. This understanding reflected what anthropologist Tim Ingold has called the 'hylomorphic perspective' [52], in which making consists of giving teleological forms ('morphe') to a mostly inert world of matter ('hyle'), It has been challenged however more recently by work in STS and the social sciences that has highlighted the more situated, materially-driven, and multi-sensory (i.e., perceived, felt, ineffable) dimensions of technological development.

Bucciarelli [14] has pointed out how such hylomorphic visions of the design process reflect 'utilitarian' understandings based on presumptions that "scientific discovery becomes the determinant of technology's functions and form" and that "who and what determines the form and function of a technology starts from the marketplaces." But in his empirical studies of emerging technologies (e.g., x-ray inspection system, a photocopy machine), Bucciarelli found that design activity followed a much more complex and unpredictable process in which social and cultural parties constantly negotiated variously situated ethical, political, and economic issues. This mirrors historical and contemporary findings in the Social Construction of Technology (SCOT) [4], where the development of technological artifacts goes through specific, uncertain, and highly situated steps of social construction and negotiation, including the

'alternation of variation and selection', the deployment of 'multi-directional models', and 'stabilization.' One effect of this work has been to broaden the terrain of design to consider a much wider range of sites and actors than conventional engineering or indeed artistic accounts have allowed. Becker's notion of 'art worlds'[9] for example has called attention to the collective and deeply collaborative nature of art-making processes, in which artwork is not the product of an individual (the artist) but that of a social and collaborative system and infrastructure in which the artist is just one of several key players. This parallels Suchman's [119] account of technology design and use, in which human action is necessarily 'situated' in contexts or circumstances which people use to achieve intelligent action. Rather than representing human action and cognition in a linear, rationalized, and self-contained (or self-efficacious) way – after the model of intelligence that arguably framed AI research of the day – Suchman described instead instances in which circumstances (or 'situations') played a complex but fundamental role in cocreating intelligent action.

Extending such theories into design, parallel work in the fields of STS and anthropology have highlighted how design process and creativity are heavily dependent on non-human and material actors in design situations. Through actor-network-theory (ANT), Latour [74] has shown how non-human things can exercise certain forms of 'agency' that influence and frame other actors' actions and qualities. Importantly, this capacity of agency is not grounded in original or innate essence, but instead appears as a dynamic and 'relational effect' of how 'actor networks' are constructed, what kinds of human and nonhuman entities comprise the network, and how these entities interact with each other. Reaching parallel conclusions in the sphere of cognition, Hutchins [51] has offered the concept of 'distributed cognition', in which human thoughts and behaviors are not entirely framed or controlled by the individual's intention, but are instead 'naturally-occurring and culturally-constituted' through interaction with surrounding socio-material actors (in the way that that the cognition of pilots is shaped, distributed and completed through the material arrangement of the cockpit around them). Thus, human cognition is involuntarily and necessarily distributed across diverse components, including 'human social groups', 'material actors and environmental infrastructure', and 'time' in which earlier events affect the nature of later events.

Other scholars and practitioners have begun to push such distributed and materially-driven perspectives in more aesthetic and multi-sensory directions (including in ways that challenge the nineteenth-century break between aesthetics and engineering described above). David Pye [98] has pointed out that despite the seemingly linear and functional nature of technology design, such rationalist perspectives do not negate or erase the presence of aesthetic choice and viability. Based on his professional design experiences from wooden furniture to more advanced technologies, Pye explains that design choices are rarely *purely* logical or rational, but also represent a series of 'aesthetic decisions' that have their own ineffable and multi-sensory mechanisms, which cannot be fully captured and explained through language and logic. Kentridge [67] and Schön [109] have emphasized the importance of reflective 'conversations' with materials in the broad design and art making process, through which practitioners "give themselves over to the medium" [67] and follow what the situation provokes through a series of multi-sensory engagements. Ingold [52, 53] similarly explains how artifacts, technological or otherwise, 'arise' within fields of influence and flows of multisensory interactions with material actors. Rather than describing making activity as fulfilling a previsioned or step-by-step solution, Ingold frames it as an organic and interactive practice with materials that operates as a kind of 'weaving', where designers "bind their own pathways or lines of becoming into the texture of material flows comprising the lifeworld."

This section has argued for situated, materially driven, and multi-sensory modes of practice both within and beyond engineering and design, and suggested that such nonlinear modes are both under-theorized and under-appreciated within the field. This work shows how much human cognition and activity, including the frequently more formalized practices of engineering and design, cannot be understood as simple and linearized process, but are better grasped and approached as a (potentially) rich set of activities in which diverse socio-material participants intertwine in both logical and multi-sensory ways. This nonlinear viewpoint also explains how even narrowly designed artifacts may be neither fully settled nor subordinate to original purposes or preassigned goals. Instead, they recast these artifacts as more independent living entities in our world where why and how they exist are "in movement, in flux, in variation [52]" based on different space-time and socio-material contexts.

## 3 NONLINEAR AND AESTHETIC PRACTICES IN HCI

In HCI and design, theoretical viewpoints highlighting situated, materially-driven, and multisensory modes of inquiry have been reflected in various methodological approaches developed over the past two decades in particular. Research through design [125], design research [72, 102], and other 'alternative' approaches (see their lists and summary in Pierce's recent work [92]) explore more constructivist modes of inquiry [91]. These approaches highlight the importance of 'situating' practices in design and research environments to generate knowledge and access to that knowledge through designed artifacts. These approaches assume that what and how to learn and make (whether research questions or designed artifacts) cannot be clearly predefined, but emerge instead and are reconstructed through practitioners' critical and systematic reflection in specific socio-material *situations*, which allow designers to make research contributions based on their strength in addressing contingent, complex and frequently open-ended problems.

Other approaches highlight more materially-driven and constructionist modes of inquiry. For example, critical making [100] underlines learners and designers' situated experiences and insights derived from hands-on activity and material engagement with DIY electronics. By integrating critical thinking and techno-making activity, this methodological approach promotes reconnecting physical experiences with technologies to conceptual critiques and inquiries around distinct social questions and problems. In cultural probes [12, 34], a set of curated artifacts, like maps, postcards, and disposable cameras, are recruited to help HCI researchers explore hidden creativities or underarticulated problems that resist discovery and awareness under more linear and hylomorphic approaches.

Technological bricolage [123], and other craft- and material-based practices [32, 45, 96, 104] have highlighted the complementarities between the practitioner's intuitive material expressions and logical engineering practices.

Extending from such situated and materially driven methods, several recent approaches have highlighted 'multisensory' and 'aesthetically' engaged modes of inquiry in which how practitioners themselves perceive and intuitively react to the material worlds around them become key ingredients of the inquiry process. For example, the concept of 'somaesthetic' and 'somaesthetic appreciation' [47, 48, 113] suggests the value of specific autobiographical inquiries that include other social members' feedback to support specific HCI practitioners who engage kinesthetically and introspectively with bodily and sensory experiences. 'The magic machine workshop' [4] suggests a short, intense, workshop-like approach that supports "radically personal visions of a potential novel technological thing", while surfacing individual commitments and underlying personal desires. 'Sound-driven design' [21] focuses on sonic considerations in design situations to suggest a mode of human-centered design informed by practices of listening and other multisensory dimensions of interaction. This approach points out a 'semantic gap problem' in such multisensory practices, which pertains to how people experience and talk about sound, and the challenges of communicating and externalizing the sonic experience, suggesting more multidisciplinary and co-design activities where multiple stakeholders engage experimentally with more open-ended design situations.

These recent nonlinear and multisensory modes of HCI inquiry actively employ specific methodological approaches borrowed from constructivism, constructionism, and pragmatism, which commonly highlight practitioners' critical and deliberate reflection and speculation on both the social and material dimensions of computing experience. For example, reflective design [110] highlights reflection on unconscious values embedded in computing by integrating participatory, value-sensitive, and critical design approaches. To support and highlight material sides of the reflection, this practice involves collecting and analyzing a set of 'mediums' [5] or producing 'annotated portfolios' [33] by linking material activities to processes of theory formation in writing. Speculative design [28, 43] advocates ethnographically-informed approaches that explore 'future scenarios' addressing essential human attitudes, assumptions and concerns. These emerging methodological forms commonly involve crossover and hybrid approaches in which ethnography and design inform each other, or where the outputs of design are regarded as interpretable and creative rather than determinate and practical [112].

Such nonlinear and aesthetic processes also commonly involve a non-utilitarian role for technological products, allowing for aesthetic and socio-political experiences that may extend beyond their practical benefits. Rather than considering technological function as something that only exists for specific utilitarian goals, the researchers and designers in these modes of inquiry have often called for richer and more holistic engagements by employing non-utilitarian concepts, calling out the 'adversarial [25]', 'hedonic' [29], 'pleasure' [36], 'fun' [49], 'ludic' [26], or 'spiritual' [9] dimensions of technological objects and encounters [36]. In the process, these objects may 'work' across multiple ways and worlds at once. Jeremijenko's Feral Robotic Dogs [25], sniffing out pollution to invite the public discussion of environment contaminants, Gaver et al.'s Prayer Companion [36], displaying a stream of spiritual information gathered from RSS news feeds, and other artistic HCI works (see, inter alia [46, 68, 76, 77, 80, 85, 96, 124]) provide rich examples of such 'boundary objects', which Star & Griesemer [117] describe as "both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites." Sengers & Gaver [111] similarly highlight the importance of "multiple, potentially competing interpretations" in design evaluations that help promote communication and interaction between different social and academic groups.

Taken collectively, recent theoretical discussions rejecting plan-based and hylomorphic understandings of technological development have been reflected in numerous methodological approaches in HCI and design. These approaches commonly highlight constructivist and ethnographic approaches highlighting practitioners' deliberate socio-material engagement and reflections. More recently, multisensory practices combined with interdisciplinary and experimental workshop techniques have been introduced to the field to support various art and nonlinear practitioners. However, comparatively little theory and method has been developed to help explain and deploy these aesthetic and nonlinear activities, or to explicate their relation to other modes of inquiry in the field. As 'somesthetic' and other 'alternative' design approaches also point out, the currently available methods of inquiry for artists in the fields of HCI and design are not sufficient and need to be updated to more effectively capture and understand practitioners' *situated*, *materially-driven*, and *multi-sensory* styles of inquiry. More art-based examples are also required to carefully identify the specific conditions and situations that might promote (or discourage) such nonlinear practice. To attend to these questions, the next two sections study three historic hybrid practitioners who actively blended art and engineering practices, and our own collaborative art project 'The Electronicists' in which 11 participants from the fields of art, music, engineering, and HCI/STS research collaborated to produce their own crossover works.

## 4 LEARNING FROM THREE HYBRID PRACTITIONERS

In this section, we review three renowned hybrid practitioners (*Klüver*, *Paik*, *Moog*) in the media art and music fields, often held separate from HCI and STEM scholarship. These practitioners were selected by the authors among other historic figures who actively blended art and engineering practices in the course of producing new forms (and often genres) of work, and were part of a larger exploratory study of comparable figures who included music producer Conny Plank, musicologist Hugh Davis, multi-media artist Wolf Vostell, and electronic musician Wendy Carlos. We were particularly interested in studying those who worked in the mid-20$^{th}$ century since it was the starting point where the continuous development of electronic and computer technologies combined with emerging genres of art, such as Avant-garde, electronic music, and media art, creating a conducive environment for art and engineering practices to blend with each other [93, 99]. Through this review,

we intend to explore how their blended art-and-engineering practices necessarily departed from either conventional engineering or artistic approaches taken separately, and the characteristics and values that were thus embedded in their productions. These can help suggest lessons around the specific approaches and conditions that might promote or discourage nonlinear and crossover practices in HCI and design as well.

## 4.1 Johan Wilhelm Klüver

Johan Wilhelm (Billy) Klüver (1927 - 2004) was a Swedish electrical engineer who mainly worked for the Bell Telephone Laboratories ('Bell Labs') in Murray Hill, New Jersey. Klüver was also a founding member of Experiments in Art and Technology (E.A.T), a historic and ongoing organization established to explore interdisciplinary collaborations between artists and engineers in the greater New York area. From the early 1960s, Klüver started employing his engineering skills and knowledge for diverse experimental art projects while assisting and collaborating with a number of leading visual and experimental artists in the New York area, including Jean Tinguely, Robert Rauschenberg and Nam June Paik. One of the biggest and most renowned projects among them was '9 Evenings: Theater and Engineering', a series of live art-and-technology performances, which occurred October 13 to October 23, 1966 at the 69th Regimental Armory in New York City [73, 88].

This project is considered the first large-scale interdisciplinary collaboration between twentieth-century artists and engineers. Led by Klüver and Rauschenberg, the project included 10 New York-based artists and 30 engineers from Bell Labs. Among these participants were notable avant-garde artists and musicians such as John Cage, David Tudor, and Robert Whitman, and renowned engineers such as Bela Julesz, John Pierce, and Fred Waldhauer. These artists and engineers worked together for ten months, experimenting with integrating the aesthetics of art and engineering into one hybrid form of work. These collaborations resulted in ten technology-mediated performances in the final show, each produced by one artist and one lead engineer with the assistance of other engineers as needed. Emerging industrial and commercial technologies rarely used for artistic and non-utilitarian purposes, such as closed-circuit television, video projection, wireless sound transmission, and Doppler sonar, were used as artistic tools and materials (sometimes for the first time) in producing these performances. For example, in 'Open Score', Rauschenberg and another Bell Lab engineer Jim McGee collaborated to produce a new type of tennis racquet interacting with the amplified speakers and lighting on stage by using the FM transmitter, pre-amped microphones, and fiberoptic cables.

While participating and organizing these art-and-engineering projects, Klüver explained how such interdisciplinary collaboration not only informed the 'internal' practice of each side of the collaboration, but also gave rise to unexpected and emergent forms of creativity unavailable to either group working on their own. As he later described [88]:

> "All the projects I have worked on have at least one thing in common: from an engineer's point of view, they are ridiculous. That is their value... The idea was that a one-to-one collaboration could produce something that neither of the two could individually foresee. And that was the basis for the whole thing, and the system developed from there."

Rauschenberg, Klüver's main art collaborator in this project, also explained that this model of artist-engineering collaboration was not meant to follow specific direction for making clear conclusions, but to explore both possibilities and impossibilities between two groups. As he explained in the interview [88].

> "An area of intellect that was so isolated, colliding with something that had no direction, which is what I think art should, that's the way it should be going. Both of them shared their infinite possibilities, and impossibilities. I think the engineers liked the spirit, and I think the artists like the mind. And the guys were working for nothing, we were working for nothing — what a way to run a business!"

## 4.2 Nam June Paik

Another hybrid practitioner who actively blended artistic and engineering approaches in this era was Nam June Paik (1932 - 2006), a Korean American artist who employed a variety of electronic media and technologies, from television to VCR to satellite, to produce his audiovisual artworks and installations. Alongside John Cage, George Macunias, and Ono Yoko, Paik was a pivotal member of the Fluxus movement, an interdisciplinary community of artists, musicians, and performers that highlighted the value of artistic and experimental process over the finished products. Paik is often considered to be the founder and pioneer of the twentieth-century tradition of video art.

In 1964, Paik moved to New York, and started using various electronic media to extend his existing art and musical expressions. To use complex electronic technologies, Paik studied electrical engineering by himself, drawn especially by Norbert Wiener's idea of Cybernetics that emphasizes complex and reflexive causality through which the results of actions are fed back as inputs to further action. While mixing such engineering knowledge with his previous artistic methods, Paik found that his hybrid practices followed not a linearized or pre-composed process, as in classical engineering or music, but were rather driven by situated feedbacks and process-oriented engagements through which he looked for "the way" rather than "a pre-imaged vision before working." As Paik described [89]:

> "In usual compositions, we have first the approximate vision of the completed work, the pre-imaged ideal, or 'IDEA' in the sense of Plato. Then, the working process means the torturing endeavor to approach to this ideal 'IDEA.' But in the experimental TV, the thing is completely revised. Usually I don't, or cannot have a pre-imaged VISION before working. First I seek the 'WAY', for which I cannot foresee what it leads to. The 'WAY'...that means to study the circuit, to try various 'FEED BACK', to cut some places and feed different waves there, to change the phase of waves etc."

In addition, Paik explained that the technologies that he used, from television to satellite, were not simply utilitarian tools achieving specific functional goals, but also held an open-ended quality and so were like 'art materials,' like oil paint and canvas, that invited his creative expression and artistic imagination. As he explained [58]:

> "As collage technique replaced oil paint, the cathode ray tube will replace the canvas. Someday artists will work with capacitors, resistors, and semiconductors as they work today with brushes, violins and junk. . .Since today we have satellites, we want to use them, discover what we, artists, can do with them. We want to try something new in the tradition of Monet and Picasso. These same instruments (satellites) are used in the applied arts, which are essential to humankind because they are useful in everyday life."

## 4.3 Robert Moog

Another hybrid practitioner actively mediating art and engineering approaches in the late 20$^{th}$ century was Robert (Bob) Moog (1934-2005), a New-York based engineer who also happened to have a musical background. Bob Moog was the inventor of the first commercial synthesizer, the Moog Modular synthesizer, produced in 1964. Moog and his company subsequently developed various novel sound interfaces, such as the Minimoog Synthesizer in 1970 with its unique modulation and pitch wheel controllers and The Moog Voyager, a digitally-controlled version of the Minimoog. These various types of Moog synthesizers have been actively used by numerous notable musicians in broad genres of music, ranging from The Beatles, to Daft Punk, to Hans Zimmer. Based on these contributions to the wider musical domain, Moog received the Grammy Trustees Award in 1970 and Technical Award in 2002 (along with Steve Jobs for the Apple computer).

Moog's early synthesizers employed a 'modular' type of technological system in which independent sound-related systems, like oscillators, amplifiers, filters, noise generators, and mixers, could connect and interact through standardized patch cables and the technology of voltage control. Such a modular type of system enabled users to produce countless sound timbres and waveforms by experimentally mixing them with each other. Moog used subtractive synthesis, such that a complicated wave form from, say, a pair of voltage-controlled oscillators (VCOs) modulating each other could be fed through a voltage controlled amplified (VCA), the unique low-pass filter he patented (VCF) and an envelope shaper. The signal could be further shaped using external interfaces, such as keyboards and ribbon controllers. The Minimoog, although still based on separate modules, hard wired this standard set up together. [13]

Similar to the characteristics of hybrid practices that Klüver and Paik described above, Moog also emphasized how such technological developments did not follow a traditional plan-based and scientific approach, and were therefore not "something you learn about in Engineering School." Instead, Moog explained that his design processes were often driven by sonic and other aesthetic factors in the same way that musicians operated by "putting a tune or a mix together." Moog explained how Herb Deutsch's 'mouth sounds' inspired his engineering ideas [108]:

> "I learned very quickly from Herb, and after a while he asked me if I could help him make some new sounds. I asked him what he had in mind, and he made some mouth sounds [imitates blops and bleeps]. That was the beginning. I knew about transistors, which were just new then, and don't ask me where the idea came from to make what's called a voltage-controlled oscillator (VCO) or a voltage-controlled amplifier (VCA), I just thought about it, in the same way as many of you think about putting a tune or a mix together, the idea came."

Moog also underlined the nature of the complex relationship between musician (human) and instrument (technological system), which made it impossible for him to design their interaction with precise objectives or pre-perceived goals before working. Instead, Moog described how his approach was driven "intuitively" by experimenting and modifying a certain "arrangement of (technological) materials." As he explained [13]:

> "The musician-instrument system contains a multiplicity of complex feedback loops, so complex, in fact that contemporary technology has so far not been able to analyze or characterize the nature of the instrument-musician interaction with precision or completeness. Thus, it is not possible to design a musical instrument by beginning with an objective set of performance specifications. Rather, a musical instrument design usually begins with a designer's intuition. In some manner, this intuition suggests to the designer that a certain arrangement of materials will result in an instrument with desirable sound and response characteristics."

In this section, we reviewed three historic hybrid practitioners who actively blended art and engineering practices for producing their own creative works. From this review, we can learn three heuristics of such hybrid practices. First, as the above STS and HCI scholars confirmed, these practitioners commonly explained that their working processes were neither fully linearized nor precisely planned with "pre-imaged visions" orienting to a priori outcomes known or predicted in advance. Instead, they explained their practices as a reflexive socio-material process in which diversely situated social and technological factors were constantly navigated while negotiating and reconstructing the functionality and aesthetics of the designed artifacts.

These practitioners also emphasized how their practices involved tool-driven and materially engaged processes. For example, Paik and the '9 Evening' participants used various utilitarian tools, such as the cathode ray tube, Doppler sonar, and satellite, for non-utilitarian and artistic purposes (like an oil brush and paint) that inspired their artistic senses and drove the functionality of the works in more intuitive ways. In such hybrid practices, technologies did not exist only to solve specific problems preassigned by designers, but also carried living and creative potentialities beyond and unknowable to worlds of utilitarian purchase and adoption.

Finally, these practitioners emphasized experimental collaboration with those from different fields or disciplines, which enabled them to produce emergent and collaborative forms that were unavailable to either field or discipline operating on its own. Such a phenomenon of collaborative emergence reflects literary theorist Roland Barthes' famous description of the objects that emerge from (truly) interdisciplinary efforts, which "do not merely confront already constituted disciplines. . . it is not enough to take a 'subject' (a theme) and to arrange two or three sciences around it. Interdisciplinary study consists in creating a new object that belongs to no one." [8]

## 5 EMPIRICAL STUDIES: THE ELECTRONICISTS

To further explore the value of nonlinear and collaborative practices and identify specific conditions of inquiry that might support them, in May 2018 we initiated a crossover project of our own, 'The Electronicists' in which 11 participants from the fields of art, music, engineering, and HCI/STS research, including the authors of this paper, teamed up to produce an interactive installation, an illustrated essay, and an audio-visual performance. These works can be found in the online gallery of the project (https://www.leokang.com/electronicists/..

This project lasted 11 months, running from May 2018 to March 2019 in Ithaca, NY. While these processes followed an inductive and open-ended process built around the general precepts of grounded theory [18, 118], the general focus of the research team fell within the following three categories: (a) how do the participants from different backgrounds interact and negotiate with each other to produce their collaborative works; (b) what advantages and difficulties arose from such interdisciplinary collaboration; and (c) what conditions and activities can support crossover collaborations where different pursuits of art and engineering co-exist in the same project?

A total of eleven people from various professional backgrounds and recruited through friends, local artists, colleagues, and past collaborators have participated in this project. Of these, five participants (Leo Kang, Steve Jackson, Trevor Pinch, James Spitznagel, Annie Lewandowski), including the three authors of this paper, planned, organized and produced collaborative works and the final show. These participants used one or two of their professional skills, such as music, electrical engineering, visual art, and academic writing, on this project. The other six participants supported this study and the creative work of the other major contributors. These participants included one percussionist, one singer-songwriter, two videographers, one audio engineer, and one English editor. All participants—seven males and four females—were between 20 and 67 years of age.

To study this project, our research team applied three ethnographic approaches. One is in-depth interviews. All major contributors sat for semi-structured interviews about their working processes, results and experiences of the project throughout different stages of the project. Another approach was art-based ethnography [7, 75], a key component of which is to utilize the produced artworks from the field site as important heuristic evidence that allows researchers, artists, and audiences to (re)access the issue of the field site in more aesthetic and material ways. For this, the contributors provided the reception and demonstration time after their final show. All participants guests could discuss the artworks. Three of approximately 50 of these attendees were later interviewed about their experience of the show.

The third approach involved participatory observation combined with video ethnography that analyzes the participants' behaviors in specific natural situations to articulate the social, material, and environmental contingencies of the fields [75, 94]. For this, three participants acted as videographers who captured the details of collaborative processes in the first rehearsal and the final show. All videos were recorded with the participants' consent, and then transcribed, coded, edited and analyzed by our research team. During and after the collaboration, the edited videos were also shared with other participants to reflexively discuss their creative processes over email and social media. The collaborations among the participants produced three types of crossover work.

### 5.1 Three Philosophers, interactive installation

'Three Philosophers' is an interactive installation consisting of three life-sized wooden sculptures that produce different audio-visual effects (fig.1). Each sculpture has its own Arduino-based interface that enables it to respond to the user's behaviors (cranking a handle, making proximate sound, touching the string). Diverse technological materials and ready-made media such as computer fans, broken vinyl, disco-ball and motors are attached to the sculptures, and these attached components move and light up by interacting with the user's behaviors.

This installation was produced through a collaboration between Kang and Jackson from June 2018 to March 2019. During this period, they held weekly meetings in their school research lab and Kang's art studio. In this period, the form and function of the work were continuously changed while they were doing collaborative activities, such as discussions, material collections, building, and tests. At the beginning of the collaboration, they intended to produce a static sculpture by using antique and used books collected at a local book fair. As they were discussing the final show with other musician participants, they started adding the sound interfaces with visualizing functions in hope of using it for the music collaboration.

Building on the research team's prior work, the working theme of this project through its early and experimental iterations was 'ideas through things.' It highlighted making aesthetic technologies an important inquiry practice for exploring socio-technical theories or one's theoretical suppositions about technology. The title, 'Three Philosophers' expresses the participants' thoughts on the mechanism of crossover practice, which could be driven by the debate and negotiation among the three different academic figures: an engineer, an artist, and a critical theorist. Although all three sculptures were supposed to be presented in the final show 'The Electronicists', only two were used since the third was found to produce unexpected electronic noise in the final rehearsal. This work received praise from the performers and members of the audience who described it as 'easy to play' and 'inventive and whimsical'. As a drawback, one musician reported that its limited pitch set and sound timbre restricted full musical expression.

**Figure 1: Three Philosophers (2019)**

## 5.2 Want to Be an Electronicist?, illustrated essay

'Want to Be an Electronicist?' is an illustrated essay on the background of the project 'The Electronicist'. Pinch suggested this essay in group email thread. "Inspired by Bob Moog, I suggest we launch a manifesto with a new name for what we are doing. . . If we do a manifesto it should be a collective document from all of us." Other participants replied with their own opinions and suggestions. In the middle of this process, Jackson added content to the original writing, and suggested reframing the essay from manifesto to 'invitation'. Kang also added four pieces of his illustrations inspired by the contents of the essay. After 20 email exchanges among the participants, the content and design of the essay were finalized.

This essay starts with a teasing question, 'Want to be an electronicist?' with the drawing of a hand that touches musical and electronic symbols, like the eighth note and diode, drawn in three open-circuit strings (fig.2). This essay explains that what 'our friends and collaborators do is' the work of an 'electronicist', a term coined by Moog which we found in a letter of Bob Moog's in the Moog Archive recently installed at Cornell University [13]. Moog coined the term to describe simply 'anyone who uses electronic circuitry and instruments to make a work of art' [84]. By explaining how such work is different from digital art, electronic music, and new media art, this essay explains that electronicists are those who can imagine and invent artistic things through engineering (and vice versa). The essay shares stories of selected recording engineers, artists, and musicians such as Connie Plank, Nam June Paik, and Hugh Davies as examples of previous electronicists.

In addition, the essay points out that such crossover projects are not solely made possible by the talents of individual artists, but always require supportive social and infrastructural networks, like "friends and partners", local "record and parts stores", and "wider scenes that gave their work meaning and value." The essay explains that a key goal of crossover collaboration is to explore the 'three-way meeting point of engineering, craft, and art practices' in hopes of spelling 'new things for teaching, for research, and for collaboration in the contemporary university.' The final version of this work was published in digital and printed formats, and shared with the audiences on the day of the final show.

## 5.3 The Electronicists, live audio-visual performance

'The Electronicists' was a live audio-visual performance which took place on March 24, 2019 from 7:30 to 9:30 pm at a rented space in Ithaca, NY. Four teams of participants presented the creative works that they had been preparing since May 2018. In the first stage of the show, JAIE, a R&B singer-songwriter, sang five pieces of music with her electric guitar. In the second stage, the team 'The Electric Golem' and Kang collaborated to present their audio-visual show in which the team played improvised electronic music with a separate interactive installation developed by Kang titled 'Intermodulator' [60].

In the third stage, all musical participants teamed up as 'the Electronicists', playing a program of largely improvised music. In this improvisational ensemble, Kang and Jackson used 'Three Philosophers' for their sound and visual expressions. In the final stage, Lewandowski and the percussionist, Chris Corsano, produced another audio-visual performance in which they used Intermodulator and Three Philosophers for their free duo improvisation. After the show, there was a 'reception & demo time' for communication between the participants and the audience, during which audience

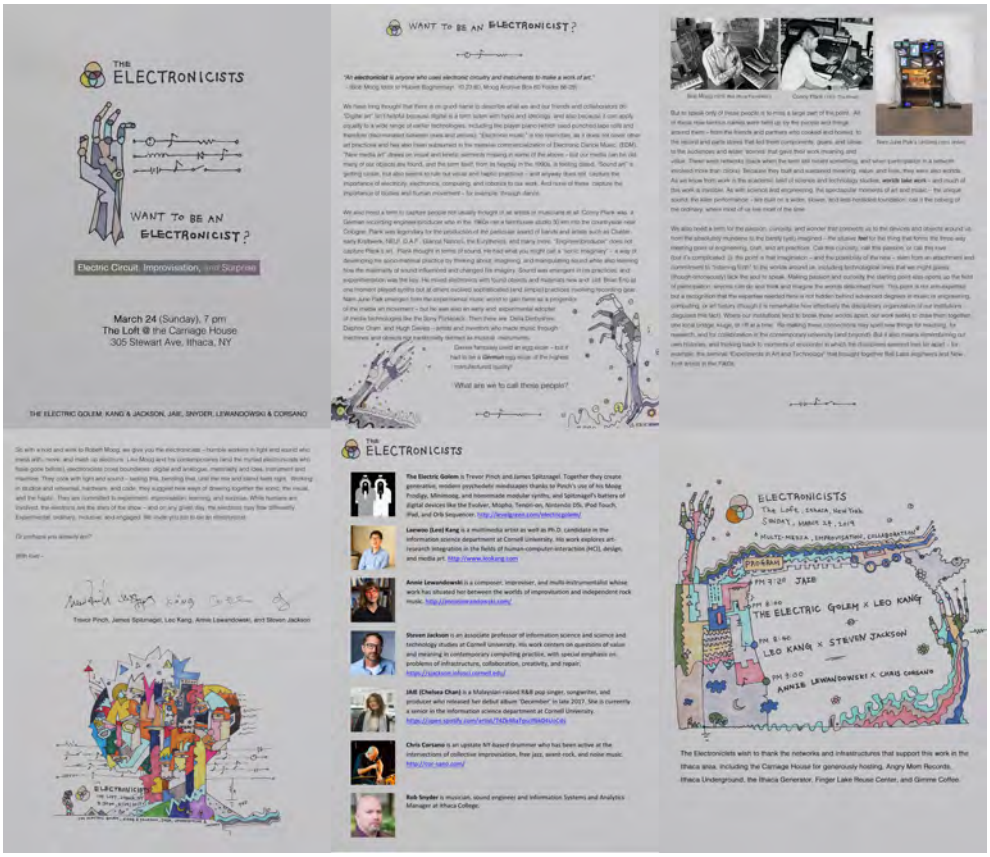


**Figure 2: Collaborative essay with illustrations**

**Figure 3: 'The Electronicists' show**

**Figure 4: Objects repurposed for building Three Philosophers**

members also experimented and improvised with several of the accumulated instruments.

In our subsequent interview study, most of the participants described how their skills and plans had often changed unexpectedly. One common finding was that participants highlighted the roles of material and environmental factors encountered in the collaboration process as important sources affecting their creative processes. For example, Jackson reflected on the fact that that some objects (see 4) discovered by chance in other collaborators offices or studios, such as interesting pieces of art and equipment, motivated certain design choices in the production of 'Three Philosophers'. He explained:

> "What it means to discover in the studio is different than what it means to discover in a library, or working with existing text. There are forms of surprise when just trying things out. Kind of weird chance encounters with material objects. Even if you think about our design choices all the way along, we didn't set out to design musical instruments in particular. But many of the choices were motivated by a particular type of material interaction."

Kang added that his circuit design practice in making 'Three Philosophers' was not driven by traditional engineering principles, but often proceeded by responding to the sounds and materials of other musicians. As he explained:

> "I am doing electrical engineering, but I'm not an electrical engineer. . . I'm just using electrical circuit, but I often break down the engineering law that I was trained in. If I make something and if it makes good sound, I just manipulate the circuit from there illogically, and make it that I don't even remember how to produce such thing. . . I just use my electrical engineering skills for traveling that imagination and this was very drawn by the sound (that other musicians made)."

Lewandowski stated that some spontaneous materials received by accident made her change her planned musical expressions to add flexible creativity. This improvisational approach was reflected in the final performance when she found one of the Three Philosophers didn't exactly work out in the final show by generating significant and unsolvable feedback issues with the wider sound system.

> "You kind of have to respond to the materials that are given. And it demands a certain adaptability, right? And I know that you went in with an idea that these instruments are all going to be there, but if one of

> them is not working, we can't get it to work, there's a flexibility that's required."

When asked what conditions and activities enabled and supported this project, all major contributors mentioned "trust" in other collaborators' professional skills and personalities. These participants insisted that social and professional trust is not constructed by chance or accident, but built over 'time', 'previous collaboration', or 'recommendation' from other trustworthy members. For example, Jackson explained that the trust built by previous collaborations as well as Lewandowski's recommendation made him more confident in participating in this experimental project without feeling "nervous" about the final outcomes. As he explained after the show:

> "I knew that something interesting would happen on March 24. And I also had confidence because of the past collaborations with Annie, Trevor, and Jim. If we hadn't done anything with them before, I would have been much more nervous about the collaboration, but I knew that they were, I knew I could trust them to approach it in a good and collaborative spirit and not be disappointed or angry or too set on 'it has to look this way, or feel this way'. So, I feel like I trusted all of the collaborators involved. And even Chris who I didn't know, I trusted him because of Annie."

Most of the participants pointed out the vital contribution of 'hidden' players, such as the supporting actors, local stores, sound engineer, manager of the performing space, and audiences and friends, as another crucial condition of possibility of the experimental collaboration. As Pinch explained:

> "So, it got me thinking about the hidden people who produce music that really make a difference and they're not usually recognized. . . They're contributing to this world and they are often hidden, but we all know it's not just the one-off musician or the band that became famous. There's a whole network of support which leads to the artwork being created."

In addition, Jackson and Pinch highlighted the importance of writing practices in their artistic processes, which enabled them to articulate what they have learned and perceived and to develop their creativities in relationship with other related works. As Pinch explained:

> "[Writing is] a skill I've learned from experience and definitely the way I think is in a writing mode as well. So when the idea that I articulate about sonic imaginaries are ideas that I can write down. So this is just my way of operating that part of me, my creativity comes out in words and in writing."

In addition to this interview study, our research team used video ethnography in the first group rehearsal, and the final setup and performance. Among the large amount of recorded data, our research team looked for processes of negotiation and decision-making among the participants. We found that many important decisions (e.g., what music to play, where to perform, who played what instruments) were not planned and designed in advance, but often emerged and were negotiated through group discussions. The description of the final rehearsal shows one such example.

> *In the afternoon of the final performance day, the major participants, sound engineers, videographers, and the stage manager gathered in the performance space, and started discussing how to organize the stage with their musical gear. While unloading and setting them up, they found that one of Three philosophers was making unexpected electronic noise, which didn't occur in the first rehearsal. Although trying to solve this error for about an hour through various professional and practical approaches such as reprograming Arduino, taping the connection, changing the audio cable, and adding a ground lift plug, they finally admitted that they would not be able to identify its problem before the show.*
>
> "I am not really sure what else I can do", the sound engineer said. "Now we just need to move on. Maybe we can just use this noise as part of our sound", Kang said. "The noise is distinctive when it is played alone, but if this came in the middle when everything else is developed, it would be less distinctive," Jackson suggested.
>
> *Then Spitznagel asked other participants to come to the stage and play their musical instruments together to check its noise level mixed with the other sounds. After the test, Lewandowski, who implicitly played a role as a sound director of the show, said that the level of the noise was considerably distracting and hurt the quality of group harmony in her ears. After another short group discussion between the participants, a decision was taken to remove the glitched installation and change the initial plan on the arrangement of musical instruments and the organization of the stage. They then tested their group sound together again, agreed that they were satisfied with the changed setting, and finished the rehearsal.*

This case shows that parts of aesthetic in this crossover work were constructed through improvisational collaborative practices in which the participants worked together to solve unexpected issues. This analysis reiterates our earlier empirical finding that the material and environmental players that the participants naturally encountered, whether inspirational or problematic in the first meeting, can play important roles in shaping and enabling the work's aesthetic. Thus, much of the aesthetics in crossover work can be conceived as a production of a complex socio-material collaboration in which human and non-human actors in the situation negotiate to produce works of situated creativity and knowledge.

## 6 DISCUSSION

In the above sections, we argued the need for frameworks and ways of thinking that might better characterize and support nonlinear and art-based practices and practitioners in the fields of HCI and design. For this, we studied three hybrid practitioners and our own project 'The Electronicists'. Based on these, this section suggests a model of 'techno-aesthetic encounter', that explores event-based creativity through the mediation of engineering, art, and humanistic engagements. We explain *trust-based experiments*, *error-engaged studios*, and *art-based ethnography* as promising (but not exclusive)

**Figure 5: Collaborative stage setup in the final rehearsal**

methodological tenets of such an approach. Finally, we explore how such theoretical and methodological frameworks can deepen and extend the topic of interdisciplinary creativity as well as learning inclusion and diversity in HCI and the broader STEM fields.

## 6.1 Background of Techno-aesthetic Encounter

The theory of 'techno-aesthetic encounter' draws in part on the work [114, 115] of French philosopher of technology Gilbert Simondon, who highlights how the presence of the aesthetic in technological practice may help "transgress ontological limits" and establish the "transductivity" of "modes of existence" that are held to operate, since some mythical branching point from a unified world of "magic" (in which technical, religious and other modes of thought were unified) according to different and now incommensurable logics. For Simondon, the presence and periodic resurfacing of the aesthetic in technical objects – never fully effaced by the nineteenth century divergence between aesthetics and engineering described above – signals the recovery or return, however fleeting, of a lost unity: an echo of a moment before (aesthetic) form and (technical) function were split into distinct and irrevocable realms. For Walter Benjamin [11, 15], writing around the same time and exploring the status of 'the work of art in an age of mechanical reproduction', this presence can be understood as a kind of 'aura': a residue which retains a principle of holism, or what Simondon would call variously a kind of 'completeness' or 'totality' akin to that found in early religious experience.

Setting aside the wider historical dimensions of their analyses, such moments of aesthetic experience restore a kind of fullness to the technical object lost under the nineteenth century split above. As reflected in the concrete world of things, this implies a kind of presence in the object itself, as revealed or obscured within a field of practice. But more importantly, it represents a (potential) aspect of what Simondon terms 'technical thought', which in his expansive and holistic understanding, can rival the 'completion' of thought in other domains (including for him religious and magical thinking). This assigns to technical objects a kind of potentiality or excess that can, *in certain moments*, exceed a narrowly functional framing and engage the wider set of values and relations invoked by the aesthetic. The individual object thus exists within an ongoing field of individuation, within which its specific difference (we might think of this more familiarly as its concrete manifestation or design) is assigned, but also the continued potentiality of its un- and re-making in which its dynamism beyond the settled form resides. Thus, when we see a technical object, we see its achieved form but also glimpse however dimly the worlds of possibility both behind and before it: we see a specific and concrete object, but also an index of other possibilities, in which 'technical thought' in its more holistic and expansive version resides.

In addition to this idea of techno-aesthetic, we turn to a language of *encounter* that draws jointly on Althusser's idea of "encounter" [3] and Dewey's event-based ways of learning [23, 24] that highlights the generation of a new inquiry space when one

is encountering a series of not-fully-determinate events. In these events, what to achieve is inherently uncertain and how to proceed requires situated collaboration and improvisation between the socio-material actors so engaged. Thus, the term encounter involves "an affinity and a complementarity of the elements that come into play" and "their readiness to collide-interlock", which "takes hold" and "takes form" and "at last give birth to Forms, and new Forms - just as water 'takes hold' when ice is there waiting for it, or milk does when it curdles, or mayonnaise when it emulsifies. ([3], p191)" As Dewey's idea echoes, the learner's cognition in this indeterminate and collisional experience is not fully separated or static from others, but continuously changing through "a combination of movement and culmination, of breaks and reunions" with other entities and "recurrently loses and reestablishes equilibrium with his surrounding." The key idea of encounter involves such indeterminate and situational inquiries and following the kinds of "aesthetic experience" produced from them. As Dewey explains:

> Where everything is already complete, there is no fulfillment. We envisage with pleasure Nirvana and a uniform heavenly bliss only because they are projected upon the background of our present world of stress and conflict. Because the actual world, that in which we live, is a combination of movement and culmination, of breaks and reunions, the experience of a living thing is capable of esthetic quality. The living being recurrently losses and reestablishes equilibrium with his surrounding. The moment of passage from disturbance into harmony is that of intensest life. ([23], p17)".

## 6.2 Techno-aesthetic Encounter as a HCI practice

Our idea is to contribute to the understanding of techno-aesthetic encounters in the context of human-computer-interaction, especially by organizing and participating in an interdisciplinary event where engineering, aesthetic, and humanistic practices come together to open a new object and inquiry space. Understood separately, the engineering practices deployed here involve linear and systematic forms of inquiry focused on problem solving and developing technological functions (e.g., designing electronic circuits, composing computational flowcharts). Art practice involves more intuitive and multi-sensory modes of inquiry that explore the work's aesthetic dimensions rather than following clearly logical and deductive methods (e.g., painting, crafting, musical improvisation). Humanistic practice involves reflective learning and analytic writing articulating the work's conceptual and theoretical backgrounds and connecting the practitioner's experimental experience to wider social and academic discussions through acts of critical reflection, ethnography, and theory making. The main goal of techno-aesthetic practice is not simply to combine the known merits of these practices, or employ one in service of the other to construct a fixed and universal method. Instead, it intends to explore undiscovered, underdeveloped, and more creative HCI inquiries through alliance, competition, and occasional moments of unity or complementarity between these now largely separated approaches.

Three key elements are involved in the kinds of techno-aesthetic encounter described above. First, they involve heterogeneous and 'transductive' modes of inquiry between engineering, art, and social science – fields which are often understood and practiced as different (and unmixable?) in the existing disciplinary structure of academia. On one level, this represents a turning back of the clock, a return to techne's roots as an integrated practice that lives *between* art and engineering. It also reflects the observations of the STS and HCI scholars cited above around the presence and underexplored potential for social and aesthetic interventions in the process of technological development. Finally, the notion of techno-aesthetic encounter is built around the notion that human cognition and inquiry intrinsically and involuntarily involve a mixture of logical, felt, and social experiences, which cannot be clearly divided or accounted for under regimes of value that routinely or automatically preference one over another. As highlighted in other examples of hybrid HCI practices (e.g., critical-technical practice, critical making, or somesthetic design), such an integrated approach can help HCI practitioners reconnect their experience with technologies to socio-cultural, psychological, and aesthetic dimensions.

Second, techno-aesthetic encounters also highlight the balance and tension between the elusive or ineffable nature of aesthetic experience, and efforts in language or writing to articulate and reflect on them. As one hybrid practitioner in our study noted, "my creativity comes out in words and in (academic) writing", reflecting a common instinct with the method of 'annotated portfolio [33]' which highlights linking material activities to processes of humanistic theory formation, and the role of critical and reflective writing practices in connecting practitioners experience with wider patterns of academic continuity and expectation in relationship with other related works. In other words, what drives discovery and creativity in techno-aesthetic practice is neither fully artistic and ineffable expressions nor purely humanistic and logical explanations. Instead, it occurs in careful dialogue and mutual adjustments between them, which helps practitioners to emerge from their own situated narrowness in the world, and connect personal expressions and inner voices to shared experiences in the broader social and engineering worlds.

Third, techno-aesthetic encounters tend (often intentionally) to produce a specific kind of artifact – techno-aesthetic objects – which can function after the manner of what Star and Griesemer have termed 'boundary objects': "objects which are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites." [112]. As with Star and Griesemer's classic definition, though the objects may be interpreted and valued differently across different communities, they also retain a consistency and commonality across them, and so provide one of the key mechanisms of translation (or what Simondon would call *transduction*) by which coherence and connectivity between otherwise different worlds is built and maintained. This allows the functional (engineering), aesthetic (art), and critical (humanities) meanings and values of techno-aesthetic objects to be neither fully separate nor fully collapsed under an overarching principle or hierarchy of order, but co-constructed in mutual, ongoing and sometimes unpredictable ways. From an evaluative standpoint, the key value of techno-aesthetic objects is not whether the individual reference points are fully

developed to satisfactory levels, but how these dimensions are resolved and combined in shared forms that can inspire and inform multiple communities (even if the mode of inspiration and meaning in those distinct communities differs).

Since techno-aesthetic objects pursue such mediating values, they may exhibit incomplete or interim qualities when experienced or evaluated from each point of view. E.A.T's tennis racquet, Feral Robotic Dogs, Prayer Companion, and Three Philosophers exhibit such heterogeneous but individually provisional values. These projects suggest neither purely inventive functions nor cutting-edge artistic craftsmanship, but instead play a role in opening new questions and producing new insights by connecting and mediating separated communities and disciplines. As highlighted similarly in the concepts of 'probes' [34], 'mediators' [39] , 'immodest proposals' [6], and 'research product' [86], the main goal of such mediating objects is to promote interplay between different "affordances" [37] by inspiring and informing different community members. What the notion of techno-aesthetic object highlights in this discourse is that such aspirational agency and affordance embedded in the artifacts involves a kind of liveness that continuously changes how designers and users think and feel based on different socio-technical situations.

## 6.3 Methodological Tenets

As a matter of practical method, techno-aesthetic encounters of the sort studied above give rise to three specific suggestions for interested HCI practitioners. The first suggestion is doing *trust-based experiments* with other social members who have different aesthetic pursuits or academic interests. As 'magic machine workshop [4]', 'meta-design [39]', and 'sound-driven design [21]' suggest, multidisciplinary and co-design activities, where differently oriented people are experimentally involved in the same design situation, help us engage unique creativities and mutually reciprocal solutions. What our study contributes to this discourse is that such experimental collaborative space, especially where participants' personally oriented and materially driven expressions are necessarily placed, requires a certain level of social and professional trust built between participants over time. As the participants of 9 Evenings' experiments gathered and extended through Klüver and Rauschenberg's mutual friendship, and one participant in 'The Electronicists' described ("I also had confidence because of the past collaborations"), techno-aesthetic encounters may depend on the cultivation of supportive and trustful worlds (in a way that organizing pop-up workshops or one-day experiments between those without social bonds may not allow for)

Another methodological suggestion for those seeking to foster or build techno-aesthetic encounters is to secure 'error-engaged studios' as spaces of safe and open inquiry. As other studio-based learning models in HCI (see, inter alia [29, 41, 87, 95]) have also highlighted, nonlinear practitioners need reflective and materially-driven spaces that can support "losing ourselves in the making while preserving the outcomes of each experiment." [40] What our study highlights in this discourse is that 'error' in such studio-based inquiries can actively help enrich and extend the practitioner's creativity. Like the mis-struck 'blue notes' of jazz, or recent HCI interests in "unmaking" [116] that enable and celebrate the failure of creative materials, mistake and error are not something to be removed or managed away, but instead can be important sources of creativity, insight, and aesthetic elegance or beauty. Careful "repair" work [49, 54, 55, 103] may form a central aspect of such error-engaged studios, and help flip existing understandings of error from an emphasis on failure to the creative potentialities that may *follow from* error – the forms of light and discovery that 'cracks', properly construed, may occasion.

Finally, we suggest 'art-based ethnography' [7, 48, 75, 94] as a key methodological suggestion, which highlights visual and somesthetic dimensions of learning by using various art making practices such as photography, videography, illustration, painting, music, poetry and essays, dance, and more. Vis-à-vis more traditionally ethnographic practices, this extended approach goes beyond simple interview or observation to include rich material engagements, kinesthetic explorations, and complex social and aesthetic interactions. Such integrated and holistic approaches offer HCI researchers deeper and more multidimensional access to the collaborative and creative processes under consideration, and provide richer insight into how human actors, materials, technologies, and situations are related and entangled. Like our illustrated essay and performances in the Electronicists project, such multi-dimensional works produced from aesthetic and collaborative engagements can themselves support sites and objects of HCI inquiry through which people can engage topics of research in simultaneously aesthetic, technical, and critical ways. As also highlighted in the ideas of critical and speculative design, art-based ethnographies can provide audiences and researchers heuristic spaces in which they can discuss and engage topics of inquiry in reflective, playful, and bodily-engaged ways.

## 6.4 Contributions and Limitations

For the HCI and STEM practitioners living in the 21$^{st}$ century, why is it important to explore nonlinear and art-based modes of learning and making, and what contributions might our concept of techno-aesthetic encounter make? We first argue that nonlinear practice can help these practitioners explore unique creativities and interdisciplinary computing and engineering works. As the core ideas in research through design [125], cultural probes [34], and meta-design [39] commonly hold, such constructive and constructionist approaches in engineering inquiry can help us attend to new problem spaces unavailable to other linear STEM approaches. They can also help us respond to uncertain and emerging socio-technical problems in more critical and humanistic ways. As the idea of critical-technical practice [1] and critical making [100] similarly highlight, increased awareness and reflection on the hidden assumptions and intricate values embedded in emerging technologies naturally enable HCI designers to have more careful social and intercultural considerations in their technology development processes [101].

Better support for nonlinear practices may also further efforts at learning inclusion and diversity, providing opportunities for researchers and contexts less well-served by existing traditions of work in HCI and the broader STEM fields. For example, nonlinear practice may support more inclusive modes of research and design for those with non-normative learning styles or distinct learning

challenges. For those with ADHD (attention deficit hyperactivity disorder), complex neurological conditions (e.g., synesthesia) or simply different kinds of minds, or those with strong and distinct art interests and practices (including painters, photographers, musicians, dancers, etc.), this approach can provide alternative modes that support entry into HCI and STEM-related subjects in more open, flexible and self-defined ways. As broad findings (see inter alia [75, 90, 97, 105, 122]) in the learning sciences and education have pointed out, nonlinear practices involving imaginative and playful activities can also support the emotional and psychological development of both young and adult learners.

Our study intends to contribute to this discussion by suggesting a framework of techno-aesthetic encounter that helps theoretically grasp the nature of nonlinear practice and methodologically support the various nonlinear practitioners in the fields beyond existing HCI methods. This model of inquiry, focusing on mediating engineering, art and humanistic inquiries, may help us think and imagine unique and creative technological systems in which functional, aesthetic, and humanistic values are not irrevocably separate, but co-constructed by shaping each other's values. Our methodological tenets can also connect and extend existing nonlinear practices in HCI. For example, practice-based HCI inquiries like Research through Design or Critical Making may explore more mistake-driven and unexpected creativity by employing our 'error-engaged studio' framework. Other workshop-based design inquires, like meta-design or magic machine workshops, may consider how trust plays an important role in collective design experiments. Moreover, such practices can be helpful for promoting interdisciplinary creativities and collaborations in general by inspiring and informing different academic communities. Especially for HCI, where a wide range of academic cultures continuously meet and collide, such a model can help to support more even-handed forms of encounter in which practitioners from different disciplines and diverse styles of learners can work together to build more reciprocal forms of creativity and knowledge.

This approach carries important limits of course. As other critiques of constructionism and constructivism have asserted [2, 83, 120], the outcomes produced from such approaches may involve ambiguous and provisional qualities which are difficult to evaluate, especially within STEM fields with modes of quality and reliability built around clear interpretation, reproducibility, and contribution. As other practice-based work in the field has already pointed out, the outcomes from practitioners' improvisational and situated activities naturally involve 'first-order' or 'provisional' qualities especially in the early stages. Although several researchers and educators in the fields are working on developing more interpretable and materially-engaged evaluation frameworks such as annotated portfolios [33], ACM DIS's Pictorial venues, and "multiple, potentially competing interpretations [111]", there is still little agreement on what to expect and how to fairly evaluate them.

Techno-aesthetic encounters may also not be well suited for those interested in and committed to more classical forms of inquiry. For example, for pure fine artists, the structure of techno-aesthetic encounters may constrain and limit their modes of work and expression, by imposing expectations of accountability and functionality less prevalent in a purely aesthetic environment. More classical engineers may find techno-aesthetic practices to be 'reckless' and illogical, often violating important design rules and principles (including reproducibility, linear progression, and more reliably functional contributions). Likewise, for more traditional critical practitioners, such as ethnographic fieldworkers or theorists, techno-aesthetic practices may require additional and time-consuming technological and aesthetic engagements that take effort and energy from more traditional fieldwork activities. While we acknowledge all these limits (and do not prescribe techno-aesthetic encounter as a meta-goal or theory for the field), our belief is that these tradeoffs are under certain circumstances worth it, and make a valuable contribution within the pluralistic and heterogeneous field of HCI scholarship.

## 7 CONCLUSIONS

In this paper, we have developed a theoretical and methodological framework of 'techno-aesthetic encounters' meant to explore nonlinear and art-based modes of inquiry in HCI and the broader STEM fields. Building on theories of nonlinear engineering from HCI, STS, and the social sciences, reviews of three hybrid practitioners, and an empirical study of our own art collaboration, The Electronicists, we have sought to support more situated, materially-driven, and multi-sensory modes of inquiry, thinkers and makers in the fields of HCI and design. As argued for above, this approach can make distinct and meaningful contributions to practices of collaboration and creativity in HCI and design, including in its interaction with art-based methods and practitioners. We believe such efforts represent modest but useful steps in the wider and ongoing project of deepening and extending the methodological and imaginative toolkit of HCI as a whole.

## ACKNOWLEDGMENTS

We would like to thank James Spitznagel, Annie Lewandowski, Chris Corsano, Chelsea Chan (JAIE), Rod Snyder, Jen Liu, Ji Hwan Seung, Adele Durham, and Carriage House Loft for their avid participation and kind support in this project. Finally, and with sadness, we note that the third author of this paper passed away shortly before the camera-ready version of this paper went to press. This paper is dedicated to his friendship and memory – Trevor Pinch, electronicist extraordinaire.

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