International Handbook of Media Literacy Education

At the forefront in its field, this *Handbook* examines the theoretical, conceptual, pedagogical, and methodological development of media literacy education and research around the world. Building on traditional media literacy frameworks in critical analysis, evaluation, and assessment, it incorporates new literacies emerging around connective technologies, mobile platforms, and social networks. A global perspective rather than a Western-centric point of view is explicitly highlighted, with contributors from all continents, to show the empirical research being done at the intersection of media, education, and engagement in daily life. Structured around five themes—Educational Interventions; Safeguarding/Data and Online Privacy; Engagement in Civic Life; Media, Creativity, and Production; Digital Media Literacy—the volume as a whole emphasizes the competencies needed to engage in meaningful participation in digital culture.

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International Handbook of Media Literacy Education

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Foreword

There can never be not media (but what is media literacy education for?)

The first part of this awkwardly phrased title—there can never be not media—attempts to draw attention to one of the key principles of this handbook: that it's plain wrong to imagine that any form of social life hasn't always been constructed by some kind of media. And if there are media, then by definition there is media literacy (otherwise how would they work?) and thus there is always some form of negotiation around the production, circulation, and reception of meaning. Media literacy has never not been with us, even if the struggle to define what media literacy might be has never been resolved (perhaps because it is always contested) but what this handbook offers is a snapshot of the ways that media literacy is being radically transformed under the conditions of media convergence (Jenkins, 2006) and the extraordinary new lifeforms of digital culture.

Media literacy is not however the same thing as media literacy education—which is the point of this handbook. The questions raised in the following sections elaborate an ongoing debate between proponents of "media effects"—that the media can, in some ways, determine opinion, attitude, beliefs, and identity, and those who espouse sociocultural and audience theory perspectives arguing that meanings are produced by people. However, "literacy" is a complex concept that allows for both perspectives: it can suggest a spontaneous, osmotic, or organic flow of meanings at the same time as it suggests the mind in society has learnt various interpretive processes which can simultaneously construct and produce meanings (Street, 1985). Literacy itself is not thus a universally uncontested concept and can be as slippery as it can be helpful so that adding it as a suffix to the idea of "media" or "digital" may raise as many problems as it appears to resolve. The idea of media literacy education suggests that living in a mediatized (Krotz, 2007) society does not mean that we pick up how to make sense of the media in the way that, for example, we learn to walk, but that some forms of teaching (and learning) are part of the way that media are enculturated.

The perspectives described in this volume tend to see media literacy education as a structured organized intervention that builds progressively on the ways that media work in everyday life. They are concerned to bring critical, political, and sociological understandings to the work that media do but they are agnostic about the sites of education. Some traditions derive from formal institutions (schools and colleges, etc.), some from informal and/or peer-led social interactions, some of wider social practices (the media industries for example) and some from regulatory powers and structures within national contexts. This then means that this handbook oscillates between universal (at least global) mechanisms and processes and local (at least national) projects. The diversity of examples collected here point to the way that education, for all its global and world culture commonalities (Baker, 2014), fundamentally operates as a national project of the state and therefore different models of media literacy garner different stakeholder consent around the world.

This brings us to the second part of my title: examining the purpose of media literacy education. In some ways the answer to this question is so obvious that it is suffocating. Since, in so many places around the world, media frequently constitute so many interpersonal and institutional interactions, it is impossible to imagine life without media—especially digital media—and thus not to put media literacy as a key objective in any educational program seems perverse. Simply by listing the place of media in personal and social relationships, in accessing education (in its most traditional sense), participating in community and social life, participating in civic life, as a consumer, as a citizen, it is impossible not to use media technologies all day and every day. Yet for all this ubiquity (not to be confused with universality) media literacy is not usually given the same status as other academic disciplines in curricula around the world.

This seems puzzling. What kind of political project could really imagine populations who can't act as citizens, who can't learn the skills needed in the workforces of the future, who can't participate in civic life or who can't learn to become "good" people? Yet media literacy is rarely afforded a central place in any or many national curricula. Most scholars suggest this is because media literacy education is always in some sense part of a wider critical project and that it is not in the interests of power to produce populations who may question and challenge (Buckingham, 2003). Yet this argument even in its own terms is fraught with contradictions. Unless we imagine a global economy stage-managed by a manipulative elite, how else but with media literacy could the workers and the citizens of so many countries act and think?

This paradoxical state of affairs, where so many acknowledge the importance of digital media in everyday life and yet seem so unwilling to invest in contemporary forms of education, can only be helped by volumes such as this, which attempt to collect comparative cases from around the world and to address these questions with a sense of scholarship and historical tradition.

Whilst media literacy may have begun its life as a minority interest, the seemingly unstoppable rise of digital culture now puts its principles firmly centre stage so that the term digital literacy is now taken as a cipher for so many types of understanding and meaning making. (Of course this Anglo term carries its own conceptual bias and the notion of competence, common in North European countries for example, frames the challenge differently (Erstad, 2013).) Whilst there is an urgency around the need for education in this area and certainly a wider constituency of interests support digital literacy in ways that they would not have supported the earlier incarnations of media literacy, the history of research into the earlier terminology raises some pressing questions for contributors to this volume.

Older versions of media literacy focused more on consumption as if literacy were solely a question of "reading" whereas contemporary research explores the dynamics of participation and creative production as the "writing" side of the coin (Sefton-Green, 1996). Furthermore, digital media frequently suggest questions of practice and use which require that research explores social contexts: again the older "mass media" paradigm was more focused on meanings and effects rather than the everyday, the relational, the mundane and the spatial (Leander & Sheehy, 2004). And third, this volume is noteworthy because of the wide range of classroom and indeed non-formal educational sites suggesting a much closer investigation of the intricate transactions that comprise teaching and learning. Here the attention to media literacy education both supports and acknowledges the learning that takes place with friends, in families, and in communities, as well as acknowledging that the power of the media is always negotiable, always contestable and constantly in flux. Fourth, whilst we know that ownership and control of much media rests in the hands of a few, making sense of the media and learning about them is still a local project. Whilst a volume such as this aims for breadth and comprehensiveness this does not mean a reliance on a single interpretive tradition or any sense of media literacy education being a universalistic singularity: if anything the reverse.

Finally, I want to say that not only is it an historical mistake not to recognize that media have always existed and have always been central to modern society—an almost banal point—but today it is almost as if interacting with various forms of media in everyday life virtually in all parts of the globe, is absolutely an all-encompassing, all-embracing experience. Sometimes it is as if there is only media! Unless education systems around the world acknowledge the extraordinary place of media in constituting social, personal, and political life, and unless the curricula and pedagogy that we have developed to date are not scrutinized, developed, and promulgated, then I believe our education systems will quite simply fail their populations and any dreams for rational democratic society will simply fade away.

Julian Sefton-Green
London, August 2016

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Preface

Purpose

Research in the area of media literacy education has been growing globally and changing in the past two decades. Emerging scholars have begun to shape the work in the field. At the same time, various fields have contributed to an increasingly divergent body of work. This is reflected in the shifting changes in academia, education, and policy such as digital media revolution, to connection with civic activism, the increasing number of physical and psychological disorders related to media uses, the role of mass and social media in addressing global issues and problems, etc. The *International Handbook of Media Literacy Education* examines the theoretical, conceptual, pedagogical, and methodological development of media literacy education and research around the world. The text builds on traditional media literacy frameworks in critical analysis, evaluation and assessment, to incorporate new literacies that emerge around connective technologies, mobile platforms, and social networks. This volume explicitly extends across the world, to show the empirical research being done at the intersection of media, education, and engagement in daily life.

The five sections that this book incorporates—educational interventions, privacy, civic engagement, creativity and production, and digital media literacy—collectively place an emphasis on the literacy practices needed to engage in meaningful participation in digital culture. This volume includes formal and non-formal pedagogy, activism, art, technology, civic interventions, and expression, amongst a wide landscape of work in the media literacy discipline. This book has a global scope, as the editors sought to ensure coverage of all continents in all the sections, rather than a Western-centric point of view.

Audience

This book is intended for undergraduate, graduate, or doctoral students who are studying media literacy education, digital literacy, news literacy, information literacy, and new literacies in the Schools of Communication, Journalism, Education, Media Studies, and Library Science. The book is important for academics in these fields as it proposes to stratify media literacy education for digital information societies of the 21st century, including ideas on the home, the school, the community, the news, and the role of public institutions in civic life.

The biggest issue facing this growing field is that while there are materials which have been written, there is no resource that carries the multitude of perspectives detailed in the Table of Contents. Today, media literacy has permeated all facets of educational disciplines, and goes beyond just reading and writing. This book stratifies the field for cohesive scholarship around media literacy going forward.

The Editorial Team

Each of the editors has a wide experience in the area of media literacy education from both practitioner and researcher perspectives. All the co-editors have published work widely both nationally and internationally, thus making this work even more intricate as we were able to gather from different parts of the world. Moreover, through the various modes of technology we communicated regularly in order to bring this work together despite time zones and global destinations. In true fashion, this work is a collaborative effort and represents a true outreach of multiple perspectives.

Authors and Structure

The book is devised and organized into five parts: Educational Interventions; Safeguarding/Data and On-line Privacy; Engagement in Civic Life; Media, Creativity, and Production; and Digital Media Literacy. The chapters incorporated within each part will include a variety of perspectives from active emerging and established scholars of media literacy. The parts allocated encompass the origins of the field as well as the changes and directions which media literacy has taken since the turn of the 21st century.

Part I: Educational Interventions, guided by lead editor Alice Y.L. Lee from Hong Kong, provides historical context for the book. In the past four decades, media literacy education has rapidly developed in school systems and communities all over the world. This part has a retrospection of various educational approaches of media literacy in the international arena in order to review related theoretical frameworks and research methods developed over the years. Studies on media literacy education programs were conducted by researchers not only in the field of education, but also in other fields such as health communication and media studies. Hence, this part looks into media literacy education in different fields. Special attention is paid to how media literacy education is employed as an educational intervention strategy, as well as the future development of media literacy education research in the context of participatory media environment.

Part II: Safeguarding/Data and On-line Privacy is directed by lead editor Belinha S. De Abreu from the United States. This part takes a look at data and privacy as a larger conversation within the context of media literacy. The discussion includes cyberbullying, but extends beyond to questioning our own understanding of what we perceive as ownership. As such, the research in this area is growing along with the number of controversial issues which have been in the media, such as Edward Snowden, school data collection, and the probing eyes of various governments. This part looks at the developing research related to data and privacy, with a more recent focus on the "right to be forgotten" and the "right to know." Further developing this area will be a look at how big data changes the media relationships of the individual, citizenry, and society. Studies look at each of these groups and the implications for each constituent such as K-12, government and policy, and through the economics—the changes from selling data to funding it.

Part III: Engagement in Civic Life is spearheaded by lead editor Paul Mihailidis from the United States. This part explores the role of media literacy research and scholarship around civic engagement in daily life. It collates empirical studies that have approached questions of media literacy as it pertains to the role of media literacy in the development of community leadership, civic voice, activism, and engaged participation in daily life. Chapters include work on local, national, and global contexts, and include informal education, the role of public, government, and public bodies, non-profit organizations, games, community advocacy groups, and a host of other civic stakeholder positions to ask how media literacy can improve civic literacy practices in people today, and embrace more inclusive and active participation in daily civic life.

Part IV: Media, Creativity, and Production was assembled by lead editor Julian McDougall from the United Kingdom. This part presents outcomes of a diverse range of research. The strands of media literacy research collated here include: creative expressions of media literacy; how media production can be understood as an element of media literacy; how media literacy is differently understood as part of a more overtly economic discourse related to employability in creative industries and computer coding as a "new literacy." As academic and educational attempts to define and measure creativity have been the subject of such contested debate for so long, this part will begin with research that investigates these broader "faultlines" in media literacy contexts and then progress to more applied research into the areas outlined above. Across and between the strands, research presented captures empirical, contemporary evidence of media literacy in the form of public media arts, citizen media exchange, creativity and authenticity within production elements of formal media education, and creativity within an 'entrepreneurial' paradigm. Key to this section is a focus on how research design and method have been utilized to elicit evidence of such an elusive category as creativity.

Part V: Digital Media Literacy was convened by lead editor Jad Melki from Lebanon. The advances in internet and digital technologies and mobile telephony have forced a paradigmatic shift in the mission of (digital) media literacy and reframed many basic media literacy concepts at the pedagogical, methodological, and epistemic levels. How can we better understand this shift and reconcile the stupendous opportunities digital and social media have afforded with the myriad risks they have simultaneously produced, and how can media literacy effectively integrate new digital literacies with traditional critical media literacies? This part deals with these questions and with consequent emerging concepts, such as participatory culture, global connectedness, networked communities, and digital cosmopolitanism, as well as reframed concepts, such as access in an era of information overload and the various outcomes of contemporary digital realities and ubiquitous media, including media addiction and digital divides.

Lastly, this book captures the emerging methodological framework as well as the international viewpoints of a continuously growing field.

14

Are We Citizen Scientists, Citizen Sensors or Something Else Entirely?

Popular Sensing and Citizenship for the Internet of Things

Catherine D'Ignazio and Ethan Zuckerman

Introduction

In his book *The Good Citizen* (1998), Michael Schudson suggests that citizens who may appear to be disengaged from civic life may in fact be monitoring media and information streams, waiting for issues that they care about to surface. The "monitorial citizen" stands in contrast to the inherited ideal of the "informed citizen." Rather than informing oneself about *all* of the relevant civic issues of the day, the monitorial citizen is operating in a world of information abundance in which knowing the details about everything from climate change to trade agreements to city councilors is impractical. She "keeps an eye on the scene" (Schudson, 1998) and is poised for action should her needs or interests be directly at stake. Schudson and scholars that followed him (Graber, 2003; Zaller, 2003; Mihailidis, 2008; Keane, 2009) primarily discuss monitorial citizenship in relation to news and participatory media, and Zuckerman (2014) relates acts of monitoring to social and mobile media.

In this chapter, we speculate that popular sensors, deployed at the individual scale in mobile phones or the city scale in smart cities, hold promise for a new informational landscape for citizens to monitor their world and mobilize their communities when threatened. As such, sensors represent new terrain for monitorial citizenship to take place. Collecting sensor data (or plugging into others' data) is becoming increasingly mainstream. We identify and explore five paradigms for the use of sensors by everyday citizens: *smart cities*, *sensor journalism*, *crowdsourced journalism*, *citizen sensing* and *citizen science*. These paradigms all make aspirational claims (citizens will be scientists, cities will be "smart") for how citizens will participate, often by turning them into professionals of some kind. We describe two case studies of the use of sensors by everyday people that complicate and challenge some of these emancipatory claims. In the conclusion, we propose that the goal for popular sensing should not be the achievement of professional expertise by all citizens. Expertise is necessary, particularly when designing monitoring protocol or making scientific claims with high stakes. Citizen participation, we argue, should be valued and celebrated as an end in itself. The role of the monitorial citizen in relation to environmental sensors is to challenge the narrow professionalism of experts and direct their attention to the questions with the most urgency to the community.

The Rise of Sensors

In 1965, Gordon Moore published an article in *Electronic Magazine* entitled "Cramming more components onto integrated circuits" (Present, 2000). This was the first articulation of Moore's law, the idea that the number of transistors in an integrated circuit doubles every two years. Moore's law – more an observation than a physical law – is often invoked as an explanation for the remarkable normalization of digital technologies in everyday life. As integrated circuits have become denser, digital memory cheaper and processors more powerful, multifunctional computers became commonplace first in every developed world office and then in most homes. As phones became multifunctional computers with a continual connection to a data network, computers became truly personal, devices one interacts with continually and in the most intimate settings. The assumptions of ever-present connectivity, cheap computation and a willingness to bring the digital into all aspects of life have led to the rise of wearable digital devices, from smart watches to personal health monitors.

As computation and connectivity become cheap enough that connected devices need not be worn like jewelry or cradled in protective cases like our phones, we are now entering the era of "the internet of things." Once designers assume they can rely on pervasive in-home Wi-Fi, there is a temptation to deploy clouds of sensors throughout the home. Devices like the Nest thermostat offer continual monitoring of the home environment and the ability to control heating and cooling while a homeowner is at work or traveling, while technologies like NannyCams offer internet-enabled surveillance of one's home and domestic employees, offering a different type of control. The rapid advent of the internet of sensing things is enabled in part by the rise of inexpensive platforms like Arduino[1] for rapid prototyping, cloud computing services that make it easier to scale new data-rich applications, powerful platforms like Mapbox[2] and CartoDB[3] that enable novel data visualization, and the manufacturing efficiencies of Shenzen's rich ecosystem for building novel hardware.

These new, always on, always connected devices extend an existing paradigm of pervasive computing, the idea of embedding microprocessors in everyday objects. These objects begin to function as extended input devices for our personal computers. This revolution in input has already transformed social relationships as the presence of cameras on most new phones normalizes the sharing of images as a new form of social interaction. As environmental sensors become more pervasive, we may see similar changes in how we understand and inhabit the spaces we encounter every day.

The quantified self movement offers one model for how people might choose to engage with sensors. The ability to measure an aspect of one's body – your pulse, EKG waves, blood pressure, footsteps or physical motion – has proved appealing to a broad set of alpha users and early adopters. One in five Americans owns some sort of wearable personal sensor, and 1 in 10 wears one every day, usually a fitness tracker like a Fitbit (PricewaterhouseCoopers, 2014). Many users of these devices move quickly from collecting data on themselves to making optimizations and life changes in response to this novel data, parking the car farther from their office to increase their step count or adding a meditation practice to reduce blood pressure levels. Some obsessive quantifiers keep detailed logs, tracking dozens of different factors as they hope to address problems of a chronic illness or optimize productivity, fitness or happiness (Dow Schüll, forthcoming in 2017). As environmental sensing of one's home, workplace and community at large becomes more routine, we might expect the rise of a similar paradigm of quantification: people who want more data about the world around them to make decisions about their health and happiness.

Popular Sensing

In the midst of this quantification boom, we note the rise of the popular citizen sensor. But what is a sensor? At the most basic level, 64% of Americans (Smith, 2015) and half of the world's population (*Economist*, 2015) now carry around highly sophisticated sensing devices in their pockets. So-called "smart" phones pack Wi-Fi, microphones, cameras, GPS chips, accelerometers, gyroscopes, proximity sensors and ambient light sensors. Newer versions might include heart rate monitors, temperature sensors and fingerprint scanners. Popular sensing platforms like Waze[4] leverage the ubiquity of smartphones to inform their real-time traffic and navigation application. The city of Boston developed a mobile application called StreetBump[5] to automatically log potholes when the accelerometer detected a large enough "bump."

Other platforms such as AirCasting[6] provide custom sensors that interface with people's smartphones. Users configure their device with their phone and it additionally provides network connectivity to upload the data. The AirCasting Air Monitor measures air temperature, humidity, carbon monoxide (CO) and nitrogen dioxide (NO_2). Another popular air monitor and community data platform, the Air Quality Egg,[7] measures CO and NO_2. Devices like the Speck,[8] developed at Carnegie Mellon, are designed for indoor use and measure particulate matter in the air. Some libraries around the country are experimenting with checking out such devices to their patrons (Page-Jacobs, 2015).

Popular sensors are not solely focused on air quality but include weather, water, soil and personal biometric sensors designed to inform us about the environment. CREATELab, the Carnegie Mellon lab behind the Speck, is also responsible for the CATTfish, a device designed to sit in the tank of your toilet and monitor changes in the temperature and conductivity of the water, ostensibly for the purposes of detecting fracking chemicals in the home. The Riffle, a low-cost water quality sensor currently in development by the Public Laboratory for Open Technology and Science, monitors the same parameters. The public radio station WNYC published a homegrown sensor for measuring soil temperature[9] as part of a story on cicadas. FarmHack, a DIY farming community, has sensor-based tools for monitoring everything from air temperature to moisture level in compost.[10] MindRider,[11] a project originally developed at the MIT Media Lab, is a bike helmet that monitors your brainwaves as you cycle through the city that governments and private sector firms are starting to use in conjunction with citizens in order to map which intersections are the most stressful. Designer Christian Nold works with communities to create emotion maps of their local environments using biometric sensors.[12] Searching for the term "sensors" on crowdfunding platform Kickstarter yields 261 projects[13] that monitor home pollution, give real-time feedback on home energy use and even correct your golf swing.

Popular Sensor Paradigms

There is a proliferation of products, prototypes, platforms and communities oriented around the collection of data by non-specialist people for civic purposes. What are the frames by which we can make sense of these sociotechnical practices? We have identified five emerging paradigms for the use of sensors by citizens: *smart cities*, *sensor journalism*, *crowdsourced journalism*, *citizen science* and *citizen sensing*. These categories have fuzzy and unclear boundaries, and are useful less as exclusive categories than as "frames" that have been chosen to understand these emergent practices.

Smart Cities

A television commercial for IBM offers a vision of a sensor-rich city. In the control room of a mayor's office, a woman scans a dozen monitors, watching different aspects of small town life. The mayor explains that with IBM's new technologies, the town is a smart town, and local government can monitor and optimize different aspects of the local environment. The mayor's guest sees her car on one of the monitors and discovers she's been ticketed, an example of the town's sensor-enabled efficiency.

Table 14.1 Popular sensing paradigms

	Who funds and owns?	*Who does the work?*	*Role of the Citizen*	*Aspirations*	*Limitations*
Smart Cities	Government and/or Corporation	Government with citizen help	Data collector; observer/ watchdog if data is published	Self-modulation; efficiency; lower costs; convenience	Over-emphasis on efficiency instead of participation; equity and bias; citizen as free labor?
Sensor Journalism	News org	Journalists, possibly in collaboration with scientists, experts and/or citizens	Data collector; source; audience	Lower cost sensors democratize data collection; enable data-driven accountability stories	Journalists not trained in science, tech, data analysis; producing credible knowledge
Crowdsourced Journalism	News org or self-organizing community	Journalists or citizens with participatory input	Data collector; contributor; community organizer	Shift from gatekeeper to listener; deeper connection with audience; collect information at scale	Contributor error; data collection protocol; audience as free labor?
Citizen Sensing	Various – from research grants to no funding	Citizens, possibly in collaboration with researchers, journalists, government	Frames questions; organizes data collection based on needs	Citizens can pose and answer their own questions; local knowledge production contributes to larger dataset	Citizens not trained in science, tech, data analysis; DIY instruments variable quality; producing credible knowledge; collecting data often not enough to create change
Citizen Science	Scientific researchers	Scientists with citizens	Data collector; contributor	Collect research information at scale; educate citizens about STEM	Perpetuates expertise gaps; citizens don't frame research questions; citizen as free labor?

Depending on who you ask, the smart city paradigm is an Orwellian nightmare (Greenfield, 2013), an opportunity for revitalized civics through increased government effectiveness (Goldsmith & Crawford, 2014) or simply dead on arrival (Offenhuber, 2016). In this paradigm, local government deploys and owns sensors throughout a community, collects the data into a centralized dashboard and optimizes local decisions based on a richer understanding enabled by data.

In some cases such as Chicago's Array of Things project[14] or Christchurch, New Zealand's SensingCity,[15] the government shares this data with citizens, making it available through APIs or as downloadable data sets. In other cases, the citizen is an (unpaid) data collector for the city, making observations with a tool like Citizens' Connect[16] and other municipal reporting apps that generate information for city departments to use. In still others, she might be able to serve as a watchdog of the urban environment, armed with these new data sets. AQICN (Air Quality Index China) is an example of a watchdog organization that uses official data sets – air quality information released by 60 nations' official environmental monitors, accessed via RSS feeds and other APIs – to compare the air pollution in Chinese cities with other cities around the world.[17]

The aspirations for smart cities center on efficiency, seeing many problems of governance as problems of insufficient information. With better data, citizens could know where to park without circling for spaces, or know that it's a delay-free day to choose public transit. Other efficiencies may be more troubling – as Kate Crawford and Jason Schultz (Crawford & Schultz, 2013) have observed predictive policing, which focuses police attention on "hot spots" and can lead to disproportionate arrests of people of color, is also a strategy for making city services more efficient through pervasive urban sensing. The smart city approach to sensors offers the promise of a city that serves its citizens better, but also the fear that sensors can be used to surveil citizens and may magnify existing structural inequalities, pervasive racism or other social ills. And while the data in smart cities is often available for motivated citizens to analyze and build upon, the sensor networks are built primarily by the city, for the city, with citizen engagement with data an anticipated but not always realized benefit (Bui, 2015).

Sensor Journalism

In the months before the 2008 Olympics, officials in the city of Beijing took drastic steps to decrease the city's legendary air pollution, taking heavy trucks off the roads, shuttering cement, chemical and steel plants, and ordering half the city's cars off the road on alternate days. The Spatial Information Design Lab, working with AP reporters whose credentials allowed them access to Olympic venues throughout the city, mapped Beijing air quality using handheld aerosol monitoring devices. By combining this data with GPS information, they produced reporting that demonstrated that Beijing had certainly reduced air pollution in the city, but that pollution could vary sharply from one street to the next, and that localized efforts to combat air pollution were often complicated by pollution from surrounding cities and regions (Tse & Quealy, 2008; Williams, 2008).

Reporters engage in sensor journalism by analyzing data from existing sensors, by deploying their own sensors, or relying on readers to deploy sensors. They interpret and visualize the resulting data sets to tell stories rooted in data (Pitt, 2014). Novel data sets from sensors used for other purposes can yield surprising and powerful stories. For example, analyzing data from Florida's SunPass automated toll system, reporters at the Broward County *Sun Sentinel* were able to identify 800 police officers who routinely drove South Florida highways at speeds of 90 to 130 miles per hour (*Sun Sentinel*, 2012). This later garnered the newspaper a Pulitzer Prize for public service journalism.

In another example, *USA Today* reporters Alison Young and Peter Eisler spent almost two months traveling and collecting data to report a story called "Ghost factories: Poison in the ground." The story explored the impacts of more than 200 smelting factories that existed prior to the formation of the Environmental Protection Agency in 1970 and left a legacy of contaminated soil in residential neighborhoods. The reporters rented XRF analyzers from Thermo Fisher which are handheld sampling devices that opened up the possibility of collecting many more soil samples (800+) at a lower cost than sending all samples for lab testing (Pitt, 2014). They verified the handheld's data by sending fewer (190) soil samples to a lab for more expensive testing. In this case, Young and Eisler used research literature and consulted with a public health scientist in order to develop a rigorous and verifiable testing protocol. "Ghost factories" led to many varied and uneven responses from environmental regulation agencies, parents and factory owners and won several prestigious awards.

While sensor journalism relies on inputs from governments, research scientists, ordinary citizens, or from the news organization's own sensors, the value comes from the journalistic analysis of and storytelling with data. Sensor journalism invites participation in the sense that it is cheaper and more accessible than ever before to measure various aspects of the environment. And in the age of networked technology and web publishing platforms, more people than ever before can analyze data sets, seek insights and publish conclusions. The promise would seem to be that journalists can continue to hold power to account, collect evidence with sensors and undertake more complex accountability journalism projects that were not possible before.

However, sensor journalism projects, particularly those in the environmental sensing realm, pose challenges around producing credible knowledge. Cheap, DIY hardware is often unvalidated and unreliable (Williams et al., 2014). Most journalists are not trained in electronics, data analysis, visualization or research study design. While aspiring to do scientifically rigorous work that can present credible evidence around pollution or contamination is a worthy aspiration, it would require a revolution in training within newsrooms. Projects like Young and Eisler's have bridged this expertise gap through collaborative study design with scientists, however even "Ghost factories" ran into issues of credibility, with several agencies claiming that because they did not use a representative sample from a large area their methods were unsound and thus not evidentiary (Pitt, 2014). Moreover, as we explore further in the second case study, the methods and incentives of journalism and science may often be incompatible. The tolerance of slow, ambiguous, uncertain and nuanced results that scientists learn to live with is a challenge for journalists, who need to tell compelling stories on a deadline to engage their audiences.

Crowdsourced Journalism

In the wake of a stolen presidential election in late 2007, Kenya erupted into violence in the early days of 2008. Fearful of inflaming ethnic tensions by reporting on the violence, *The Daily Nation* and other major Kenyan newspapers decided to stop coverage of most incidents of property violence and looting. Fearing that the newspapers were ignoring important stories, Kenyan blogger Ory Okolloh worked with local software developers to build a new tool, Ushahidi (Swahili for "witness"), which allowed individuals to file reports of violence via mobile phone or web and place those reports on a web-based map. The Ushahidi team realized that this crowdsourced reporting method and the software they'd produced to enable it could be useful for projects around the world (Zuckerman, 2007).

Crowdsourcing also comes into play when journalists want to invite "a group of people to participate in a reporting task—such as newsgathering, data collection, or analysis—through a targeted, open call for input; personal experiences; documents; or other contributions" (Onuoha et al., 2015). Journalists now rely on readers to collect large data sets when data is not otherwise available or when the data consists of collecting and reporting on many personal experiences such as the legacy of Agent Orange for war veterans (Paris, 2015). In another example, ProPublica wanted to track whether stimulus spending on infrastructure was reaching local communities. Reporter Amanda Michel organized hundreds of volunteers to call local transportation departments and find whether road and bridge projects had been funded (Michel, 2009). A reporting task that would have been beyond the ability of almost any newsroom was easily achieved using crowdsourcing and coordination.

Crowdsourced journalism practices are evolving to include not simply the use of the audience to collect data but also the involvement of citizens and communities in the audience "at every stage of the journalistic process—from story assigning, to pre-data collection, to data mining, to sharing specialized expertise, to collecting personal experiences and continuing post-story conversations" (Onuoha et al., 2015). In order to understand how and when to invite people into these processes, news organizations are hiring "Engagement Editors" (Powers, 2015). These people are often tasked with monitoring and cultivating quantitative measures such as likes and shares across social media as well as designing crowdsourcing initiatives for audiences to connect in deeper and more qualitative ways to the process and outcomes of reporting.

Crowdsourcing techniques with environmental sensors start to blur the lines between sensor journalism and crowdsourced journalism. In 2013, the data news team at public radio station WNYC mobilized their audience to assist in answering a scientific question: When will the cicadas come?[18] Brood II cicadas hatch every 17 years and make a distinctive high-pitched buzzing noise to attract mates. But what day will they arrive? Scientists believe cicadas hatch when the soil temperature 8 inches below the surface reaches 64°F. So WNYC invited listeners to purchase $80 kits and assemble cicada trackers which would monitor soil temperatures and post results to a website, allowing predictions on when the cicadas would appear (O'Donovan, 2013; Pitt, 2014).

While crowdsourcing is clearly a powerful method to engage readers and generate data sets, it requires participants to have comparable resources to obtain data. While most participants in the ProPublica example were equally able to call their local Department of Transportation, and most of those documenting property destruction in Kenya had access to cameraphones, developing a crowdsourced data set on air pollution would require participants to have comparable air sensors, properly calibrated and deployed in similar ways. The Cicada Tracker project managed to skirt some of these questions around sensor comparability and data quality based on DIY hardware because the project is framed as reader engagement rather than scientific proof. The stakes would be different and the burden of proof higher if readers were asked to measure water contamination in Flint.

The aspiration of crowdsourced journalism is to tackle reporting challenges that are otherwise untenable, to engage more communities, more deeply, and to democratize the process of creating media through involving a large set of readers in the reporting process. However, it is easier for professional journalists, or others who have an established media presence, to mobilize people to participate in crowdsourced reporting efforts. And crowdsourcing raises inevitable questions about the quality and accuracy of information collected. Reddit's "Find Boston Bombers" community was a crowdsourcing project with good intentions but tragic outcomes, inaccurately linking troubled student Sunil Tripathi to the Boston Marathon bombings, causing his family immense pain (Wade, 2014). ProPublica and others have acknowledged the challenges of verifying and fact-checking the large amounts of qualitative data that they receive for crowdsourcing projects ("CPNN Community Call #2 – The Way We Work(flow)," 2016). If crowdsourced journalism with sensors emerges as an important paradigm, questions of accuracy will arise around collection and interpretation of data, as organizers strive to understand how participants collected their data and participants examine whether the analysis of their data was fair and accurate.

Citizen Science

Since 1900, the Audubon Society has been mobilizing members of the US public to go outside at Christmas and count birds.[19] Observers gather in groups with at least one experienced birder and follow a specific counting protocol to conduct their bird census. The data collected has been used by scientists to demonstrate that common American birds are in decline and by the Environmental Protection Agency (EPA) as one of 26 indicators of climate change.

The Christmas Bird Count is one of the earliest examples of citizen science in which members of the public partner with scientists to provide data for research projects. With the advent of networked technologies, citizen science projects have multiplied and platforms like Zooniverse,[20] Galaxy Zoo[21] and CitizenScience.org exist to match scientists' research questions to citizens willing to volunteer time and expertise. Amateurs perform work online – such as classifying galaxies or identifying whales in photos of the ocean – and offline such as observing birds in their backyard for Cornell's eBird[22] project, which seeks to create a comprehensive, crowdsourced database of avian biodiversity in the Western Hemisphere. The most well-organized citizen science projects include educational and peer-based community experiences that build scientific learning in formal and informal ways (Bonney et al., 2009). These might include online and in-person communities, educational materials, games and more.

Data collection turns out to be the easiest, though not the only, form of collaboration between citizens and scientists. While the term citizen science tends to be used to denote amateurs collecting data for research questions framed by scientists, Jennifer Shirk et al. (2012) have outlined a typology of public participation in scientific research (PPSR) that names this contributory model as just one of five possible ways that citizens and scientists can work together on questions of shared concern.[23] What falls under the umbrella of citizen science currently includes a variety of practices ranging from donating some of your computer's processing cycles to look for extraterrestrial life (SETI@home[24]) to observing birds (eBird) to co-directing the agenda of a water quality monitoring initiative (Sherman's Creek Conservation Association project described in Bonney et al., 2009).

Like crowdsourced journalism, the promise of citizen science lies in the scale of participation that would be unthinkable for any research scientist on their own. A platform called iNaturalist has logged more than a million observations of local floral and fauna and regularly schedules "bioblitzes" to draw out members of the public to collect data with a mobile app (Decker, 2015). And some citizen science projects move beyond a simple volunteerism model where they start to think about mobilizing specific communities with shared interests. For example, a recent research study in the UK outfitted recreational surfers with GPS devices and temperature sensors in order to systematically collect sea-surface temperature data, an important coastal health indicator (Brewin et al., 2015). They estimate that a wide-scale deployment could build on the shared interest in conservation of surfers and scientists and collect more than 40 million measurements per year.

Much of the work involved with citizen science – analyzing imagery, entering data, counting birds, whales or cells – is very much the day-to-day working life of a scientist, or at least, a graduate student. At best, participating in the scientific process without needing to quit your day job increases interest in and understanding of science, helps scientific work be completed faster, and may help participants formulate and carry out their own scientific experiments. At worst, citizen science is a way of turning volunteer effort into unpaid labor with the promise that participation is a path toward scientific discovery. Without training participants in the work of building and testing hypotheses and analyzing data, it is unrealistic to expect participation in data collection to turn citizen participants into scientists. It is likely that people able to participate in these experiments are those with disposable income and time.

Citizen Sensing

As fracking – drilling for oil by injecting underground rock formations with water and chemicals to release trapped pockets of oil – becomes increasingly common in rural America, many homeowners are worried that their water wells could be polluted with toxic chemicals. CATTfish, developed by the CREATE Lab at Carnegie Mellon and mentioned above, makes it possible for homeowners to monitor their water quality. The CATTfish sensor, shaped like a white catfish, floats in the tank of a homeowner's toilet and provides information on water temperature, conductivity and dissolved solids whenever the toilet is flushed and the tank refilled. A change in sensor readings can reveal infiltration of a water well by fracking chemicals, and a homeowner can seek more extensive testing to see if her water supply has become contaminated.

Citizen sensing aspires to put the powerful sensors used by scientists and industry into the hands of ordinary citizens and communities, who often have strong personal motivations to answer questions about their environment with data. Many projects, such as the Air Quality Egg,[25] aggregate individuals' contributions into a collective data set, which might be owned by the sensor manufacturers or made available via open licenses. In some cases, the data sets are used by scientists or journalists for reporting and analysis.

But not all citizen sensing projects are about aggregating and scaling data sets – some are about aggregating and scaling community. For example, the Public Laboratory for Open Technology and Science[26] is a non-profit group of hardware hackers, environmental advocates, scientists and educators. It consists of chapters that are geographically located (Northeast US, Gulf Coast, Jerusalem, Spain, etc.[27]) and linked through networked technologies. PLOTS offers low-cost DIY environmental monitoring tools and tutorials that allow people to capture low-flying aerial imagery, air and water quality monitoring, and specific contaminant testing for things such as formaldehyde and oil. The knowledge produced within the community is open source and a citizen or community member learning to use the tools (or build their own) in a specific context can tap the wider network of expertise.

Citizen sensing has a great deal of appeal for individuals who believe they may be affected by environmental hazards: compromise of the water supply (CATTfish, Riffle), airborne radioactive particles (Safecast radiation sensor), air pollution (Speck, Air Quality Egg), as sensors help communities answer personally relevant questions, as well as contributing their experiences to broader data sets and, perhaps, broader social good. Furthermore, citizen sensing offers the idea that everyone can engage in science, or at least in the data collection that leads to scientific discovery. Whereas citizen science invites participation in inquiry designed by scientists, citizen sensing imagines that the research questions are framed by communities themselves based on locally-driven concerns.

In practice, many of the individuals who engage in citizen sensing and citizen science are highly educated, wealthier individuals with the time and financial capital to participate in "serious leisure" activities (Haklay, 2013). Using these devices to collect data, to analyze and interpret it, is often fairly challenging and demands some level of training and expertise. Knowing whether users can rely on the data they collect is even more challenging. Many citizen sensors are attempts to make expensive lab equipment more affordable and more widely available. These cheaper sensors are often inaccurate (Williams et al., 2014), not validated with standard industry protocols, and can be hard to calibrate. This makes any evidentiary claims using citizen sensors open to scrutiny and rejection. Finally, collecting data alone is rarely enough to accomplish social change. Identifying a change in your water conductivity with a CATTfish is a first step in a long process that might involve higher precision tests, reports to the EPA and eventually a legal confrontation with drilling companies. Citizen sensing may offer a first step in a long road toward social impact.

Are We Citizen Scientists, Citizen Sensors or Something Else?

As the rough taxonomy above suggests, the world of science, journalism and communities using environmental data and sensors is a messy one. Ideas like citizen sensing and sensor journalism are just starting to emerge as new terms and paradigms, and are used to mean different things in different contexts.

Despite the uncertainty and ambiguity of the term, "citizen science" is a very attractive frame to attach to sensor projects. The current US emphasis on STEM education makes it appealing to parents to engage their children in scientific research. But while projects like eBird may be engaging to a broad audience who enjoy observing birds in their locales, the actual science – determining migratory patterns, tracking impact of climate change on species – requires access to the whole data set as well as to a set of analytic techniques beyond the knowledge of most participants. Will such participation challenge the "cult of the expert"? Or will it reinforce the notion that while data collection is open to the general public, analysis is still in the realm of professional scientists? Or will eBird – along with hundreds of other citizen science projects – help draw a new generation into scientific careers?

We consider two case studies that examine sensing projects and ask whether they are best understood as citizen science, sensor journalism, some other category within our rough taxonomy or as something else entirely.

Case Study #1: Safecast

On March 11, 2011, a 9.0 Richter scale earthquake and a resulting tsunami caused massive destruction to Japan, including the crippling of the Fukushima Daiichi nuclear power plant. Joi Ito, Pieter Franken and Sean Bonner – open source software advocates and hackers with strong ties to Japan – began working to acquire Geiger counters so they could help friends and family answer their concerns about radiation levels in their neighborhoods.

Commercial providers of Geiger counters quickly exhausted their supplies, and the team switched their plan from buying and distributing counters to building them and helping anyone who wanted one to build one as well. Partnering with Singapore-based hardware designer Bunnie Huang and legendary software architect Ray Ozzie, as well as a Hawaii-based Geiger counter manufacturer and a Portland, Oregon web development shop focused on mapping radiation, they began envisioning a device that was capable of a high degree of precision, but inexpensive enough to deploy widely. The members of the globally distributed team met face to face in Tokyo. As they discussed the work with local experts, they realized that most sampling near Fukushima would need to happen from within sealed cars, and that the Geiger counter would need to be sealed within a rigid, weather-resistant shell. Taking a cue from Japanese cuisine, they built the meter in a bento box and called it the bGeigie ("Safecast History," 2011).

In April 2011, a Kickstarter campaign raised $36,900 to back Safecast's radiation mapping efforts, and gave radiation meters to the 10 largest donors as a thank you gift.[28] By June 2012, the team had launched a Kickstarter focused on selling the iGeigie, a more basic unit than the bGeigie, and raised $104,000 from 290 backers.[29] The uptake of the iGeigie suggested an audience for an inexpensive radiation meter, and Safecast now offers a kit version of an updated bGeigie design for $450.[30]

But while Safecast has built a popular product, it has been clear throughout the project that its priority is data collection, collecting 30 million readings over the past five years. Most of these readings come from a set of 600 bGeigie units used by volunteers to trace radiation in Japan (Bonner, 2015). One volunteer, Joe Moross, has driven more than 50,000km for the project, collecting data every five seconds and uploading it to the Safecast set (Winter, 2013). While much of the data focuses on Japan, reports have come in from every continent, and large stretches of the Czech Republic, Germany and France have been mapped in detail.[31]

All data associated with Safecast is openly available for download, a policy that is consistent with the founders' motivations for beginning the project. Joi Ito, one of the project's founders, has explained to reporters that Safecast is a response to the "data-scarcity problem" and the Japanese government's unwillingness to release detailed data from Fukushima (Brown, 2011). Subsequently, the Safecast team discovered that the government often didn't have data at a fine enough granularity for homeowners to make decisions about the safety of their families:

> We know from our efforts that radiation levels can fluctuate in very short distances, so that simply crossing a street can sometimes yield dramatically different readings. Readings that have been published by official sources in most countries generally do not provide detailed geographic coverage, and sometimes reported data for an entire city is based on just a single reading. We feel this is at best too vague to be useful and at worse intentionally misleading.
>
> *(Safecast, 2012)*

Safecast is a project that has successfully used citizen science and crowdsourced data collection to create a rich data set that's both scientifically and journalistically important. But it is also a project that illustrates the complexity of those terms.

Safecast is often portrayed as a success story for citizen science instruments sold via Kickstarter. But while data for Safecast is crowdsourced, most of the reporting comes from volunteers in Japan who have been given bGeigie meters, rather than from purchasers of the meters. It's unclear just how many people will be willing to pay $450 and hours of their time to assemble a Geiger counter simply to receive reassurance that their houses are free of radiation. Furthermore, Safecast's model relies on people with meters either using them regularly to collect data from different places, or loaning them out to increase the geographic coverage of their map.

Using the Safecast meters reveals another possible problem with crowdsourced scientific data collection: boredom and burnout. Everyone hopes to discover a pocket of radiation with their meter, but fortunately there's not too much stray radiation around. One of our authors – Ethan Zuckerman – took a Safecast meter to a shuttered nuclear plant in rural western Massachusetts, hoping to detect radiation. Once he was within 300 meters of the dry storage casks, he discovered first that readings were no higher than anywhere else in the area and second that the casks are protected by men with large guns who discourage unannounced citizen science experiments (Zuckerman, 2013). Once a Safecast volunteer tests her local area, will she have the incentive to collect hundreds of thousands of readings like super-volunteer Joe Moross, or will she become disinterested in collecting yet more readings of background radiation?

If a volunteer does find high levels of radiation using the Safecast meters, Safecast provides few tools to harness the data they generate to organize next steps such as community mobilization or organizing an advocacy campaign. This is by design. From early in the project, the founders have insisted that "Safecast is not anti-nuclear, nor pro-nuclear – we are pro-data. Data is apolitical" (Safecast, 2012). While we can disagree with this statement (since data, organized and collected by humans, can never escape being political) this is an important part of Safecast's strategy. The organization has worked hard to establish itself as a trustworthy source of data about radiation levels in Japan and around the world. If Safecast were too tightly associated with an advocacy effort, project co-founder Sean Bonner explained at a workshop hosted by the authors, it would lose credibility with the Japanese government and with users. By making data openly available, users can advocate using the data they collect, but they are the advocates, not Safecast.

Data alone is insufficient for drawing scientific conclusions or policy recommendations from Safecast readings. A 9,000-word blogpost from Safecast volunteer "azby" makes clear just how difficult it can be to understand the implications of radiation readings in answering questions about human health. Azby and collaborators wanted to evaluate whether the Japanese government's decontamination procedures were working and making it possible for villagers evacuated from the towns closest to Fukushima to return to their homes. The post explains in great detail what data the government did and did not release and what is known and unknown about how the data was collected, then details Safecast volunteers' efforts to collect radiation data in towns that are currently uninhabited. In careful, cautious detail, the authors confirm that radiation levels are well below levels found before cleanup was conducted, but also find that levels are well below those measured after cleanup. This indicates that natural radioactive decay is responsible for much of the dissipation of radiation, and estimate that the government's cleanup efforts had the effect of a few years of natural decay, but were insufficient to make villages inhabitable at the government's target "safe" level of radiation exposure (azby, 2013).

Azby's post makes clear just how difficult it is to conduct robust citizen science. Answering a question that's easy to articulate – are the government's radiation cleanup efforts working? – is fantastically difficult to answer, requiring interpretation of the government's data, estimation of snow cover's effects on the government data, collection of original data, alignment of the new data sets with government data, interpretation of the collected data and building a model that considers the role of natural radioactive decay in evaluating the success of the government efforts. Azby's conclusions are similar to ones the government has come to: In many areas, decontamination efforts are likely to be ineffective, and a better strategy may be to wait for natural decay to let villages become inhabitable again in a few decades.

Safecast has succeeded in producing a laboratory quality instrument that is actively used by volunteers to collect crowdsourced scientific data. The project clearly demonstrates the value of crowdsourced data collection as a method for generating novel data sets, though it offers cautions about whether volunteers will remain motivated to continue collecting data beyond initial interest. While Safecast data offers a potential goldmine of crowdsourced results for journalists, the complexity of understanding the Safecast data suggests that journalists will need a great deal of scientific training to properly contextualize the results. While azby's work indicates that it is possible for dedicated volunteers to conduct citizen science with the Safecast tools, it also demonstrates how demanding this work is, and suggests that this may be a challenging paradigm for non-specialists to engage with.

Monitorial citizenship provides a useful frame to understand the Safecast efforts. The Fukushima disaster was certainly an issue of personal concern for those worried about exposure to radiation. The Safecast project, acting as a check on the government's official figures, suggests a second sense of monitorial citizenship. Rather than monitoring media information streams, citizens may monitor using their own sensors and data collection efforts in order to determine whether the government is doing its job and whether its data are believable, complete and correct.

Case Study #2: Teaching Water Sensing With the Coquí

For the past two years, D'Ignazio has been running an experimental sensor journalism module in her Data Visualization classes at Emerson College, a small arts and communications-focused school in Boston, USA. The goal of the module is to introduce the students to the concept of telling stories with sensor data, build their own sensor, use it to collect data, and then reflect on the experience. The students are undergraduate journalism majors and have little to no experience with data analysis, sensors or science.

The module involves four class sessions and features several guest lecturers. The first class consists of a lecture about the emerging field of sensor journalism from a graduate student who is conducting research in the area. The class discusses various case studies. In the second class, a hydrologist from a local community advocacy organization presents the environmental context for his work: The Mystic River – a post-industrial urban river that has numerous environmental justice issues and is desperately in need of funding and political will to clean it up and make it safe for aquatic life, boating and swimming. He discusses the efforts of volunteer citizen monitors to collect water samples and additionally does a demo of the high-quality and expensive instruments that he uses to collect turbidity, conductivity and other measurements at various locations in the river. In the second half of the class, students work in groups with the help of a third guest from the Public Laboratory for Technology and Science to build their own DIY water quality instrument. The coquí is a simple educational circuit that measures the conductivity[32] of water and outputs the measurement as sound. When conductivity is higher, the pitch that the coquí emits is higher and vice versa.

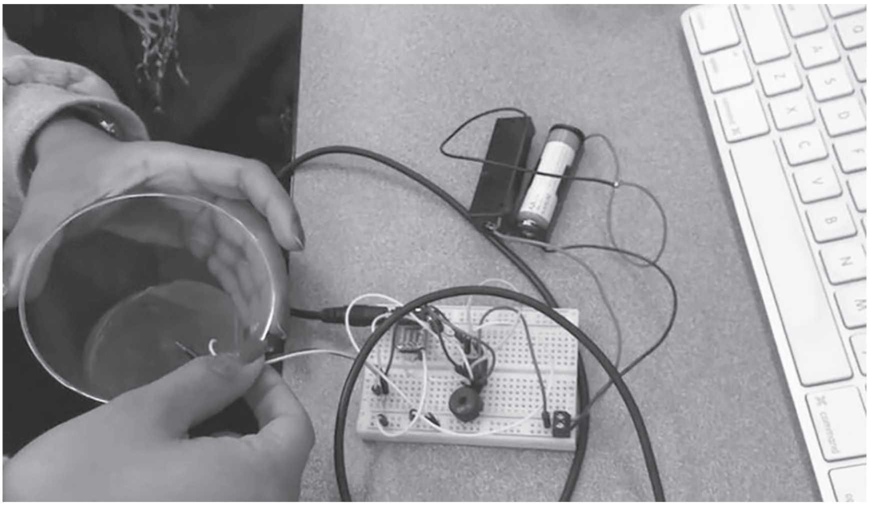

Figure 14.1 One student uses the coquí conductivity sensor she built to test a water sample.

For the third class, students bring in water samples from the field and they write a preliminary blog post with some background research and photos about the sites where they collected the samples. They try to get one sample that looks "clean" (new snow, clear river water, tap water) and one that looks "dirty" (brackish or polluted water, roadside puddles). During the class, they use their coquís to assess the relative conductivity of their samples by listening to differences in pitch. They film these sounds and place the short videos on a collective map of Boston.[33] We spend the last half hour of class discussing how to interpret data. Students share some of their hypotheses for why their samples have high or low conductivity. We discuss the relationship between conductivity and water quality and drinkability. We discuss the limitations of what we can know from only conductivity, from only sampling a river at one time and at one location. We start to brainstorm about the implications and

Table 14.2 Students' reflections on sensor journalism, 2015

Pros	*Cons*	*Questions*
Autonomy for journalist to conduct their own investigations	Limited by technology and reporter's knowledge	Who's going to make policy around this?
Innovative tool and you can collect your own data	High stakes for incorrect results	At what point would the average journalist be considered credible/legit to undertake this kind of investigation?
Empowers journalists	Possibly very high cost (tech investment, personal time investment, lab costs for verifying data)	Is it ethical for a journalist to collect their own data?
Watchdog	News orgs might not see the relevance/value	Who is the ombudsman of sensor data?
Greater accessibility of data to journalists and communities	Lack of manpower and resources to do this well	Journalists are producing credible public knowledge. What are the consequences of being wrong?
Changes our idea of what journalism is	Speed – news deadlines don't work at the pace of science and lab tests	
	Accuracy – pressure to get to conclusions quickly	
	Verification – how do you verify and fact-check sensor data? Crowdsourced sensor data?	

complications of sensor data for journalists. The students' homework is to write a short essay about the potential benefits and the real challenges of sensor journalism. In the fourth and final class, we discuss their essays and create a collaborative list of pros, cons and questions.

As Table 14.2 shows, after three classes of action and discussion the students come up with astute and salient reflection points that demonstrate their understanding of journalism's role and responsibility in the production of knowledge for the public.

Most of the students situate the potential benefits of sensor journalism as an extension of investigative reporting. Collecting data from sensors represents a possible new avenue for monitoring powerful institutions and holding them to account, the classic formulation of investigative journalism as "custodians of public conscience" (Ettema & Glasser, 1998). Several were enthusiastic about the idea that they themselves could conduct an investigation and collect their own data about the environment.

While the possible promise of storytelling with sensors was exciting, the overall attitude of the students was skeptical. We grouped the concerns expressed in their essays (see Table 14.2) into four main categories: *expertise*, *speed*, *incentives* and *risks*. In four classes, we had attempted to give non-technical students a crash course in water science, sensors and electronics, DIY hardware and local environmental issues. One of the main takeaways of the students, currently studying writing and digital storytelling, was uncertainty that they would ever know enough about any one of those areas to be able to design and carry out an investigation. Said one student, "Even during our class experiment, it was obvious that many of us barely understood how to build the Coquí sensor or how it worked, and we even had experts helping us" (Tremblay, 2015).

Even though the falling costs for data storage and hardware assembly have made it more affordable, journalists alone do not have the *expertise* in instrumentation, experiment design and data analysis to operate as informal scientists and carry out environmental investigations. The *speed* of news and the speed of science are different. A news story that takes several months to prepare is "long" and, based on the allocation of scarce resources, needs to deliver on the effort and funds invested in the form of audience interest and readership. And even when a journalist can obtain it, rigorous, scientific information does not always make for a good story. Sometimes there is simply no "news" in environmental data and the careful, watchful monitoring of, for example, water quality levels does not lend itself to human drama.[34] The *incentive* toward story and audience might lead journalists to jump to meaning long before the scientist would arrive at a conclusion.

Students articulated significant concerns around the *risks* of publishing incorrect information. We saw this play of *incentive* toward story and *risk* in the class where students came to the intuitive conclusion that water with higher conductivity was necessarily polluted. D'Ignazio and the guest lecturers pointed out that ocean water, due to its salt, has very high conductivity. Healthy stream water that has a lot of organic matter will have higher conductivity. Drinking water with minerals like the Evian brand will have higher conductivity. Likewise, compounds like oil, alcohol and sugar have low conductivity, so polluted water might contain those but still have low conductivity. In the same body of water, conductivity will vary across both space (where you sample in a body of water) and time (when you sample, whether it is after a storm, during a drought). In short, making conclusive meaning about water pollution from a single measurement is downright impossible. Complicating this even further is the fact that most of the DIY hardware sensors available have varying levels of accuracy and have not been independently tested or verified. For example, the EPA published a guide to low-cost air quality sensors and could find no correlation between the readings from its equipment and the aforementioned Speck air quality monitor (EPA report, 2014). For this reason, data gathered from DIY hardware is unlikely to be evidentiary, though it may serve to gather public attention and garner the political will for more testing. But at what cost? If a journalist makes a claim that a river is polluted and it turns out they were simply wrong, it significantly tarnishes their personal reputation and that of their publisher. As a student summarized it, "The major flaw in sensor journalism at the moment is its verifiability."

Where does this leave us for sensor journalism and citizen science? On the one hand, requiring that journalists be able to design and run scientific experiments is placing an unrealistic knowledge burden on a field that is in an unprecedented period of shrinkage and job loss (Doctor, 2015). In addition to coding and interactive storytelling, we cannot simply add "scientist" and "DIY hardware hacker" to the growing list of skills that the so-called "newsroom unicorns"[35] need to have. On the other hand, there is an increasing amount of data available via sensors deployed by governments, corporations, universities, media and citizens. To completely write-off these new information streams because of these challenges and risks means neglecting a potential treasure trove of news sources, like the sensor data that made the *Sun Sentinel*'s Pulitzer-winning story possible.

Perhaps the answer to this conundrum lies not in training journalists and citizens to be more like scientists and not in inventing better and cheaper technologies but in engineering new social relationships between scientists, technologists, journalists and citizens.

Maybe We Are Citizen Citizens

The paradigms we outline in this chapter suggest that data collection, analysis and reporting is often managed by professionals, be they city administrators, scientists or journalists. Citizens' roles range from that of "beneficiary" (in the smart cities model) to "data collector" (in citizen sensing and citizen science), though rarely "co-investigator." As a result, it can be difficult mobilize widespread participation in these projects, as citizens often do not see the benefit of purchasing sensors, or in continuing to collect data beyond an initial investigation.

One solution to this dilemma may be to offer a paradigm that considers citizens not as untrained scientists, amateur urban planners or inexperienced journalists, but as citizens. In *The Good Citizen*, Michael Schudson suggests that we stop demanding that citizens follow every political issue that might affect them and accept that engaged citizens are active around issues of particular interest that they believe they can affect. Schudson calls these "monitorial citizens" because they continually monitor the civic landscape to see if they need to take action (Schudson, 1998).

We might think of the families in Japan who bought or borrowed Safecast sensors, or the homeowners in Pennsylvania who bought CATTfish as monitorial citizens. Alerted to the possibility of harm from water pollution or radiation, they began actively monitoring their local environment. Their motivations are less scientific than personal, but they are likely to discover that a sensor rarely provides an answer that's as simple as "safe" or "unsafe." Coming up with a more sophisticated answer will almost surely involve learning some of the science behind the sensors. Their monitoring has at least three effects. Monitoring builds community solidarity and helps citizens determine whether to take action as citizens to demand a corporate or government cleanup or other actions to mitigate environmental harm. Furthermore, monitoring acts as a check on government and corporate power, reminding authorities that citizens are watching, measuring and sensing, and may take action based on what they discover.

While some monitorial citizenship projects are novel, like Copwatch, which trains citizens to monitor and film encounters with police to counter abuses of power, monitorial citizenship in the environmental realm is well established practice. For example, each of the three major rivers in the Boston metropolitan area has a science-driven advocacy organization that runs a Citizen Water Monitoring Network (CWMN) for that particular watershed. The organization trains volunteers in water sampling techniques and citizens go out monthly, take samples in different locations, and drop them off at the watershed association to be sent out to the lab. These programs are more than 20 years old and, in some cases, have helped to keep swimmers and boaters safe for more than 50 years (Matias, 2015).

Experts still play a key role in projects of this sort – the models that the Charles River Watershed Association uses to measure water quality depend on the skills and knowledge of scientists on staff at the non-profit as well as the labs where water samples are analyzed. But the participation of citizens who collect water samples is recognized and celebrated. The effort generates powerful bonds of solidarity and community through participatory practice. Being a steward of the watershed becomes an important part of these citizens' identities, according to Patrick Herron, Deputy Director of the Mystic River Watershed Association. While informal learning is a major part of the shared experience, the goal is not to turn all participants into scientists, but to ensure that our concept of citizenship expands to include monitoring the health of local environmental systems.

While one of the byproducts of participation in a CWMN might be informal scientific learning for citizens, another byproduct might be that scientists hear and learn about citizens' concerns about their local watersheds. Rather than seeing expertise as a one-way street, from amateur to professional, perhaps we can consider how to design sociotechnical structures – such as CWMNs – that can be models for pooling expertise, labor, learning and advocacy to achieve better social outcomes. The citizen's role in these models may be not be to *achieve* expertise but to *challenge* the narrow professionalism of experts in order to focus on the most urgent questions of public health, equity and social justice.

Notes

1 http://arduino.cc.
2 www.mapbox.com/.
3 https://cartodb.com/.
4 www.waze.com/.
5 www.streetbump.org/.
6 http://aircasting.org/.
7 http://airqualityegg.com/.
8 www.cmucreatelab.org/projects/Speck.
9 http://project.wnyc.org/cicadas/.
10 http://farmhack.org/tools.
11 http://mindriderhelmet.com/.
12 http://biomapping.net/.
13 On February 7, 2016.
14 https://arrayofthings.github.io/.
15 http://sensingcity.org/.
16 www.cityofboston.gov/doit/apps/311.asp.
17 http://aqicn.org/publishingdata/.
18 http://project.wnyc.org/cicadas/.
19 www.audubon.org/content/american-birds-annual-summary-christmas-bird-count.
20 www.zooniverse.org/.
21 www.galaxyzoo.org/.
22 http://ebird.org/content/ebird/about/.
23 Their typology includes contractual, contributory, collaborative, co-created and collegial projects.
24 http://setiathome.ssl.berkeley.edu/.
25 http://airqualityegg.com/.
26 Note: D'Ignazio is an organizer for PLOTS.
27 www.publiclab.org/places.
28 www.kickstarter.com/projects/1038658656/rdtnorg-radiation-detection-hardware-network-in-ja.
29 www.kickstarter.com/projects/seanbonner/safecast-x-kickstarter-geiger-counter.
30 http://shop.kithub.cc/products/safecast-bgeigie-nano.
31 http://safecast.org/tilemap/?y=37.9&x=31.4&z=3.
32 Conductivity is a measure of water's ability to transfer electric current. On its own, water has very low conductivity. In water monitoring, a conductivity measurement can provide a basic idea of how much "not water" is in the water. Water with higher conductivity means there is more "stuff" in the water but it does not tell you whether the stuff is good, bad or neutral.

33 http://bit.ly/bostonconductivitymap.
34 This just in: "River has the same conductivity as yesterday and the day before."
35 Unicorns are journalists who can do interviewing, writing, reporting, software coding, data wrangling and design.

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