The Potential for Citizen Science in Information Systems Research

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The Potential for Citizen Science in Information Systems Research

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Abstract:
In this paper, we explicate citizen science in information systems research. Citizen science in IS research is a partnership between IS researchers and people in their everyday lives. Citizen science projects in the IS field are defined by phenomenon that interest both citizens and scientists and by the intervention of citizens in scientific processes for the purposes of scientific literacy and a more informed citizenry. We make the case for citizen science as part of a movement in IS research towards societally impactful research at the confluence of human behavior, technology, society, and environmental sustainability. We discuss the origins of citizen involvement in science and contemporary notions of citizen science from sociological, natural science, and public policy perspectives to build a working definition for the IS field. We provide examples of how one can leverage citizen science in IS research and discuss larger ideas for the possibility of citizen science.

Keywords: Citizen Science, Information Systems Research, Environmental Sustainability.

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1 Introduction

Is information systems (IS) research encountering a shift in what the field considers a contribution to knowledge? Is IS research extending beyond its sociotechnical roots in business organizations and towards researching extra-organizational phenomena at the confluence of human behavior, technology, society, and sustainability (Winter et al., 2014; Irwin, 1995)? If this is indeed the case, then what can IS research do to further engage the public to make relevant societal contributions? While answers to these questions are not immediately accessible, they touch on considerations for IS research outside the context of the organization (Winter, Berente, Howison, & Butler, 2014; Tilson, Lyytinen, & Sørensen, 2010; Hirschheim & Klein, 2012), and present opportunities for IS research in a global community (Gurstein, 1999; Watson, Boudreau, & Chen, 2010). In this regard, we explicate citizen science for IS research. In particular, we describe a type of IS research that focuses on engaging citizens in scientific processes, enhancing scientific literacy, and creating a more informed citizenry about science and technology in citizens' everyday lives.

As increasingly powerful technology continues to find itself in the hands of citizens regardless of whether they reside in a developing or advanced nation, increasingly large knowledge gaps continue to persist about science, the science that surrounds technology, and technology's effects in society (Hanson & Narula, 2013; Stromquist & Monkman, 2014). For IS research, investigating these issues goes far beyond the traditional debates around technology adoption, managerial implications, or the latest debates on social media, mobile, analytics, and cloud computing in the business domain. Instead, it makes the clarion call for IS research to consider influencing public knowledge in the knowledge it produces. We, of course, would not be the first to propose similar objectives. C. West Churchman in his keynote address at AMCIS 2004 chastised the IS research community for not doing more to help societal and global problems (cf. Porra, 2001). Similarly, Enid Mumford argued for the community to shift its focus from business-driven research to exploring societal issues such as drug addiction, crime, and poverty (Mumford, 1999; Porra & Hirschheim, 2007). Even earlier, Russell Ackoff documented how academics could contribute to changing the lives of people in poverty in a meaningful way (Ackoff, 1974). Thus, in the context of citizen science, key questions emerge at a societal level that the IS research community can begin to ask. For example, do citizens view IS research, and the technology it studies, as intellectual grandeur? Do they view it with an heir of inevitability or disenchantment? Or do they see science and technology as tools to unify power and exact control (Irwin, 1995)? Moreover, is it possible that a more informed citizenry may be able to influence these trends? It is the ideas of influencing citizen knowledge and allowing citizens to influence science that is central to this research essay. In this regard, we discuss citizen science as a scientific process that seeks to move the monoliths of “science” and “public” closer together (Irwin, 1995) as we seek to fuse the ideas of scientific analysis and citizen intervention for the purposes of IS research.

In citizen science, citizens can actively contribute to science either through intellectual effort, surrounding knowledge, or their own tools and resources (Socientize Project, 2013). Participants can provide experimental data for researchers, raise new questions, and even co-create new scientific research streams (Bonney et al., 2009a; Wiggins & Crowston, 2015). In citizen science, citizens intervene in scientific processes to add their opinion and knowledge to scientific research endeavors and, in the process, enhance their own scientific literacy, acquire a deeper understanding of scientific work, potentially acquire new interests in science, and perhaps even transfer this knowledge to public discussion. In the words of the European Commission on Citizen Science (Socientize Project, 2013, p. 06):

\[\text{As a result of this open, networked, and trans-disciplinary scenario, science-society-policy interactions are improved, leading to a more democratic research based on evidence-informed decision making as scientific research is conducted, in whole or in part, by amateur or non-professional scientists.}\]

Citizen science has had profound effects in shaping bodies of knowledge in fields such as ornithology (Sullivan et al., 2009) and astronomy (Lintott et al., 2008) and can potentially reveal new insights in fields such as IS as we seek new understanding about how information technology (IT), laden in nearly every aspect of our social worlds, influences human behavior, communities, society, and environmental sustainability (Cooper, Dickinson, Phillips, & Bonney, 2007; Newman et al., 2012). We contend that citizen science, used in the context of IS research, can be a way to engage citizens on IS research topics and enrich the perspectives of both the citizen and the scientist. We contend that by engaging citizens, we can broadly distribute research across a continuum ranging from the values of the scientist to the values of the...
citizen. In doing so, we can engage with citizens to play a critical part in constructing IS knowledge, disseminating that knowledge both online and in their community, and potentially revealing societal implications from IS research. With citizen science, citizens in their everyday lives, and IS researchers in their academic lives, create an opportunity to engage in a discussion around science in new ways and shape contributions that impact both academia and society.

This paper proceeds as follows: in Section 2, we discuss the history of citizen involvement in scientific progress. In Section 3, we discuss contemporary citizen science to develop a working definition for citizen science in IS research. In Section 4, we offer three examples of how citizen science is beginning to impact IS research. In Section 5, we discuss the grand challenges of citizen science research in IS. In Section 6, we contextualize our discussion by discussing citizen science’s limitations and, in Section 7, conclude the essay.

2 Science, Citizens, and Professionalism in Academia

Science contains an extremely deep and complex history. However, among this history is its inseparability, engagement, disengagement, and now re-engagement with people’s lives. At times, major scientific discoveries have been the product of those closely affiliated with the church, in other times by citizens in non-scientific roles undertaking scientific endeavors, and in yet other times by those directly affiliated with academic institutions (Miller-Rushing, Primach, & Bonney, 2012; Silvertown, 2009; Chargaff, 1978; Crombie, 1967). In this section, we focus on understanding a portion of scientific history, particularly as it relates to the intersection between citizens and scientific activity, because this intersection can be one of our best tools in explaining citizen science as a contemporary phenomenon (Porra et al., 2014; Hirschheim & Klein, 2012).

Until the late 19th century, science was principally performed by gentlemen scientists—those who pursued scientific discovery independent of financial remuneration and largely without university or governmental affiliation (Segen, 1992). For example, Rene Descartes wrote his first essay on the scientific method before becoming affiliated with an academic institution. He was a person with extraordinary questions who made a living off bond investments, later became affiliated with Italian Cardinal Guidi di Bagno, and even later became affiliated with Leiden and Utrecht Universities in the Netherlands (Clarke, 2006; Gaukroger, 1995). In another example, Francis Bacon was most notably a politician, not an academic. He was a member of British Parliament and later an attorney general, and he developed much of his work on empiricism over the course of his tenure as a politician (Gaukroger, 2001). In the Americas, Benjamin Franklin, possibly the most prominent example of a citizen scientist (Silvertown, 2009), was interested in the phenomena of ocean currents while serving as a deputy postmaster. Specifically, he was interested in why it took merchant ships that left from London less time than mail ships that left from Cornwall when the merchant ships had a much longer and complex journey through the English Channel. From this enquiry, he discovered the Gulf Stream, and planted seeds for the field of oceanography. Franklin’s curiosity also led him to solve many of the key questions of the times and advance our understanding on topics such as electricity, cooling, optometry, and even human decision making (Franklin, 1916). Similar to Franklin, Charles Darwin’s interest in evolutionary biology was born from his medical education. He became so engrossed in questions about the natural world that he neglected his education and chose to study marine invertebrates independently, which eventually led him to Captain Robert Fitzroy, a five-year journey aboard the HMS Beagle, and seminal theories on the evolution of species. Much of Darwin’s work was without financial remuneration; only much later in Darwin’s life did he receive grant money from the English Treasury and become affiliated with a university (Browne, 1995).

Both Franklin and Darwin are also exemplars for our contemporary conception of citizen science. They were not simply intellectually engaged citizens who made discoveries on their own but scientifically curious citizens that engaged others in their quest for discovery. Both Franklin and Darwin actively involved outsiders in helping to collect data and also in building networks of collaborators all over the world. It was Franklin who engaged notable citizens of his time to construct the American Revolution, advance science, and fuel the industrial age (Franklin, 1916). In turn, it was Darwin who used a network of citizen collaborators to collect data about the pollen distributed by insects and attract notable public officials of his time to eventually fund his research (Browne, 2010). Franklin and Darwin were citizens first and scientists second. They engaged people in their everyday lives to advance science, and they attracted interest in scientific discovery from citizens to help lead them down paths of major discovery.
By the mid-20th century, however, one can argue that science had become professionalized (Beer & Lewis, 1963)—dominated by universities and government-run research laboratories with little outsider involvement (Chargaff, 1978; Feyerabend, 1993; Feyerabend, 1978). By this time, science largely became the work of those called scientists and largely excluded citizens. Even the Audubon Christmas Bird Count, potentially the oldest known citizen science project, was started by an ornithologist, Frank Chapman, who was affiliated with the American Museum of Natural History, and, while citizens helped collect the data for the project, only those with scientific expertise controlled it (National Audubon Society, 2016). By the mid-20th century, even the statistical methods used in scientific analysis had begun to evolve to the point of implicitly limiting outside involvement. Psychologists and statisticians such as Pearson, Fisher, Cronbach, and others were changing many of the statistical tools scientists use today in order to make larger generalizations from smaller samples (Haggbloom et al., 2002; Kupermintz, 2003; Porter, 2010; Rao, 1992). With these new tools, scientists could more clearly demonstrate analytical rigor and, in doing so, make it more convenient to never venture beyond samples.

The institutionalization of science in the mid-20th century is one of the main reasons for the emergence of contemporary citizen science. By the 1970s, philosophers such as Paul Feyerabend had begun to call for a “democratization of science” (Feyerabend, 1980; Feyerabend, 1993), and leaders in the scientific community had begun to call for a return to science by “nature-loving amateurs” in the tradition of Descartes, Newton, and Darwin (Chargaff, 1978). We contend, along with others in multiple fields, that citizen engagement in science is experiencing a resurgence and that citizen science is but one component in search of fulfilling this larger need (Miller-Rushing et al., 2012; Bonney et al., 2014). Furthermore, we contend that the ubiquity of our always-on, connected digital lives helps enable individuals to participate in citizen science and that IS research can come to know this activity in multiple respects.

It is because of our connected world that scientists can more easily engage with the public in scientific discourse, collect data, understand conversations about scientific matters, and store, process, and publicly share data at lower cost. With contemporary citizen science, an engaged citizenry involved in scientific activity comes full circle. It returns science to its citizen roots, and this time, with the Internet and massively scalable computing as a way to collect and analyze data, we are seeing an evolution of ways that citizens and scientists can interact (Silvertown, 2009). For example, projects such as the Christmas Bird Count (National Audubon Society, 2016) and eBird (E-Bird Project, 2016) now principally use Internet-enabled technologies to collect wildlife data from citizens. In eBird, for example, citizens can easily upload data over the Web or with apps on their smartphone and see real-time graphs of bird populations or migratory routes across the world. In making the case for citizen science in IS research, we contend the widespread use of IT has created new forms of discourse where social behavior and action as exhibited over the Web, mobile phones, and social media can both further engage and educate citizen populations or migratory routes across the world. In making the case for citizen science in IS research, we contend that the history of citizen science is still being written as new collaborative technologies, new forms of data sharing, and new storage and processing capabilities fuel the resurgence of a scientifically engaged public and the scientifically aware citizen.

3 Viewpoints on Contemporary Citizen Science

Contemporary citizen science largely emerges from the difficulty in achieving balance between scientific expertise and the needs and knowledge of citizens (Irwin, 1995; Bonney et al., 2009a; Fischer, 2000; Wiggins & Crowston, 2015). In citizen science, science is inextricably linked to the benefits and detriments of technology in our everyday lives and the societal implications that go hand-in-hand with a scientifically informed public. Technology offers new possibilities but also new threats to freedom and autonomy (Irwin, 1995). Further, in citizen science, a scientifically informed citizenry is inseparable from both policy and sustainability outcomes (Irwin, 1995; Bonney et al, 2009a; Fischer, 2000). In this research, we depict contemporary citizen science through three influential viewpoints: the works of Alan Irwin (Irwin, 1995; Irwin, 2001), Rick Bonney (Bonney et al., 2009a, Bonney et al., 2009b; Sullivan et al., 2009), and the European Citizen Science Association (ECSA) (ECSA Strategy, 2015a; ECSA Principles, 2015b). These works are some of the most widely cited works in citizen science and are, in many ways, similar but also have distinguishing characteristics as a result of their distinct vantage points. In this research, we characterize Irwin’s work from the sociological perspective, Bonney’s work from the natural science perspective, and the ECSA’s work from a policy perspective.

From the sociological perspective, Irwin (1995) posits that science and technology may offer a body of facts about the world and a framework for rational thought, but it may also blind us to alternative value
systems about ourselves and the world around us. Drawing from Max Weber’s idea of disenchantment (Weber, 1958) and framed by the increase of bureaucracy and rationalization during the Industrial Age, Irwin evokes Weber to describe science and technology as a double-edged sword in contributing to human progress but undermining human values. Irwin argues for a citizen science that democratizes citizens’ understanding of the relationship between science, technology, and progress, and he relates it directly to issues of environmental sustainability in offering four objectives for citizen science:

1) **Amelioration of technological culture**: Irwin describes citizen science as a way to mitigate the “tragedy of technology” as there should be no “inevitability or immutability in the direction of science and technology” (Irwin, 1995, p. 8). He also states that science needs to be self-critical in the face of public skepticism about its linkage to progress because, at present, “public groups are frequently portrayed as ignorant or irrational in the face of scientific progress”.

2) **Promoting citizen culture**: the lack of citizen culture in the current ethos of science warrants reconsideration of the relationship between citizens and scientific expertise. Irwin calls for scientific analysis to start from the perspective of citizens as opposed to the “higher rationality” of scientists and elite groups. He calls for a citizen’s view of science instead of a scientist’s view of citizens and to establish a more symmetrical relationship between public and formal expertise.

3) **Science for the people**: scientific undertakings should directly serve the public, and, moreover, we should rethink the complex relationship between science, technology, and human values so that citizens possess a greater ability to influence policy decisions that affect their lives.

4) **Sustainable development**: Irwin sees science, knowledge, democratization, and social progress as inseparable from environmental sustainability. As a socio-scientific issue, Irwin argues that threats to the environment and impending threats of global development cannot be successfully tackled without fully considering local and global initiatives as well as citizen-oriented and state-led programs. In summary, Irwin’s ideas carry important implications for societal knowledge, and he views citizen science as a vehicle for tighter relations between scientific expertise and non-scientifically oriented citizens in tackling some of society’s most pressing issues.

In addition to the sociological issues that Irwin raises, the widely cited works of Rick Bonney and his co-authors have sought to explicate levels of citizen involvement and inform researchers on how one can effectively design citizen science projects for “scientific and educational outcomes” (Bonney et al., 2009a, p. 977; Bonney et al., 2009b; Sullivan et al., 2009). Bonney’s work is action oriented: he focuses on delineating what constitutes a citizen science project, levels of contribution, and how one could go about designing a project with citizens at the core. For example, if a project is **contributory**, citizens primarily help collect and analyze samples or observations, which represents the way most citizens have contributed to citizen science projects. That is, they mostly provide enthusiastic free labor, which produces unique forms of data that fosters new forms of discovery (Dickinson, Zuckerberg, & Bonter, 2010). If a project is **collaborative**, citizens help develop explanations, have a say in data collection methods, and analyze and interpret data. Lastly, if a project is **co-created**, citizens participate in defining the research questions, gathering preliminary information, disseminating conclusions, discussing results, and performing any of the activities from **contributory** or **collaborative** projects. In turn, successfully designing citizen science projects requires:

1) A scientific question that attracts participants (Bonney et al. (2009a) suggests keeping it simple to attract large audiences).

2) An evaluator team that comprises scientists, educators, and technologists to ensure scientific integrity; beyond scientists alone, projects require educators to explain its significance, technologists to develop the infrastructure to help team members collect and analyze data, and an evaluator to ensure the project meets measureable objectives.

3) Established methods for developing, testing, and refining protocols, data forms, and educational support materials.

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1 Our wording was added to Irwin’s objectives to describe his intent for the context of this article. He also does not title these objectives directly, but does elaborate on them extensively. We adapted his elaborations to illustrate the sociological perspective.
4) Formal participant recruitment efforts (e.g., Bonney’s major project, eBird (Bonney, 2009b), has concentrated its recruitment efforts on middle school teachers).

5) Formal participant training efforts tailored to citizen scientists.

6) Formal procedures for accepting, editing, and displaying data where both scientists and citizens should have a voice in how data is conveyed to the public.

7) An open analysis and interpretation of data.

8) Collaborative dissemination of results.

9) Measurement of both scientific and scientific literacy outcomes.

Lastly, policy perspectives have become increasingly important in citizen science (Bowser & Wiggins, 2015). The ECSA has developed 10 policy-oriented principles to guide the design and outcomes of citizen science projects (ECSA Principles, 2015a):

1) Citizen science projects should actively involve citizens in scientific endeavors that generate new knowledge or understanding. Citizens may act as contributors, collaborators, or as project leaders and should have a meaningful role in the project.

2) Citizen science projects should have a genuine science outcome. For example, answering a research question or informing conservation action, management decisions, or environmental policy.

3) Both professional scientists and citizen scientists should benefit from taking part. Benefits may include the publication of research outputs, learning opportunities, personal enjoyment, social benefits, or satisfaction through contributing to scientific evidence.

4) Citizen scientists should be able to participate in multiple stages of the scientific process, which may include developing the research question, designing the method, gathering and analyzing data, and communicating the results.

5) Citizen scientists should receive feedback from the project, which can include how their data are being used and what the research, policy, or societal outcomes may be.

6) Because citizen science is a research approach like any other, one should consider and control for its limitations and biases. However, unlike other research approaches, citizen science provides opportunity for greater public engagement and democratization of science.

7) Citizen science project data and meta-data should be made publicly available, and, where possible, results should be published in an open-access format. Data sharing may occur during or after the project unless security or privacy concerns prevent sharing.

8) Citizen scientists must be acknowledged in project results and publications.

9) Citizen science programs must be evaluated for their scientific output, data quality, participant experience, and wider societal or policy impact.

10) The leaders of citizen science projects should consider legal and ethical issues surrounding copyright, intellectual property, data sharing agreements, confidentiality, attribution, and the environmental impact of citizen science activities.
Table 1. Three Perspectives on Citizen Science

<table>
<thead>
<tr>
<th>Sociological perspective (Irwin, 1995; Irwin, 2001)</th>
<th>Natural science perspective (Bonney et al., 2009a, 2009b; Sullivan et al., 2009)</th>
<th>Policy perspective (European Citizen Science Association, 2015a, 2015b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citizen science projects can affect society in several ways:</td>
<td>Citizen science projects can involve citizens by having them:</td>
<td>From a policy perspective, citizen science projects should follow 10 principles:</td>
</tr>
<tr>
<td>1. By ameliorating technological culture (e.g., removing the inevitability or immutability of science and technology’s thrust upon citizens).</td>
<td>1. Help collect data.</td>
<td>1. They should involve citizens in scientific endeavors.</td>
</tr>
<tr>
<td>2. Promoting citizen culture in science (e.g., scientific analysis beginning from the perspective of citizens).</td>
<td>2. Help analyze data.</td>
<td>2. They should have a genuine science outcome.</td>
</tr>
<tr>
<td>3. By directly serving people (e.g., science in direct service to the public).</td>
<td>3. Help create scientific endeavors.</td>
<td>3. They should benefit both professional scientists and citizen scientists in taking part.</td>
</tr>
<tr>
<td>4. Sustainable development as part of citizens’ involvement in science. (e.g., citizen science as inseparable from informing citizens on matters of environmental sustainability).</td>
<td></td>
<td>4. Citizen scientists should be able to participate in multiple stages of the scientific process.</td>
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<td></td>
<td>Citizen science projects should possess the following characteristics:</td>
<td>5. Citizen scientists should receive feedback from the project.</td>
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<td></td>
<td>1. A scientific question that attracts participants.</td>
<td>6. Citizen scientists should acknowledge citizen science’s limitations and biases.</td>
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<td></td>
<td>2. An evaluator team.</td>
<td>7. Citizen science project data and meta-data should be made publicly available.</td>
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<td></td>
<td>3. Established methods.</td>
<td>8. Citizen scientists should be acknowledged in project results and publications.</td>
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<td></td>
<td>4. Formal participant recruitment efforts.</td>
<td>9. Citizen science programs should be evaluated for their scientific output, data quality, participant experience, and wider societal or policy impact.</td>
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<td></td>
<td>5. Formal participant training efforts. Training efforts must be tailored to the citizen audience.</td>
<td>10. The leaders of citizen science projects should consider legal and ethical issues.</td>
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<td></td>
<td>6. Formal procedures for the acceptance, editing, and displaying of data.</td>
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<td>7. An open analysis and interpretation of data.</td>
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<td>8. Collaborative dissemination of results.</td>
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</table>

The three perspectives point toward citizen science activity with greater implications than simply science-centric contributions to knowledge. Further, citizen science has educational, societal, and environmental sustainability implications that IS researchers should also pursue. As we discuss in Section 4, IS is uniquely situated among the spectrum of citizen science research. As Irwin (1995, p.4) states:

*Information technology, for example, offers us vastly improved communication systems, greater efficiency, easy (at a price) access to databases and knowledge systems, the possibilities of more leisure time, greater productivity, and a decentralized approach to decision-making. At the same time, it offers the routinization of clerical tasks, unemployment, the centralization of power and the potential (through advanced security systems and databases) for loss of freedom and autonomy.*

IS research can be part of citizen science outside the traditions of the IS domain and can advance societal projects in their own right. For example, IS researchers could play an integral part in natural science citizen science initiatives and publish the experiences of citizens and themselves. Alternatively, citizen science projects could be developed where citizens collect data, collaborate with IS researchers, and co-create research projects that improve scientific literacy and inform the public. From either angle, the key difference between social science research, natural science research, and citizen science is a) the intervention of citizens at varying levels of the scientific process (Bonney et al., 2009a), and b) the “intervening” citizens are not simultaneously the subject of scientific inquiry (Irwin, 1995, p. 63). Given this explication, we offer the following definition for citizen science in IS research:
Citizen science in IS research is a partnership between IS researchers and people in their everyday lives. Citizen science projects in the IS domain involve a) IS phenomenon of interest to both citizens and scientists, b) the intervention of citizens in the collection, collaboration, or co-creation of scientific endeavors for the purposes of scientific literacy education and a more informed public, and c) citizens themselves not being the direct subject of scientific inquiry.

4 Citizen Science in IS Research

Citizen science may be a relatively new approach for IS research, but the concepts that embody citizen science have existed in IS research traditions for decades. Thus, we contend citizen science is best viewed as situated among current research activities. For example, it bears considerable resemblance to participatory design (PD), which was founded on the simple standpoint that those that technology affects should have a say in how it is crafted (Bjerkness & Bratteige, 1995; Bjögvinnsson, Ehn, & Hillgren, 2012a). Furthermore, new forms of PD go beyond workplaces to discuss it occurring in the context of “multiple terrains that blur traditional distinctions made between public and private and the state and the market” (Bjögvinnsson, Ehn, & Hillgren, 2012b, p. 127). Thus, from the standpoint of engaging with non-scientific expertise to accomplish an objective and doing it in the public domain, PD does not differ much from citizen science. However, PD and citizen science differ in several ways that warrant clarification:

1) PD is rooted in the idea that it can improve the knowledge upon which systems are built, while citizen science is rooted in improving scientific literacy about topics that affect citizens from a societal and sustainability perspective.

2) PD is rooted in the need to manage expectations about new technology to reduce the potential for resistance to change, while citizen science is rooted in strengthening citizens’ voice in the deployment of science and technology that affects their everyday life.

3) PD is rooted in the democratization of technology development (public or workplace) by giving members the right to participate in technology design decisions, while citizen science is rooted in the democratization of science vis-à-vis citizen intervention into the scientific process to improve on point 1 and 2 (Irwin, 1995; Bonney et al., 2009a; European Citizen Science Association, 2015b; Bjögvinnsson et al., 2012b; Bjerknes & Bratteig, 1995; Kyng, 1991; Bjørn-Andersen & Hedberg, 1977).

We can make similar distinctions between citizen science and other IS-related research traditions. For example, user-centered design (Garrett, 2010; Greenbaum & Kyng, 1991) is based on users’ intervening in the design process, not scientific processes. Action research (McNiff, 2013; Argyris, 1970; Davison, Martinsons, & Kock, 2004) entails that experts (and not ordinary citizens) reflectively intervene to solve an immediate problem. Lastly, crowdsourcing research ( Howe, 2006; Wiggins & Crowston, 2011) engages the crowd actively (e.g., Seafloor Explorer, 2016) or passively (e.g. SETI@Home, 2016) to phenomenologically investigate the nature of content generation from users, and it can involve the crowd in contests, fundraising, problem solving, and digital and physical product development (Lukyanenko, Parsons, & Wiersma, 2016a; Deng, Joshi, & Galliers, 2016; Steelman, Hammer, & Limayem, 2014); however, unlike citizen science, crowdsourcing is not rooted in citizens’ intervening in the scientific process.

In sum, while citizen science often embodies tenets from the aforementioned research traditions, it also bears an exclusive focus on citizens’ intervening in the scientific process vis-à-vis an active engagement with the crowd to enhance scientific literacy from educational, societal, and environmental sustainability perspectives. It is also nearly impossible to draw clear contrasts between research traditions, particularly in the social sciences, because they can be quite similar in their philosophical paradigms, research methods, and analytical techniques (Porra, Hirschheim, & Parks, 2014). Rather, we feel one can best distinguish via examples. In Sections 4.1 to 4.3, we offer three examples of citizen science research that can be useful to the IS field. The examples provide three different perspectives: a citizen science research project where IS researchers partnered with environmental toxicologists (Germonprez, Levy, & Kolok, 2015), a design science paper that explicates a framework for citizen science in developing nations (Robinson & Imran, 2015), and a paper that describes data-quality issues in crowdsourcing with a popular citizen science project as its main example (Lukyanenko, Parsons, & Wiersma, 2014).
4.1 Example 1: Social+Science: Using Social Media in Citizen Science (Germonprez et al., 2015)

Researchers have used citizen science in numerous ways to understand the environmental factors industrialized nations have on their own populations (Silvertown, 2009; Cooper et al., 2007; Dickinson et al., 2012). In this project, Germonprez et al. (2015) undertook citizen science to monitor atrazine levels in watersheds across the Midwestern United States and to facilitate conversations about these observations through social media. The conversations related directly to the health of a community because atrazine is an herbicide linked to birth defects and cancer (Garry, Schreinemachers, Harkins, & Griffith, 1996). The project explored the engagement of citizen volunteers and the use of everyday social media technology in both the collection of data and in the participation of scientific processes over social media to measure atrazine levels in the Mississippi River watershed. The research, conducted by IS and environmental toxicologist researchers, used volunteers in communities living near industrial farms to help collect data vis-à-vis atrazine test strips and water samples taken from the watershed. Furthermore, the volunteers used social media to post, read others results, and take part in an online community to discuss a critical environmental issue in their community. The volunteers also not only participated in collecting the data but also learned from the IS and environmental toxicology researchers about how to analyze and share scientific results. The volunteers also shared the data in online social media circles and worked in educational settings in the region to discuss the results. The research highlighted how the confluence of citizens, everyday social media technology, and formal experts can play a part in enhancing the scientific literacy of citizens and broadening the discussion about scientific topics that affect the sustainability of a community. Specifically, it highlighted an observable space in a networked technology environment where natural science and social science research could intertwine in making contributions to scientific knowledge in understanding levels of atrazine, the role of social media technology in informing the project, and making contributions to public knowledge about both (Wiggins & Crowston, 2012; Newman et al., 2012).

4.2 Example 2: A Design Framework for a Technology-mediated Public Participatory System for the Environment (Robinson & Imran, 2015)

This project offered a design framework for citizen science projects in developing nations. It took a theoretical tack by exposing the gap in public research by government organizations in developing nations. In particular, they expose how government organizations rarely work with their own citizens to gather indicators that measure the nation’s progress. As Robinson and Imran point out, there exists a paucity of citizen science systems for reporting on the conditions of these nations and a potential for technology-driven citizen science, as smartphone access and cellular infrastructure are increasingly available in nearly every country. In their research, citizen science acted as a springboard to theorize about how one can understand a nation’s progress. They advanced a design theory to: 1) enable optimal participation in the participatory system, 2) support a diversity of device accessibility, 3) support a diversity of engagement despite a lack of literacy and ICT skills, 4) support cost-neutral participation and contribution, and 5) develop frameworks to understand differing motivators for participation. At the time of publication, their project was being experimentally tested in the Guntur District in the Andhra Pradesh Region of India, and, while ongoing, the project highlighted the use of concepts central to IS research and similar fields. In this case, it highlighted the ideas of technology-mediated participation (Nov, Arazy, & Anderson, 2011a; Preece & Schneiderman, 2009), design science (Hevner, March, Park, & Ram, 2006; Peffers, Tuunanen, Rothernberger, & Chatterjee, 2007), and usefulness beyond the context of sociotechnical systems (Winter et al., 2014). With their research, they eventually hoped to systematize the design so that one could transfer citizen science structures from domain to domain (e.g., from healthcare to education or from country to country).

4.3 Example 3: The IQ of the Crowd: Understanding and Improving Information Quality in Structured User-generated Content (Lukyanenko et al., 2014)

In this project, Lukyanenko et al. (2014) use a popular citizen science project, eBird (E-Bird Project, 2016), to understand user generated content in the context of crowdsourcing (also see Lukyanenko et al., 2016b). The study proposed that classification models, such as those that seek to classify bird species, result in lower information accuracy (more classification errors) when the classes defined in an information system are unfamiliar to the contributor and that classification-based information models can result in information loss when the classes used to record data are missing attributes that the contributor observed.
Based on experiments that involved undergraduate business students in classifying bird species, the project attested that lower information accuracy is indeed an issue when classes of information (e.g., classification of a genus versus a species) do not directly coincide with user knowledge and that information loss occurs when the corpus of attributes experienced are not present in the information classification scheme. The study was indirectly related to enacting a citizen science project; however, it was part of an interesting citizen science research agenda to further understand the design of user generated content (Lukyanenko, Parsons, Wiersma, Siever, & Maddah, 2016b). This work exposed the idea that scientists in citizen science projects must account for gaps in knowledge between the scientist and the citizen, that the ways user generated content is elicited deserves further attention, and that information modelling decisions should take citizen’s knowledge of the phenomena under study into account.

The point in illustrating these examples is that citizen science has begun to find traction by IS researchers and neighboring fields. It has been mentioned as an area of study as IS research grapples with moving beyond the “organizational container” to study extra-organizational infrastructures (Winter et al., 2014), as a way to garner citizen participation in understanding extra-organizational technological phenomena (Prestonpik & Crowston, 2012; Nov et al., 2011a), in understanding and designing the technologies that support virtual collaboration in scientific research (Wiggins & Crowston, 2012), and in understanding the motivations of digital volunteers (Nov, Arazy, & Anderson, 2011b).

These examples also highlight that citizen science offers another dimension to the arguments for pluralism in IS research (Banville & Landry, 1992; Goles & Hirschheim, 2000). It can help bridge the divide between IS research and those who can benefit from its use. It can steer IS research towards more relevant undertakings and more alternatives to the spectator approach (Dewey, 1929) to how we develop IS knowledge. With citizen science, IS researchers can think of new ways to engage citizens and, moreover, listen to citizens as we seek to develop relevant forms of knowledge. Indeed, we can seek to understand not only the systems that enable citizen science but also the structuration that occurs between people and technology in the context of publicly engaged scientific activity and, perhaps most importantly, new phenomena an engaged citizenry might help us discover.

5 Ideas for Citizen Science in the IS Field

Citizen science helps us know more about human behavior in new IS contexts. It considers research streams where we, as researchers, are participants in scientific processes that are emergent, uncontrollable, and where data flows around us irrespective of our involvement. In this publicly engaged form of science, we are not necessarily controlling the experiments, manipulating the variables, or defining the setting. We become participants in a world of science to which we are simply members in an ever-emerging scientific conversation. Monarch butterflies migrate with or without our scientific involvement. El Niño occurs beyond the reach of organizational research questions. And, in both cases, a non-scientifically trained citizenry may have less of an in-depth understanding of scientific analysis but may have greater insight and impact into how these issues affect their community. Information endlessly flows throughout our world, and why should IS research not allow these streams of information to intervene to confront the larger societal, economic, and environmental grand challenges we face (vom Brocke, Stein, Hofmann, & Tumbas, 2015)?

As researchers, we can broaden our perspectives when we purposefully engage with citizens in the activities and theories that embody IS research. Our perspectives will change when, for example, we allow citizens to intervene as we study the information from location-aware smart medical devices located in their community or the neural response data from oximetry sensors when citizens are informed of tragic events. In turn, we can learn more about the forces of people, combined with our data-driven world, and framed through IS theory to produce new forms of science and discovery well beyond the bounds of an organization.

Citizens’ intervention in IS research activity can also impact how we look at the burgeoning fields of data science and data analytics (Chen, Chiang, & Storey, 2012), the communal and societal shifts affected by the open source revolution (Benkler & Nissenbaum, 2006), and the “greening” of IS and its impacts on our environment (Dedrick, 2010). A need and opportunity exists for pioneering thinking in investigating societal, economic, and environmental sustainability issues, and IS research is well positioned to be a key participant in this interdisciplinary engagement. IS researchers can participate as developers of new citizen science initiatives, as participant observers to existing programs, and even as observers to the
impacts of citizen science on the IS field. We, as IS researchers, can make a societal impact by understanding and engaging the existing world of science inquiry that is rapidly emerging all around us.

In particular, IS researchers can ask questions in the context of engaging the public in IS related scientific activity. We can ask what one can learn when engaging the public in IS research and elucidating IS theory. We can identify how citizen engagement can steer the direction of the field. We can ask about how one can use IS theory to provide advances in new societal, economic, and environmental contexts. Lastly, we can ask what IS research can learn about its own theories when citizens put our theories to use. In turn, when we engage citizens in the context of IS research, we can know more about how information is distributed, how technology can be designed, what constitutes IT-enabled social practices, and how citizens engage with IT in new and emerging areas of IS research.

Citizen Science may run counter to a sense that IS research is about designing solutions to problems, but it allows one to ask what happens to our theories and methods when placed into the world. What does design become when 7th graders influence scientific activity? What does policy and standardization look like when citizens are actively tracking snow depth via Twitter? How can one understand optimization when monarch butterflies are being tracked from Mexico to Canada via citizens and their cell phones? It is quite likely that these contextual shifts will result in new critiques of our theories and even the forking of existing thinking into new lines of inquiry. The 2015 Cyber-Innovation for Sustainability Science and Engineering (CyberSEES, 2015) program at the National Science Foundation illustrates how IS research can be pushed to play a key role:

The CyberSEES program aims to advance interdisciplinary research in which the science and engineering of sustainability are enabled by new advances in computing, and in which computational innovation is grounded in the context of sustainability problems. Computational approaches play a central role in understanding and advancing sustainability. CyberSEES supports research on topics that depend on advances in computational areas including optimization, modeling, simulation, prediction and inference; large-scale data management and analytics; advanced sensing techniques; human computer interaction and social computing; infrastructure design, control and management; and intelligent systems and decision-making.

In sum, the widespread, intensive use of computing technologies introduces sustainability challenges and motivates new approaches across the lifecycle of technology design and use. As IS researchers, our IT-related science can now be part of a communal experience as the social, digitally enabled exchange of information between people builds adaptability to understand more about the places we live and the lives we lead. Entry into these experiences require that we consider the generalizability of our theories into entirely new contexts (Lee & Baskerville, 2012), build the social systems to support such societal and environmental research, align with the places and cultures we engage with, link the local and shared interests of all participants, and weave a community of support and contribution throughout the project (Light & Miskelly, 2014). While technology is a key enabler in these investigations, there is, surprisingly, only a nascent IS research agenda around how to understand its design in various forms and contexts (Malmborg, Light, Fitzpatrick, Bellotti, & Brereton, 2015).

6 Implications and Limitations

While we write this essay to express a significant opportunity for citizen science in IS research, citizen science is difficult to perform and limited in what it can accomplish. First and foremost is that citizens will inevitably view issues to be explored by science differently from their own knowledge, perspective, and interests, which could cause deviations in the types of data that a scientist may expect versus what a citizen can provide. This situation could not only cause issues with data quality (Lewandowski & Specht, 2015; Lukyanenko et al., 2016a) but could also change the scope of phenomena one seeks to study. Thus, citizen science may best apply to larger, more general studies and less so to more targeted research streams. It is also noteworthy to point out the sheer challenge in conducting citizen science experiments: they involve considerably more interaction with those outside scientific domains, outside expertise to help train people and manage the project, and massive amounts of data that go far beyond the scientist’s direct control. Furthermore, citizen science projects often coincide with projects in the natural sciences, and, thus, constitute an interdisciplinary effort.

Nevertheless, given calls for IS research to move beyond the organizational container (Winter et al., 2014) and given that major IS journals seek to address societal challenges through special issues (Majchrzak, Markus, & Wareham, 2016), we contend we also need to consider alternative research activities to
expand the portfolio of how one can conduct IS research. Citizen science is but one such activity. It accommodates the broad and large-scale exchange of impactful information, and requires teams that include a variety of technological, management, communal, educational, and environmental sustainability skills. It would be the rare IS researcher who would be able to manage all necessary skills, so we must consider diverse research teams to include people who can help us understand the position of IT in a rich scientific world, such as neighborhood association members, aquatic toxicologists, social demonstrators, and K-12 students. Citizen science extends IS research to involve people seeking to participate in their scientific world, contribute through lightweight technologies, and improve their confidence in IT skills to support (Light & Miskelly, 2014).

Through citizen science, IS researchers can create cultural connections with participating communities and foster knowledge sharing and a collaborative spirit that help make societies sustainable (Malmborg et al., 2015). We can become participants with people who may want to study IT, foster new models of local action and learning, and create communities of science in solving complex problems. We can use IT as an entry to work with people to understand the world around us, the processes of science, and the societal, economic, and environmental impacts that collaborative teams can have. We can create community cohesion through IT as a requirement for environmental and economic resilience (Light & Miskelly, 2014) and foster the technical and scientific dispositions of all those involved (Clegg & Kolodner, 2014).

7 Conclusion

In closing, we contend that citizen science can act as a vehicle for IS research to enhance public scientific literacy and to engage and inform the public beyond the organizational domain. As a research community, we must support such participatory work by continuing to broaden the perspectives in current IS journals, recognizing IS research contributions when published in partner fields, and supporting researchers engaged in creating both scientific and societal impact. We must recognize that citizen science does not just entail engaging with citizens. Citizen science is an enterprise that is equally contributory to both the citizen and science. Citizens are not transferable resources any more than scientists are political capital. Citizens and scientists are people grounded to their context who build understanding and foster growth in areas that matter to them. There are times when citizen interests overlap with those of scientists, and it is then, when shared interests form, that citizen science can occur. As IS researchers, we must look for these overlaps, participate in their messy interactions, and encourage research where we are participating members of truly collaborative teams that make social and sustainable change.
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