5 Art, Design, and Performance

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Recent science and technology studies (STS) have been demonstrating an increasing interest in art and design as emerging fields of inquiry. While art practices have been the focus of a scattered but increasing number of individuals and projects in STS and related disciplines for decades, issues in design have also recently become a key concern of STS. Such studies draw on a long tradition in STS to explore how the social world is inscribed into technology in the processes of its making and use (Bijker, Hughes, and Pinch 1987; Latour and Woolgar [1979] 1986; MacKenzie and Wajcman 1999), including their design (Star and Ruhleder 1996; Suchman 2011). Other studies that have inspired the recent attraction of STS in art and design concentrate on the entanglements of art and design things and practices in heterogeneous and messy environments (Latour 2008; Law 2004). They explore how in such environments, actors and artifacts are continuously being (re-)arranged in changing hybrid formations by complex processes of translation, which stabilize and destabilize the sociomaterial order in a given space and time. The study of art has also been inspired by well-known works such as Caroline Jones and Peter Galison's (1998) *Picturing Science, Producing Art*, which analyzes the role of visual representations and cultures of vision in science and art. All these studies demonstrate that art and design are deeply entangled with sociotechnical worlds.

In this chapter we will develop an argument for art and design as new, growing, and challenging fields for future research in STS. Michael Fischer proposed as early as 2003 to bring together science and technology with "the social sciences, arts, and humanities, which constitute the analytic understanding and cultural commentaries about the societies of (post)modernity" (Fischer 2003, 305). Bringing these approaches into conversation might turn STS into a key player "which would be integrative, critical, technically competent, and culturally resonant" (ibid., 305). Following this view, we will explore how STS scholars can benefit from the ways artists and designers bring about new futures and work in speculative modes of inquiry that are not necessarily beholden

to established epistemological frames, methods, conventions, and practices. We argue that STS could broaden its ways of investigating and intervening into technoscientific worlds through an engagement with art and design in four ways:

1. The involvement of art and design in exploring both the production and stabilization of scientific facts and the development and use of technological artifacts and sociomaterial networks can generate other enriched forms of knowledge, which includes aesthetics, across *all* of the senses (Benschop 2009).
2. STS (and science in general) could tap into enlarged methodological repertoires. Art and design works can thus counterbalance the more standard cognitive and social science approaches of STS by injecting ambiguity, complexity, speculation, and agonism when displaying and communicating science.
3. Art- and design-inspired ways of enacting and communicating research results can enable STS work to reach broader audiences than written scientific work, thus facilitating the inclusion of wider publics in the reflection on science and technology and contributing to its democratization.
4. Art and design interventions can be forms of radical political engagement with sociomaterial worlds and thus can participate in the shaping of technoworlds and the formation of technosocieties. Art and design methods might enable an alternative way for STS to get involved in sites where science and technology are constructed—experiments in codesign, participatory and adversarial design, and critical making are key in this respect.

Two questions are at the core of this enterprise. First, what can STS learn from art and design and apply to its broader scope of analysis?

The first half of this chapter, "STS Perspectives on Art and Design," asks how STS can—through an engagement with art and design—account differently for notions of performance, affect, multisensory embodiment, aesthetic play, invention, radical experiment and the forms of experience brought about by intervention, hacking, critical and disruptive design, "care," and critique that take place by way of art and design practices in science and technology. Throughout our review of the literature we point to a range of recent analytic subjects that have turned to new research directions such as improvisation and invention, embodiment, sensorial knowledge, and "haptic creativity" (Myers and Dumit 2011), "material engagement" (Malafouris 2008), contingency and material agency, performance and performativity, "adversarial design" (DiSalvo 2012), and "critical making" (Ratto and Hertz 2014).

Second, we ask if science has traditionally been seen as the premiere site of knowledge production (Knorr Cetina 1999), then what kind of knowledge does art and design produce and how does this knowledge challenge traditional paradigms of scientific knowledge (production)? What new research areas do art and design suggest for STS, from art dealing with living systems to questions of disruption and adversity in design practice? The second half of the chapter, "Art and Design as STS Methods," thus looks at ways to include art and design practices to explore issues in science, technology, and society. In this section, art and design and their performances are discussed as methods for STS analysis. This part will complement the future research agenda by suggesting issues for further examination such as genealogies of technoscientifically influenced art, "civic technoscience" (Wylie et al. 2014), emergent "biological sensibilities" (Fischer 2009), as well as "counterimages" (Burri and Dumit 2008).

STS Perspectives on Art and Design

Improvisation, Creativity, and Invention

In what ways do creativity and improvisation come into play in the (re-)configuration of sociomaterial arrangements such as the fabrication and appropriation of new works in art and design? How are unanticipated incidents handled in art and design practices? How can the subsumption of creativity and invention under neoliberal capitalist rhetorics of "creative industry" and "innovation" (Pang 2012) or of traditional gender, race, and culture distinctions carried forth in big science be critically interrogated (Fouché 2003; Lerman, Oldenziel, and Mohun 2003; Oldenziel 1999)? Such questions should be further explored by STS scholars, given STS's long-term exposure and examination of issues such as gendering in scientific practice, the questions of expertise in relationship to invention, and the role of material contingency in the production of knowledge.

In experimental practices in science, improvisation, creativity, and invention have always played important roles (Milburn 2015; Rheinberger 1997; Wylie 2015). STS may thus gain from carefully looking into the role and enactment of creativity, improvisation, and invention as crucial epistemic tools in art and design (Hallam and Ingold 2007; Montuori 2003). Theater and dance worlds, for example, explicitly theorize the *training* of improvisational skills, emphasizing that, "[i]mprovisation is by its very nature among the most rigorous of human endeavors ... Improvisers prepared themselves by making improvisation a regular practice, a daily practice even" (Gere 2003, xiv). Improvisers also emphasize the processes of developing collaborations, such as devising, again with an attention to training in the process.

Training in improvisation takes place through workshops and handbooks, and studies of these might provide STS with another level of attention to the making of scientists and engineers. Halpern (2010), for example, explores how theater-based role-playing

can enable students to experience science, so-called theater in science education. At the same time, the new field of critical improvisation studies points to the long history in which creativity and improvisation have served as concepts to demarcate race and gender, reserving creativity as a label for privileged bodies, while nonetheless practically serving communities in political critique and survival (Fischlin, Heble, and Lipsitz 2013; Goldman 2010; Heble and Caines 2014; Moten 2003). These works point to an as-yet-understudied assumption within STS about the place and role of creativity and improvisation in science and technology–related practices.

Simultaneously, STS can combat the tendency to associate creativity and invention within Euro–North American capitalist, neo-liberal narratives of progress (Eglash 2004; Fouché 2006; Verran 2002). STS studies of non-Western design cultures can challenge predominant ways of understanding innovation as outcomes of mainly Western (creative) industries and countercultures. For instance, Lindtner and Li (2012) show how Chinese hackers appropriate Western countercultural approaches by drawing at the same time on China's tradition of open source manufacturing, thus redefining what "innovation" means for China.

Embodied Knowledge, Material Engagement, and the Senses

STS has long described scientific knowledge as being embodied, that is, tacit and implicit (Haraway 1991; Polanyi 1967), and has highlighted the role of emotions in the process of knowledge production. These discussions reflect long-standing debates in cognitive science, philosophy, and human-computer interaction (HCI) on the nature of knowing and the manner in which such embodied knowledge gets represented and enacted, particularly within systems, artifacts, and technical practice itself (Dreyfus 1979; Haraway 1988; Suchman 1987; Wenger 1998; Winograd and Flores 1986).

Paralleling Haraway's "situated knowledges," Suchman's (1987) notion of "situated action," defined as "simple actions taken in the context of particular, concrete circumstances," was originally directed at plan-based models within early AI and HCI-based systems but has recently been broadened by Suchman herself and others to reflect on media art, design, and digital gaming (Suchman 2004a, 2007).

Although emerging from different epistemic histories, these running debates on "situated knowledges" (Haraway), "situated actions" (Suchman), and more recently "enactive cognition" (a research program which argues that the experienced world is determined by mutual interactions of the physiology of the organism, its sensorimotor circuit, and the environment) (Alač, Movellan, and Tanaka 2011; Noë 2004; Varela, Thompson, and Rosch 1991), all revolve around a central critique of the reduction of human experience to formalized sets of rules or computational models at the price of neglecting embodied, sensorimotor, and concrete perceptual action in the world.

Polanyi's (1967) claim that "we know more than we can tell" has recently been extended by Cambridge archaeologist Lambros Malafouris. Investigating a potter working with clay, he claims that artistic and creative practice is not only a form of tacit knowledge but "material engagement": "brain, body, wheel and clay relate and interact with each other through different stages of an activity" (Malafouris 2008, 19) in complex ways.

Malafouris's argument that artistic practice is always a constellation of material, cognitive, and biological forces and that "verbal description, however detailed, can hardly capture the phenomenological perturbations of real activity" (Malafouris 2008, 20) also reconfirms the long-standing claim that certain forms of artistic knowledge can only be sited in what Csordas (1993) calls "somatic modes of attention." Such somatic modes are "culturally elaborated ways of attending to and with one's body in surroundings that include the embodied presence of others" (ibid., 135) that are difficult to render into signs or texts. Attending to and with one's own body and the bodies of others exemplifies a core STS argument that knowing is always framed by the unknown acts and becomings of bodily existence.[1]

What "embodied knowledge," "material engagement," and "somatic modes of attention" ultimately suggest is that knowledge itself is forever entangled with bodily senses. While the visual sense has received much attention in STS when looking at the ways scientific images are interpreted and perceived (e.g., Coopmans et al. 2014; Dumit 2004; Fischer 2003; Jones and Galison 1998; Lynch and Woolgar 1990), more recent studies draw attention to bodily senses other than vision that are involved in scientific and artistic knowledge production, such as listening (Helmreich 2015; Mody 2005; Pinch and Bijsterveld 2004; Roosth 2009; Supper 2014, 2015), touching (Fischer 2003; Myers and Dumit 2011), and tasting (Burri, Schubert, and Strübing 2011; Paxson 2013; Roosth 2013b; van de Port and Mol 2015). Such body-centric studies framed through the more general concept of "affect," the process by which emotions and feelings affect bodies without being able to be described in language or representations (Angerer, Bösel, and Ott 2014; Gregg and Seigworth 2010), deserve much further exploration in STS. Concepts like "good hands" involving embodied skills used in biology (Fischer 2003) or "haptic creativity" in which scientists and artists' "data, instruments, and bodies and identities are continually reconfigured within their apparatuses" (Myers and Dumit 2011, 241) suggest new avenues for exploring how researchers' "thinking with eyes and hands" (Latour 1986) generate new forms of knowledge.

One area that STS already benefits from but could help enlarge its sensorial and affective scope in the future is the burgeoning cross-disciplinary field of sensory studies, which brings together a range of disciplines interested in "a cultural approach to

the study of the senses and a sensory approach to the study of culture" (Howes 2013). Debates about artistic research or research-creation that understand art practices as forms of tacit knowledge production are another field of reference for STS (e.g., Borgdorff 2012; Riley and Hunter 2009).

The use of bodily senses in interacting with the world is part of what makes up an aesthetic experience. The study of embodied knowledge in art and design and the manner in which practice is understood through its own "endogenous" theoretical and methodological claims may thus enrich STS insights into processes of knowledge production.

Performance and Performativity

The focus on embodied knowledge always is related to two key words that have gained much credence in STS over the past twenty-five years: *performance* and *performativity*. As Herzig (2004, 130) writes, "given the heightened recognition of contingency, temporality, and reflexivity made possible by performative analyses, it is perhaps not surprising that a number of recent studies of science reveal a quiet but steady turn toward this useful analytical tool."

The appeal of performance and performativity in a study of STS and art and design is that both terms do boundary work by embodying core concerns that link STS and artistic and design practices: the tension between representations and objects/processes in the world; the sociotechnical construction of things and phenomena; questions of material agency, contingency, and the power of actants beyond humans; and finally, the tension between observation and participation.

The word *performance* was originally used to describe actions, happenings, and time-based events (particularly involving the body of the artist) emerging out of the visual arts during the 1950s through the 1980s and referring to human activity involving a physically sited, co-present live and social event with the *human body* and *human agency* at the center of action (Goldberg 1976; Phelan 1993; Schneider 1997).

In art, the body has always been an important subject of inquiry and representation. Artists have used and experimented with their bodies forever—by dancing, playing theater, and doing artistic performances that have involved manipulating the body through prosthetics, surgery, and technical adornment (Fischer 2003), forming social plastics, or simply inquiring into their own corporeal existence in space and time. Performance studies' conceptions of corporealization, or "body techniques" (Mauss 1973), as a performative act (Butler 1988) thus align specifically with STS's focus on the body as a subject (Berg and Mol 1998; Cussins 1996; Mol 2002) and as a scientific instrument within research processes and material practices (Knorr Cetina 1999; Latour 1986, 2004; Shapin 1994), as well as on the role of gestures in the construction of expertise, which play an important role in the ways research is carried out and results are interpreted and experienced (Alač 2008; Burri 2008).

One area that could benefit from further STS studies, however, is a focus on the *moving* body as an important instrument in the manufacturing of science. While there has been substantial work from historians of science like Dagognet (1992) on Étienne-Jules Marey's chronophotography and Landecker (2006) on the use of microcinematography by tissue culture pioneer Alexis Carrel, both have focused more on the role of scientific instruments in creating an analytic of time and motion beyond what the eye can see than on how the performing body itself becomes an essential part of the research process. Here, concepts of exploring how researchers "lean into the data" (Hustak and Myers 2012; Myers and Dumit 2011) and perform their bodies (Herzig 2004; Myers 2015) when producing and displaying science as well as the body as scientific instrument in research processes (Fischer 2003) would also benefit from an understanding of performance in the artistic realm.

The term *performance* was quickly recontextualized in the first "performative turn" emerging from anthropology, sociology, and linguistics in the mid to late 1960s, particularly influenced by the work of Cambridge linguist J. L. Austin, who coined the term *performative* to describe speech as enacting rather than simply describing a situation (e.g., the words "I do" spoken at a wedding, for example, do a specific kind of work (Austin [1955] 1975). This performative turn, which eventually birthed the anthropologically centered discipline performance studies in the 1970s, sought to shift focus away from the stage to phenomena such as everyday social interactions, rituals, festivals, sports, games, and urban practices (Conquergood 1989; Garfinkel 1967; Goffman 1959; Turner and Schechner 1983).

Principally, anthropologist Victor Turner's notions of "culture as performance" or "cultural performance" both stem from a deeper anthropological project to critique a concept of culture that Dwight Conquergood (1989, 83) described as filled with "static structures and stable systems with variables that can be measured, manipulated and managed." Thus, by highlighting the tensions between both observing and acting, direct experience and the representation of an experience in textual form, performance thus came to be seen as an anthropological method troubling these dichotomies by examining the frenetic sites of conflict and human action and their potential for transformation.

In the 1980s and 1990s, however, a substantial shift took place with the introduction of the term *performativity*. Reflecting back on Austin's notion of the performative as a linguistic act rather than description, the increased use of the term is chiefly attributed

to philosopher Judith Butler, who sought to describe gender not as an ontologically "stable identity or locus of agency [...] but rather an identity tenuously constituted in time—an identity instituted through a stylised repetition of acts" (Butler 1988, 519).

One influential STS-derived response to Butler's linguistic and human body-centered focus is physicist and feminist STS scholar Karen Barad's notion of a "post-human performativity"—a concept that brings together a range of natural-cultural material, social, scientific, human, and nonhuman factors in order to question "the givenness of the differential categories of 'human' and 'nonhuman,' examining the practices through which these differential boundaries are stabilized and destabilized" (Barad 2003, 808). In broad strokes, scholars like Barad (ibid.) and Andrew Pickering (1995) have used the notion of performance and performativity to critique what Pickering has labeled the representational idiom of science—the idea that scientists are "disembodied intellects making knowledge in a field of facts and observations" (ibid. 1995, 6). Instead, performative forms of knowledge production focus on "doing" in scientific practice (Barad 2003; Biagioli 1999; Callon 2007; Latour 1986; Law and Singleton 2000; Mol and Law 2004; Shapin and Lawrence 1998).

A closer reading of the literature, however, demonstrates more nuanced and complementary ways in which the terms *performance* and *performativity* are utilized and interchanged in STS parlance (Salter 2010). First, performance describes the actions of human scientists in their experimental work within the confines of the laboratory, aligning with early microstudies of laboratories in the 1970s and 1980s from scholars like Latour and Woolgar, Knorr Cetina, Fujimura, Traweek, and others who focused on the shift to science as a cultural practice. Scientists "perform" experiments—that is, they directly *manipulate* and *transform* materials through instruments and apparatuses in real time. Hacking (1983) argued that experimental practice is not about merely shaping existing phenomena but instead radically constituting new phenomena by manipulating, altering, abusing, or subjecting it to "interventions," "interferences," and transient processes (Knorr Cetina 1992, 127).

Second, performance is used for the attribution of acts to nonhuman things, substances, and processes; the acts of material itself or what matter *does* rather than what it is. As Herzig (2004, 130) writes, matter thus "appears not as some passive, fixed physicality chastely awaiting discovery but as contingent, temporal and active. The genes, fruit flies, computers and atoms that populate scientific practice emerge only as nodes of interminable, multivalent, contested processes."

Pickering (1995) makes a distinction between representations and performances, assigning performance to acts and forces beyond human bodies. "Performances are what agents do, whether human or nonhuman. My conviction is that we need to move

to a performative (rather than representational) idiom for studying and reflecting on science (and on being in general)" (Pickering 2010, 195).

Yet, according to Barad, Pickering's post-humanist idea of performativity leaves aside the political import of performativity, particularly its "arguably inherently queer—genealogy" and performativity's connection to post-structural, feminist, and queer studies theory and activism (Barad 2003, 807). Instead, Barad's notion of "intra-action" suggests that entities do not preexist the world in which they operate but are relationally constituted through a continual process of material-discursive possibilities. In other words, knowers and things known (what Barad labels *phenomena*) mutually arise through their intra-actions based on concrete, ever-evolving material circumstances (for example, scientific instruments and apparatuses) and post-human performativity describes the manner in which such phenomena act and become embodied with social-cultural-technical meaning, forms of power, and significance (Barad 2003, 815).

Finally, performance signifies the manner in which scientists "stage" or "direct" (to use theatrical language) their findings and knowledge—or, the acts of matter, before a public. Scholars such as Latour (1987) and Schmidgen (2011), who have described the theatrical acts inherent in laboratory practices in the biological sciences such as the evolution of anatomical theaters or "spectatoriums" in the nineteenth century, have long used theatrical language to characterize the techniques by which scientists "stage" for the public (the audience) the results of things "rehearsed" in laboratory settings in order to create levels of belief. Stephen Hilgartner (2000), as another example, analyzed science advice as a performance of experts toward their audiences while engaged in impression management.

That performance is so freely utilized within STS is not without its critics. Herzig argues that even though performance and performativity have taken deep root in STS parlance, these notions still rely on an ultimate conception of performance as endlessly producing something—knowledge, bodies, or relations. As she provocatively asks, "must all intra-actions be generative?" (Herzig 2004, 138). Instead, Herzig cites Zoë Sofia's (1993) criticism of STS's "use value" and "practicality" perspective on science, asking whether there is room for an approach to performativity that is not based on the generative power of human-nonhuman agency but rather from unproductive acts like "squander," "excess," "desire," "unproductive expenditure" (Bataille 1991), and waste. Thus, by depicting the irrational, the aberrant, and the queer, performance and performativity could also be useful in questioning the political underpinnings of human and nonhuman doing and agency inherent to scientific (and artistic) practices.

Contingency and Material Agency

Another arena where questions of human and material doing and agency have made their mark is design. In fact, design practices have become an inspiring field of scrutiny for STS in recent years (Coletta et al. 2014; Ehn 2011; Irani, Dourish, and Mazmanian 2010; Latour 2008; Shove 2014; Storni 2012; Volonté 2014; Woodhouse and Patton 2004; for ethics in design see Le Dantec and DiSalvo 2013; Shilton 2012; Steen 2015). In a broad understanding of embodiments and enactments, and adopting an understanding of the performance of nonhuman things, STS studies on architecture, in particular, have demonstrated how material objects like buildings perform the "scripts" and (sociotechnical) worlds inscribed into their design (Farías and Bender 2010; Galison and Thompson 1999; Moore and Karvonen 2008; Yaneva 2005, 2009, 2012).

Using actor-network theory (ANT) methodologies such as following the actors and their networks combined with controversy studies (Pinch and Leuenbeger 2006; Venturini 2010), analysts aim at understanding the social-material context of architectural *practice*. In *Mapping Controversies in Architecture*, for example, Yaneva (2012) asks the question, "Who designed the Sydney Opera House?" Was it the Danish architect called Jørn Utzon, who eventually withdrew from the project but whose name still adorns the sail-like building? Was it the engineering firm Ove Arup, without whose expertise in structural engineering "Utzon's" building could never have been? Or, is design spread among the various constituencies (the Labor government at the time, the Australian public), instruments, materials, computational models, and systems of calculations?

What forms such questions is not how the fixed and finished architectural object can reveal the social forces that made it possible but, rather, the exploration of specific "shapes, fabrics and material arrangements" demonstrates how "the built environment either reflects or produces social life" (Yaneva 2012, 106). The concept that the materiality of a building (or any art or design object or environment) is contingent, created by different forces, events, and trajectories and "shaped more by external conditions than by the internal processes of the architect" (ibid., 105) suggests a different approach to previous theories of material agency like Pickering's (1995, 2010), in which agency is situated within artifacts.

Disruption and Critical Design

While design and architecture—just like art—can be understood as unstable material practices, they can also serve to disrupt established methods and ideologies. In what DiSalvo labels "adversarial design," both the design process itself as well as its objects give form to problematic situations, providing a method of inquiry to grapple with a diversity of actors and agendas "which often seem incongruent" (DiSalvo 2012, 290). Adversarial design is only one of a number of contemporary forms of design inquiry that go by names such as "critical design" (Ward and Wilkie 2009), "participatory design" (Ehn 2008), "contestational design" (Hirsch 2008) and "reflective design" (Sengers et al. 2005) and that are influenced by or serve as subjects for STS. The common element across all of these different forms of design inquiry is that they seek to challenge the normative frameworks of what design is and its assumed constituencies, as well as focus on how design practices operate *critically* in relationship to technology and society, producing new forms of (speculative) objects (Dunne and Raby 2013; Ehn 2008; Loukissas 2012) and publics (Callon, Lascoumes, and Barthe 2009; Latour and Weibel 2005; Marres 2007).

A case in point is Latour and Weibel's 2005 *Zentrum für Kunst und Medientechnologie* (ZKM) exhibition *Making Things Public*. The exhibition inquired into the political representation of things in democracies by precisely assembling a heterogeneous array of projects, ranging from texts, images, installations, and interactive interventions, staging encounters between science, art, and politics, and thus using design to produce and debate knowledge and things.[2] Design is critical not just in terms of its resultant objects but also in terms of the manner in which such objects and products operate in the formation of new democratic forms of participation that, similar to the objects of science, are equally contingent, pluralistic, and dynamic (Bjoergvinsson, Ehn, and Hillgren 2010; Le Dantec 2010).

Extending earlier STS notions of infrastructure (Bowker and Star 1999; Star and Ruhleder 1996) as sociotechnical structures that organize human doing and the technologies that enable such doing, the concept of *infrastructuring* (Le Dantec and DiSalvo 2013; Pipek and Wulf 2009) describes the process of bringing together the full range of design activities, from development, deployment, and enactment (so-called a priori activities such as interpreting and articulating) to appropriation, redesign, and maintenance (so-called design in use) (Karasti and Baker 2008). With infrastructuring as a framework, the notion of innovation thus arises from both emerging and established communities of practice and their actions rather than through strictly technocratic systems already in place.

Already Suchman's (2007, 2011) work at Xerox PARC in the 1990s began to think about infrastructuring in her arguments that "local improvisation," the appropriation of specific work practices within local sites, resulted in the reception of an existing technology and its integration into new sociotechnical contexts. Such local improvisational activities function as "the generative practices out of which new technologies are made" (Suchman 2004b, 170). Following Suchman's lead that design is always a contextually and geopolitically situated activity and that much design literature focuses on

work paradigms within the "hyperdeveloped world," recent work from Irani and Silberman (2013) on Amazon's Mechanical Turk (AMT) "human computation resource" system describes the author's tactical media CSCW intervention "Turkopticon," a software extension which acts as an "ethically motivated response to workers' invisibility on the AMT system" (Irani and Silberman 2013, 614). In this sense the Turkopticon project opens up the question of how design is always political and can both operate "in the world" as an activist intervention in critical crowdsourcing and simultaneously be tied to and dependent on a large-scale, functioning sociotechnical infrastructure.

Similarly, the paradigm of "critical making" describes the role of creative, critical activity within academic and design contexts (Maeda 2013; Ratto and Hertz 2014) as well as a material-theoretical research program (Ratto 2009, 2011). By using material practices to extend, and unpack concepts such as "materiality," "affordances," and "objects," critical making acts both as a series of methodological commitments and as a metaframe for generalizing across a range of diverse sociomaterial-technical contexts and sites (Ratto and Boler 2014; Whitson 2013).

Art and Design as STS Methods

In addition to being subjects of STS analysis, art and design may also be used as (experimental) methods in STS inquiry—thus contributing to unconventional ways to explore the social (Lury and Wakeford 2012). The inclusion of artistic and design practices contributes to deeper and more multifaceted insights into science and technology and their entanglements with complex sociomaterial worlds.

Genealogies of Technoscientific Art

Experimenting with science and innovative technologies has been a long-standing interest and persistent engagement of artists. They have explored early painting and graphic technologies through to digital plotting, image apparatuses, and sensors, while at the same time making these very technologies the subject of inquiry. As early as 1923, the inaugural exhibition of the Bauhaus in Weimar was entitled "Art and Technology: A New Unity." In the 1960s cybernetics, what Edward Shanken has called a "cultural mindset," began influencing a wide range of artists/thinkers, from John Cage and Nam June Paik to Roy Ascott, Gordon Pask, and James Tenney, all of whom became interested in the application of feedback-based systems to art (Kahn 2007; Shanken 2003).

STS scholars like Turkle (2005) and Suchman (2007) have long explored the performativity inherent in cybernetic and interactive systems from within the sites of research

laboratories and everyday use of technologies. While increasing numbers of (media) art historians and media theorists have examined the successes and failures of the complex of "art and technology" (Grau 2003; Kwastek 2013), STS has mainly ignored the historical genealogies of such work—an area that would be worthy of future study given art and technology's long-time entanglement with questions of infrastructure, invention, innovation, and experimental practice.

This complex has been made even more prescient given the range of cultural institutions internationally dedicated to explorations in art and technoscience, ranging from the ZKM in Karlsruhe, Germany, V2 in Rotterdam, the NTT-ICC in Tokyo, and the annual Ars Electronica Festival in Linz, Austria, to organizations outside the European/North American/Japanese axis such as the HONF (House of Natural Fibers) in Indonesia, the ArtScience Museum in Singapore, ArtCenterNabi in Korea, Arte Alameda in Mexico, or a range of centers in Brazil, Peru, Colombia, Senegal, Tunis, and Chile. Such institutions have been dedicated to providing both infrastructure and know-how to artists and designers to realize artistic works focused on new technologies while supporting critical discussion and debate with their broader publics on the sociocultural implications of such technologies. This has been particularly important in settings outside of North America and Europe where access to such knowledge and technologies has been limited. While these institutions strive to reflect on the role and aesthetic and ethical implications of artistic inquiry into our technoscientific worlds within their very specific cultural milieus, STS insights, particularly around the role of infrastructuring, intervention, and the role of material knowledge in the formation of new sociotechnical imaginaries discussed in our chapter, have not been a primary focus of their attention.

Art, Innovation, and Policy: The Studio Lab

One site in which art, science, and technology have been strongly linked is studies of research settings (government- and industry-sponsored research labs) within science policy studies examining interdisciplinarity (Gibbons et al. 1994). In a white paper for the Rockefeller Foundation, Century (1999) focused on the relationship between science policy studies and innovation applied to art science projects. In particular, Century's coining of the term *studio laboratory*, which described "a new class of hybrid innovative institution (...) where new media technologies are designed and developed in co-evolution with their creative application" (historical examples included Bell Labs, Xerox PARC, EVL, and the CAVS-MIT) was influential in U.S.-based private foundations like Rockefeller and Ford and in U.S., Canadian, and UK research policy circles

in articulating the relationship between new media artistic practices and the sociology and economics of innovation.

More recent work from Barry and Born (2013) building on their collaboration with Weszkalnys (Barry, Born, and Weszkalnys 2009) has further explored the relationship between art and science as part of a larger trend toward new forms of interdisciplinary knowledge production remaking humanities and social science research while sociology of knowledge studies also have examined artistic practice and the intersection of research policy, institutions, and innovation agendas (Nelson 2015). For example, Hennion (1989) and Born (1995) have applied methodological formulations from STS to the sociology of music and larger issues of cultural production. Fourmentraux (2007, 2010, 2011) has also extensively studied the organizational dynamics of innovation within the interface of art, science, and industry, focusing on large-scale, university-cultural-industry new media consortiums like Hexagram in Montreal.

Intervention, Engagement, and Civic Technoscience

One of the major arguments for the inclusion of art and design in STS is that both practices engage broader publics beyond the strictly peer-based ones found in science. In his study of Dunne and Raby's notion of speculative design, Michael (2012) argues for "designerly public engagement" over "public understanding" with artists, the former making use of ambiguity, inventive problem-making, and explorations of complexity. Indeed, there has been much STS literature dedicated to the argument that art can work in public engagement or art methods can function as "out-of-the-box" informal science education (de Ridder-Vignone 2012).

Yet, as Barry and Born (2013) point out in their ethnographic study of interdisciplinarity, there are different "logics" at play in the manner in which art and science configurations operate in their agendas, intentions, and goals. Indeed, part of artists' interventionary interest to STS is the boundary work such projects do, collapsing distinctions between art and science and art and society. In particular, some art science constellations involving engagement and the "public understanding of science" tend to function under a "logic of accountability," which reduces or mitigates artists' critical work in scientific contexts to instrumental, "decorative," "celebratory," or "superficial."

Instead, another logic, that of ontology, operates in many art science projects in which a more radical form of "interdisciplinary production" takes place in which both the object and subject of research is questioned, reworked, and reinvented through sustained, deep, and long-term mutual collaboration and where new forms of material and social objects are invented (Barry and Born 2013). Outside of institutional contexts, such practices as hacking involving DIY biology (Meyer 2014), hacking as an intervention into political economy (Söderberg and Delfanti 2015) and the larger field of "amateur" and "citizen science" (Rogers 2011) act artistically and technologically to change worlds. For example, Wylie et al. have provocatively called for a "civic technoscience," where "new material technologies in combination with new social and literary technologies can sustain a civic research space external to the academy and where nonacademics can credibly question the state of things" (Wylie et al. 2014, 118).

Emergent Biosensibilities

Artists' involvement with biotechnologies has received concentrated attention from STS scholars. Indeed, this larger, very heterogeneous category of artistic work with living systems called *bioart(s)* engages with the ethical, aesthetic, and social implications of (engineered) living matter, and is carried out in both science labs and art studios, taught in art schools, and increasingly institutionalized in special programs and academic centers.[3] In what Fischer (2009) called emergent "biological sensibilities," artists working with biotechnology propose new ways of living with (and caring for) emerging ecological forces of biology and biotechnology as well as "forging modes of representation and intervention that synthesize practices from science and engineering" (da Costa and Philip 2008, xix–xx).

One of the most important institutional catalysts for this work has been SymbioticA, the Centre for Excellence in Biological Arts located within the Biology, Physiology, and Human Anatomy Department of the University of Western Australia in Perth. Founded in 2000 by designer Oron Catts, cell biologist Miranda Grounds, and neurologist Stewart Bunt with the support of Western Australian state lottery funds, SymbioticA has attracted international artists, designers, scientists, anthropologists, sociologists, STS scholars, and others to research and experiment with living matter within a university research context.

SymbioticA and the bioarts in general have been the subject for a number of recent STS related studies (Dixon 2009, 2011; Rogers 2011; Roosth 2013a; Salter 2015). These works have focused particularly on the manner in which bioarts destabilize assumed ontological categories of living and nonliving, explore care and regeneration in relationship to the use of biomatter, and detail new art forms based on the use of genetic engineering techniques to transfer synthetic genes to an organism or to transfer natural genetic material from one species into another, to create unique living beings.

One of the central foci for STS in studies of the bioarts has been articulating the entanglements of institutional settings, technical work in the science lab, and the differing intentions and agendas of artists within such settings (Dixon 2009; Dixon, Straughan, and Hawkins 2011; Kac 1998). For example, in their early tissue culture

work under the moniker TCA (Tissue Culture and Art), Catts and partner Ionat Zurr (currently the academic director of SymbioticA) developed tissue-culture-based art works that not only brought laboratory procedures into cultural settings but also worked toward an "aesthetics of care"—attending to and being mindful of the use of living material in aesthetic practice (Catts and Zurr 2002).

Other fields in the life sciences are also addressed by artistic inquiry, including synthetic biology, nanotechnology's obsessions with scale (de Ridder-Vignone and Lynch 2012), and biomedical subjects such as reproductive medicine and the neurosciences (e.g., Scott and Stoeckli 2012). On the one hand, biomedical and brain imaging used in these fields are aesthetically very appealing for artists. On the other hand, artistic engagement with biomedicine and the life sciences has been fostered by a variety of artist-in-residence programs, for example, at the Wellcome Trust in the UK (http://wellcome.ac.uk).

Moving between Art, Design, and STS

The inclusion of art and design in STS raises methodological challenges: How can artistic and design methods be involved and used in STS to reflect on science and technology? In other words, how to do (social) science through art and design? When exploring this issue, STS itself becomes experimental; it not only observes people "thinking with eyes and hands" but uses eyes and hands to intervene and interfere in spaces and sites where science and technology are constructed, distributed, used, incorporated, and enacted. Such a performative approach to the exploration of science and technology can be understood as practices of "witnessing," which produce "knowledge without contemplation" (Dewsbury 2003). Rather than just passively observing and reflecting, knowledge emerges through an active engagement and interplay of senses, bodies, implicit knowledge, and material objects.

Researchers moving between STS and art have been undertaking first steps to linking artistic inquiry into science and technology to STS. By drawing on both artistic and scientific knowledge when doing research, they perform STS-informed art practice, and, more often, collaborate with artists and designers in their research projects on science and technology.

Pioneering scholars in this emerging field were mostly trained as both scientists and artists or have developed a special interest in STS while having a background in art.[4] The outcomes of their projects are mostly art works, which only in a few cases are complemented with written work. For example, Natalie Jeremijenko's environmental health clinic located at New York University (environmentalhealthclinic.net) approaches the topic of health from a contextual environmental perspective. Instead

of diagnosing individual illnesses and providing patients with pharmaceutical prescriptions, the clinic "treats" peoples' environmental concerns with knowledge and specific data on environmental aspects, and with prescriptions for local actions (Schaffer 2008). This art project relates scientific and STS knowledge to political intervention.

Some STS researchers strive for a transdisciplinary mode of inquiry into science and technology when looking for project specific collaborations with artists and designers. The outcomes of such projects have been written rather than art and design works (Halpern et al. 2013). Collaborations between scientists and artists have been practiced in a variety of projects in the past (e.g., Gabrys and Yusoff 2012; see also Hannah 2013). For example, a joint research project run by Stanford University and the University of Edinburgh called Synthetic Aesthetics sought to bring together artists, designers, synthetic biologists, and STS scholars to examine the aesthetic-sociotechnical issues surrounding the burgeoning field of synthetic biology (Ginsberg et al. 2014). Synthetic Aesthetics seeks the possibility of radical experimental collaboration, "opening up" synthetic biology by making possible emergent forms of critique that might not occur within traditional disciplinary boundaries (Frow and Calvert 2013).

It is a rare STS project that includes art in its outline. One example of such a collaboration is the ModLab, a project carried out at the University of California–Davis. STS served as a bridging language between humanities, performance studies, sciences, and social sciences to theorize the co-construction of art practices (drawing, painting, theater, and dance), game design, and interdisciplinary tool development in the sciences, in this case a 3-D virtual environment and modeling language. Collaboratively designing performances and art installations in turn are also generating concepts for STS scholars.[5]

Counterimages and Future Work

These examples have to be seen as only first steps in an endeavor to include art and design in STS thinking about science and technology more systematically. Building on John Law's (2004) quest to invent new methods in order to grasp the multiple social realities and shape the social worlds in intended ways, the inclusion of art and design practices in STS contributes to both explore *and* intervene in sociomaterial arrangements.

STS can benefit from such an approach in both analytical and normative terms. Analytically, the involvement of art and design in exploring both the production and stabilization of scientific facts, and the development and use of technological artifacts and sociomaterial networks, may generate another, enriched form of knowledge that includes aesthetics, such as visual, sonic, and haptic dimensions. The whole repertoire

of sensual and performative practices and resources may be used as methods in such inquiry and become part of the research process, thus contributing to a broader perspective on and understanding of the research subject. STS (and science in general) may profit from such enlarged methodological repertoires also in the communication of research results. In normative terms, artistic and design methods may facilitate STS interventions in sites where science and technology are constructed—experiments in codesign and participatory design are important in that respect—and become part of our everyday lives and practices.

We suggest seeing the growing conversations and hybridization between STS and art as a site where *counterimages* are being produced; creative responses to the rhetorical power of dominant cultural scientific images and visualizations also contribute to the social studies of scientific imaging and visualization (Burri and Dumit 2008). STS not only may profit from a critical appraisal of these works but also may be inspired to develop and extend its own methods by including art and design in its analysis. By doing science through art and design, STS may extend its capability of reflection, reach new publics, and, most important, get new insights into the cultural workings and implications of science and technology.

Notes

1. A case in point is the field of dance, which has increasingly turned to interactive new media technologies (navigable CD-ROMs/DVDs as well as online databases and interactive websites) that combine still and moving images and sounds to articulate different forms of knowledge systems that are difficult to describe in textual form. For example, the "Nagarika" interactive DVD by the Bangalore-based dance company Attakkalari, described as an "integrated information system on Indian physical traditions" is an extensive research project that attempts to communicate the complex movement vocabulary and taxonomies of gesture in the Southern Indian dance form of Bharatanatyam through interactive video demonstration of expert practitioners (nagarika.attakkalari.org). Similar approaches have been developed with the American choreographer William Forsythe, who has long utilized interactive new media to communicate complex movement knowledge or what he calls "movement research."

2. An earlier exhibition from Latour and Weibel, *Iconoclash* in 2002, may be seen as an iconic precursor to the approach of *Making Things Public*, in which heterogeneous projects of artists and theorists were displayed in order to question the issue of representation in science, art, and religion (Latour and Weibel 2002).

3. Bioart is taught and institutionalized, for example, at the Bio Art Lab at the School of Visual Arts, New York—SVA (bioart.sva.edu), SUNY Buffalo, and Rensselaer Polytechnic Institute, New York. The Arts & Genomics Center at University of Leiden (NL) also engages in this field (artsgenomics.org). Examples of projects in bioart are discussed in Reichle (2009).

4. Examples are Natalie Jeremijenko (nataliejeremijenko.com), Chris Csikszentmihályi (edgyproduct.org), Phoebe Sengers (www.cs.cornell.edu/people/sengers), Hanna Rose Shell (web.mit.edu/~hrshell/www), Tad Hirsch (publicpractice.org), Yanni Loukissas (yloukissas.com), and Simon Penny (simonpenny.net).

5. Projects so far include Dream Vortex, Play the Knave, Datamining Beckett, Glitch, and Frack: The Game. See http://modlab.ucdavis.edu and https://ucsota.wordpress.com/2011/11/30/joe-dumit-expressing-the-caves/.

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