Citizen science and community-based rain monitoring initiatives: an interdisciplinary approach across sociology and water science

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Citizen Science and Community-based rain monitoring initiatives: an interdisciplinary approach across Sociology and Water Science

Authors:

Giuseppe Tipaldo, Paola Allamano*

First author
Università degli studi di Torino, Department of Culture, Politics and Society
Second author*
paola.allamano@polito.it Politecnico di Torino, Department of Environment, Land and Infrastructure Engineering

Abstract

Why do people engage in Citizen Science projects? The aim of this contribution is to explore the social mechanisms that push non-experts (i.e. citizens) to invest energy, time and (sometimes) money in collaborative initiatives on the ground of scientific research. Some relevant examples from the domain of community-based rain measuring are scrutinized, merging the views of a water scientist and a social scientist. After briefly discussing the limits of outdated approaches to Science-Technology-Society issues, Social Identity theory and new media mechanisms are analysed as key variables to understand what is new in today's science coming across citizenship. A discussion on the importance of accounting for the uncertainty inherent with the observations coming from crowdsourcing initiatives, possibly the most challenging side effect of what we call Citizen Science 2.0, closes the paper.

Introduction

Citizen Science (CS), Public Engagement, Community Science and Community-Based Monitoring are among today's most popular locutions[1,2,3,4,5] used to label the progressive convergence of spheres sharply separated in modern science (end of XIX century onward)[6,7,8]. These spheres are politics, economics, society and science itself.

Citizen Science, the main topic of our contribution, can be defined as «a scientific practice in which volunteers from the general public assist scientists in conducting research»[9]. CS, to put it in another way, «enlists the public in collecting large quantities of data across an array of habitats and locations over long spans of time»[10]. It is a form of collection of data – in some cases followed by a computational activity – run at a social level, «where members of the public are recruited to contribute to scientific investigations»[11]. It is, to sum up, the field of interaction «between conventional (university/agency/industry) and community-based scientific knowledge systems» [5, p. 842].

Recent CS stems from a paradigm shift within Science, Technology and Society studies (STSs), precisely addressed as the «Science Mode 1 vs Science Mode 2» change[12,13]. STS is such a diverse research domain it would be a losing battle to try and put together every single proposal/review/study addressing the post-academic-science turn. For our purposes, what we can do is underline the main traits the great majority of literatures converge on. First comes the issue of knowledge production: academic science, or science «Mode 1», has had problems defined only by the academic community; on the contrary, «Mode 2», or post-academic science, differentiates from the past because knowledge originates within a specific context of application as the outcome of multiple interactions between a number of stakeholders (academics, private researchers, industrial or economical lobbies, decision-makers, end-users)[14]. Second, the nature of these interactions shapes the form of knowledge: science «Mode 1» is the land of separate, distinct, clearly-defined disciplines clotted around the seek for scientific homogeneity, whereas «Mode 2» is physiologically heterogeneous, as knowledge is here a product of (many) different fields of study gathered around a multidisciplinary project[15,16,17]. Third and last comes the quality check issue. Traditional science was founded on an endogenous solution to provide a certificate of quality: the blind peer-review. Though this still remains largely valid today, quality in the post-academic science era is a game being played on a great variety of tables, whose main interest can be briefly referred to as social accountability[17].

In spite of the abundance of research programs and publications, CS is still largely lacking a comprehensive discussion on which social mechanisms push social actors (i.e., the citizens) to invest energy, time and (sometimes) money to engage in CS projects. In the following we will concentrate on those few aspects we believe essential to the scope of filling this gap in CS literature. We thus explore where and how CS could find theoretically and methodologically solid connections to a general model of «science for and with society»[18].

To better frame the discussion, a set of citizen science projects will be used as a representative example to testify the increasing attention toward CS, the motivations of CS contributors, and the paradigm shifts entailed by recent technological advancements. The domain of community-based rain measuring is selected, among others, for the number of active projects, the long-standing tradition behind these projects and interest demonstrated both by scientists and citizens for cooperative rainfall monitoring.

Citizen Science: a long-standing story at a turn of events

Despite today's common sense, it can be easily demonstrated that CS is in fact the native form modern science took at birth and maintained for approximately three centuries (Fig. 1). One among the most influent figures of the scientific revolution during the Renaissance period, Galileo Galilei (1564-1642), used to be a draper before being appointed to the chair of Mathematics at the

«Studium» (as they called at that time the University of Padua). The man behind the «first great unification in physics», Sir Isaac Newton (1643-1727), had been withdrawn from school at seventeen to become a farmer, and it took an hard negotiation with his second-time-widowed mother to have him back and finishing his education. The father of the evolution theory, Charles Darwin (1809-1882), «sailed on the Beagle as an unpaid companion to Captain Robert Fitz Roy, not as a professional naturalist» [19, p. 467]. Things were not going differently on the other side of the ocean: «Benjamin Franklin (1706–1790) was a printer, diplomat and politician»[19], and a great contributor to the advances of modern mass communication theory and technology, Thomas Edison (1847-1931), is still and foremost remembered as an «inventor», rather than a «scientist». Science as a «vocation» – with the words of Max Weber[6], one of the founding fathers of Sociology – has a far longer tradition than science as a (paid) profession, the latter dating approximately somewhere around the second half of the 19th century [19, p. 467].

The first examples of CS of the new era (science as paid profession) reportedly took place in the USA, with the Christmas Bird Count by the National Audubon Society (run since 1900), and in UK, in coincidence with the British Trust for Ornithology foundation (1932)[19]. Since then, CS contexts have spread years after years across the globe.

What is new, then, in today's science coming across citizenship? There are at least three indicators that can help answer the question. One is the boost of both scientific and public interest on CS. The amount of scientific works (i.e. papers and books) containing the locution «citizen science» has risen by almost 1300% from the 1981-2000 period to the last fifteen years (Fig. 2). Though data provided by Google are not immediately comparable with those above, scientific and online public interest trends are indeed significantly related: they both show a strong positive trend over the last ten years (Fig. 3). Institutional attention has been of course rising, too: from continental multi-billionaire programmes as the European Horizon2020, to national or even single academic initiatives, one could fruitlessly struggle to find something in the Research and Innovation department not foisting social and public engagement (whatever the label may stand for) as a pre-requisite for approval.

Another evidence – probably the most relevant from a sociological perspective – of a profound chasm between past and today's CS relates to changes in science communication register. Developments over the last two decades have increasingly questioned what has been already known in the literature of Sociology of Science as «knowledge deficit» model[20]: that is, scientists treated as someone who has attained the «pinnacle» of a «superior form of knowledge» [21, p. 90-91] and, on the opposite side, citizens to be adequately «educated» because of their ignorance. Consequently, «knowledge deficit» considers the process of science communication always activated by the sender, whereas the receiver is static and passive.

What distinctly separates contemporary CS from its historical precursors is that «it is now an activity that is potentially available to all, not just a privileged few»[19]. Accordingly, recent CS is no more bound to the traditional frame of «scientists using citizens as data collectors» for time and budget saving benefits[22,23], nor to any technocratic approach; it rather promotes «citizens as scientists»[16] who may be «qualified by experience» [5, p. 843], having «a richer knowledge of a given field or aspects of that field than many professionals» [24, p. 549].

Finally, be it an adaptive answer to deep structural change within funding possibilities and policies and/or an anti-paternalistic sensitivity resulting from fresh air inwardly circulating the global scientific community, CS projects are now spread in almost all scientific domains: astronomy[9,25,26] , biodiversity[27,23], chemistry[29], ecology[23,25,27,29], ornithology[25], water quality and hydrology[5,27,30], climate and atmospheric sciences[31], etc.

Participative precipitation monitoring: some significant examples through the lens of social identity theory

Composing the landscape of CS projects in the water sciences is not within the scope of this paper. Nor is it to exhaustively and extensively discuss social identity theory *per se.* We will concentrate, instead, on those few aspects we believe are essential for answering the main question at the basis of this contribution: why do people engage? That, in the language of Social Science, should be translated as follows: which are the main social mechanisms that push social actors to invest energy, time and (sometimes) money in a CS project? We select the domain of precipitation monitoring as a significant domain to exemplify the evolution of the CS phenomenon at the cross-border between science, technology and society.

Precipitation has always raised both the interest of scientists and people. The first documented "scientific" precipitation measures were made during the seventeen century[32]. But non systematic measures of rainfall (and snowfall) can boast an even longer tradition. We can confidently say that almost each individual has stopped, at least once in his life, to observe a thunderstorm and many of those individuals have tried, at least once in their life, to collect (measure) the rain. Precipitation measuring thus represents an ideal terrain where to observe the interplay between academic and citizen science.

The goal that is typically chased by scientists and professionals resorting to participative approaches in precipitation monitoring responds to the need of intensifying precipitation monitoring (e.g. rainfall, snowfall) both in time and space, with respect to standard (and static) monitoring networks. This need emerges from the structural sparseness of standard precipitation monitoring networks, which often prevents adequate representations of rainfall patterns. A first successful example of a long-standing cooperative "observing network of, by and for the people" is represented by the NOAA's National Weather Service Cooperative Observer Program (Coop), run by the US National Oceanic and Atmospheric Administration (NOAA) since 1890[33]. More than 8700 volunteers contributed to the project running and maintaining cooperative stations where precipitation measures are taken and transmitted every day. Since then, numerous initiatives aimed at involving citizens in collecting rain measures were proposed, e.g. the CoCoRaHS[34] and Rainlog[35] projects (see table 1).

From a sociological point of view, all these initiatives are grounded on the traditional CS paradigm, being the process of rain monitoring activated by the sender and the citizens involved mainly to serve as data collectors. More, as no evidence of a substantial personal benefit can be found in any of the CS cases above, one could easily be misled and interpret engaging behaviours of thousands of people as irrational.

During the XIX century, classical economists and/or sociologists, like Walras, Jevons and Pareto, proposed the so called «homo oeconomicus» paradigm, making the assumption of a man solely driven by external motivations accordingly to its ability to satisfy needs and wants (i.e. utility function). On the opposite side, first mass communication theories – deeply influenced by Marxism and its consecutive revisions – looked down to individuals as an atomized, suggestible and thus easy-controllable crowd of people.

After decades of researches and discussions, modern sociological theory is harshly critical against these two ideal typical models, which, for opposite reasons, are considered unsuitable to account for the complexity of the actual social life[36, 37, 38, 39, 40]. Attitudes, preferences and actions are instead reinterpreted, by the so called «homo sociologicus» paradigm, as the outcomes of a non-deterministic multi-dimensional process of Self construction[41,42].

The Self construction process involves a number of components from two different yet complementary dimensions: i) the individual part of the Self (or Self-perception) and ii) the social component of the Self (social identity). Within this second component, the one that directly affects CS projects – as well as any other public engagement initiative – is the theory of Self categorization.

The theory of Self categorization moves from the assumption that «individuals strive for a positive self-concept» and because self-concept is influenced by social identity (i.e. the image you got as a feedback from «significant others») «individuals strive to achieve or maintain positive social identity» [43: p. 40; 44: p. 16].

The influence of social identity on the single is pervasive. That is to say the impact of the «social» component of life affects the «actor» in many ways: during the identification process, in which the individual constantly negotiate inputs from what perceives as the «inside» (ingroup) and the «outside» (outgroup) of his/her social life environment. In the adaptation (or socialization) process, when the social actor acquires from the group the collection of values and norms (s)he will use as a moral, ethical and practical guide through the complexity of real life. And this happens both at the micro level and – under certain circumstances – at the macro level, where personal preferences turn into collective actions.

Social identity may, therefore, provide more solid theoretical tools to investigate what - with one of today's most popular expression – may be defined as "virality" in CS: it is not (always) just a matter of rational utility (in the neoclassical acceptation of the term) nor a mere mass imitation phenomenon (as in those first mass communication theories influenced by critical Marxism).

At given moments in history, an individual would in fact move in a different direction of what is assumed by the classic economic theory accordingly to the utility function. In other terms, given some surrounding conditions persons are likely to endorse sets of resources allocations which would appear as biased, irrational or unmotivated to a rational-choice observer: they would indeed act to maximize the «profit» of their ingroup at the expense of their personal self-interest[42, 44, 45].

For some people, then, the desirability of virtuous behaviour appears so entrenched as to cancel out cost perceptions, transforming the commitment itself into a good one in and by itself, an action that requires no additional external recompense[46]. In order to enable this mechanism, an external «catalysing event»[47] is needed, one that is capable on the one hand of supplying new and vital energies to the systems of those minority groups that are active on a specific issue (i.e. waste recycling, environmental and species protection, climate changes, security issues related to rainfall intensity, etc.), and on the other hand to increase the salience of the issue itself in public debate. The outcome is a change – at least temporarily – in preference between the private sphere and public commitment, leveraging public engagement. A general scheme of what discussed in this section is presented in Figure 4.

What is new and how to sociologically interpret it

It is clearly not a coincidence that new participative paradigms for the diffusion of "citizen observatories" have arisen, based on the emergence of smart sensor networks as a new generation of monitoring infrastructures. The proliferation of devices such as smart phones, cameras, drones etc. is causing, in fact, a rapid shift from targeted and static forms of information collection to always-on and ubiquitous forms of data generation[48, 49]. The five projects listed in the second part of table 1 are examples of this new way to perform CS. These initiatives share the final goal of intensifying at ground (rain) monitoring networks by integrating standard and unconventional measures.

First, at the intersection between science, society and business, stands the Weather Underground project. It has been the first commercial weather service providing real-time weather analytics via the Internet, pioneering the avenue of weather big data since 1995. Weather Underground currently uses observations from over 100000 personal weather stations[50]. The intrinsic value of these data has been indisputably recognized in the recent acquisition by IBM of the Weather Underground platform.Another relevant example comes from the mPING project, for Meteorological Phenomena Identification Near the Ground [51, 52].It collects public weather reports through a free app available for smart phones or mobile devices. . Citizens' reports are used in a variety of ways, including to develop new forecasting technologies and techniques.

In a related vein, the project UKSnowMap[53] relies on citizens' messages and tweets to collect snow rate and snow depth data and show them on maps.

A different approach is presented in 54, where the authors propose to exploit the paradigm of the Internet of Things to use moving cars as rain rate tracers by correlating rainfall to windshield wipers velocity. The results of a wide application of such a paradigm would certainly allow to raise a huge amount of data with a high value for professionals and scientists.

Finally, in 55, a new technique for crowdsourcing rain rate measures is presented based on the automatic processing of images and videos registered in rainy conditions. The technique lends itself to being ported to personal portable devices equipped with imaging sensors, thus becoming another example of citizen science 2.0 in hydrology. However the project and the citizen engagement strategy are yet to be deployed.

It is evident that the potential of these projects not only depends on the possibility of relying on new smart techniques for data collection but rather on the ability to involve the users in a new way, building a two-way and lasting relationship. To design the engagement paradigm of a project one should hence take into account the different types of motives for citizens to engage in science.

Citizen Science literature identifies at least two factors that appear to have a main role in public engagement. One intercepts the micro dimension of self-reflection on personal preferences, which can be reasonably represented by the tension among moral/ethical values and personal utility. The other stands at a macro level, where – following what has been already discussed above (and in Fig. 4) – private closure may under certain circumstances turn into collective action.

The two factors generate a 2x2 matrix outlining four ideal types of motives for citizens to engage in science (Fig. 5):

1. *Rational egoism*: when cost-benefit analysis produces positive expectations in individuals whose ego component usually prevails on social context when making decisions.
2. *Group Leadership*: it pushes to action individuals who, while perceiving themselves at the same level of others within a given context, are looking for a personal utility from social activities, being sensitive to immaterial rewards such as personal image, reputation and (self) esteem.
3. *Social advocacy*: it is the most powerful motivation in all those cases we identify as «catalytic events», in which an individual – pushed to action by belief, faith and/or solidarity – goes in contrast of what is assumed to be reasonable and predictable by rational-choice theory. At the opposite of the «rational egoism» leverage, catalytic events provide ground for men to act to maximize the «profit» of their ingroup at the expense of their personal self-interest: social context and «significant others» prevail on ego.
4. *Individual advocacy*: when values remain the main driver for action yet people care their individual component more than the ingroup, social advocacy transforms into individual advocacy: solidarity, belief and faith are here weaker motives than the reach for noteworthiness.

Classifying the projects in table 5 according to these ideal types would be certainly simplistic, since each project is the result of composite behaviours by its contributors. However reading the projects through the lens of social sciences at least allows one to perceive the main drivers of the contributions.

Under this perspective, we classify each project according to a couple of attributes: on the one hand the social engagement mechanism adopted by the project proponent (Fig. 6, x-axis), on the other hand the innovativeness of the enabling technology, i.e. the technology adopted by the citizens to contribute to the project (Fig. 6, y-axis). The positions in the plan are determined by attributing higher values to the projects fostering citizen engagement and the adoption of smart and novel technologies.

From mass communication to accuracy issues.

Though social identity processes are fundamental in clarifying when, how and why people engage, under certain circumstances, in public activities, today's CS phenomenon can not be deeply understood without putting on the table the mass media, as they represent some of the most important variables in scientific communication.

For the great part of its life, mankind has gathered and elaborated information through face-to-face interactions, that is, «individuals interacted with one another primarily by coming together and exchanging symbolic forms, or engaging in other kinds of action, within a shared physical locale» [56: p. 81] . On the contrary, for the last one hundred years, the world which we inhabit and experience, leaves the individual with nearly exclusively indirect forms of knowledge[56, 57], because «the real environment is altogether too big, too complex, and too fleeting for direct acquaintance. (...). And although we have to act in that environment, we have to reconstruct it on a simpler model before we can manage with it» [58: p. 16]. That is to say, the social actor moves within a «pseudo-environment», where the media play a central role as an easy source of images for understanding the turbulent and complex world.

Representations of science, technology and their relationships with citizens and society are included in this general framework. The contemporary concept of public space is in fact turning into a mediatised public space, where the media «get together» the various interlocutors publicly, as in a modern arena where the plurality of interests and visions are confronted. Here an ever-growing share of the information given to citizens is generated and, for most of them, this is the best – if not the only – approximation of reality available[59].

In the era of remediation[60] between traditional and new media, with mobile/wearable devices becoming more and more integrated with the individual, and Social Media like Facebook, Instagram and Twitter, among the others, having attained the top of the media system pyramid, at least four macro-phenomena need to be considered discussing implications of contemporary mass communication on CS.

1. Since pioneering studies on «the two-steps flow of communication»[61, 62] and the social network analysis[63] frameworks, social sciences have accumulated a tremendous amount of empirical evidence about personal and social relationships as relevant intervenient variables on media effects in a given context. In other words, role, position, status and social capital do differently affect the way people perceive (scientific) information, represent reality and, in a non deterministic way, eventually decide to engage. More, peculiar sets of social characteristics and media coverage may dispense different amount of trust and credibility to the sender of a scientific message, actively contributing to presenting him/her as a valid and trustworthy opinion leader, not rarely quite independently from his/her scientific curriculum.

2. While asking what media do on public, exploring what individuals use media for is relevant alike. People use media for a variety of needs and gratifications[64]: sociability, information-seeking, entertainment, utility, fashion and status. Any of these (not seldom in combination) may act as a strong motive for citizens to expose to scientific communication and, sometimes, to personally engage.

3. It has been more than 40 years since McCombs e Shaw[59] demonstrated media coverage (in terms of intensity, duration, pervasiveness and persistence) influences issues' salience and priority within the public agenda. In recent times, several studies have somehow connected the agenda-setting function of mass media to science communication and engagement in science by non expert,

showing that a growing number of issues involving science, politics and society (i.e. public policy-making, research and innovation investments, education, scientific controversies and conflicts, etc.) are nowadays addressed by policy-makers when they reach a high salience within the public agenda through intense (and/or alarmist) media attention [65, 66, 67, 68, 69, 70, 71]. On the opposite way, as media attention physiologically increases self-consciousness of those (groups or individuals) who get under the spotlight, active minorities (in our case CS groups) are increasingly using traditional and new media to be part of the public arena.

4. The effect of new media on society: personal media (i.e. mobile and smart phones, tablets), social media (social network sites, blogs, web 2.0 services, etc.) and wearable devices have known a rapid process of domestication and social shaping over the last few years, becoming an integral part of everyday life[72]. Among the most pervasive consequences at the societal level, a structural change in individuals/groups networks has occurred, as «the network metaphor applies not just to new media technologies, but also to the patterns of social relations and the institutional formations associated with them»[73].

Innovation in media technologies opens to a wider range of possible paths in CS both from the side of the proponents (the scientific community) and from the one of citizens. Yet, this is not free of side effects. The main critical point from a methodological perspective is the reliability issue: as Cohn[74] put it, «amateurs may make mistakes, may not fully understand the context of the study, or may produce data that might be unreliable». It is not a small thing, as validity and reliability represent two fundamental requirements to convey solidity to any scientific content. We will briefly discuss the issue in the next paragraph.

The challenge of untrustworthy information in crowdsourcing applications

The use of personal media and wearable devices to collect measures from the citizens arises a new generation of sensor networks, where a crowd of possibly anonymous users are involved in the task of collecting data from the surrounding environment and providing it to the community. One of the main consequences of this phenomenon is whether or not we can trust the sensor readings provided by the individuals engaged in the network. In standard monitoring systems, reliability may be traced back to the capacity of the sensor to provide consistent results under a range of different conditions, i.e. to provide results which are correct within a prescribed accuracy range: for example, rainfall gauges are considered to be reliable if the accuracy in the estimation of the rainfall rate is below 5%[75]. The reliability of a sensor cannot therefore be defined in absolute terms, but sensors can be ranked for increased reliability depending on the accuracy of the measurements they produce. Reliability is thus strictly connected to the measurement of uncertainty: the values attributed to a measured quantity are intrinsically dispersed around a central value, which may or may not correspond to the real value we are measuring (leading to unbiased or biased measurements, respectively); this dispersion is due to our incomplete knowledge of the quantity, being this incomplete knowledge of aleatoric or epistemic origin[76]. Measurement uncertainty can be conveyed by providing information on the whole probability density function of the values attributed to the measured quantity, or, more commonly, by only providing the standard deviation of this distribution. A correct quantification of measurement uncertainty is the key to tackle the problem of untrustworthy information in crowdsourcing applications: mechanisms should be implemented able to validate the reliability of the reports by the system users and to derive information about the uncertainty associated with the values collected by each user. Collective knowledge and confirmations on the same reported event from different users may be used to quantify measurement uncertainty. Another approach to validate information from users in the system is to have trustworthy users identified in the sensor network and thereby consider any information proceeding from them as the reference whereon basing the comparison[77,78]. A typical example here is that of standard tipping-bucket rain gauges used as the reference to quantify measurement uncertainty of other sensors. Each sensor or user can thus be tagged with an indication of its measurement uncertainty. A collective measurement can finally be obtained by combining together (e.g., through a weighted average) information from the different sources, where the weight attributed to each sensor/user is inversely proportional to the corresponding measurement uncertainty. The resulting collective measurement will be more accurate (i.e., more reliable) than any of the individual measurements, thanks to a reduction in aleatoric uncertainty deriving from the combination of independent sources.

The way forward does not therefore pass through the crude separation between reliable and unreliable measurements, with the first, typically coming from standard sensors, are kept in the analysis, while the others, typically from the crowdsourcing, are discarded. In contrast, measurements should be ranked for their reliability and suitably combined to provide a collective measurement. The real challenge in this field is thus to provide suitable tools for quantifying measurement uncertainty of different data sources, including crowdsourced data.

Conclusion

Despite the abundance of works on Science Technology and Society in a great variety of fields, multidisciplinary approaches focusing on Citizen Science are still a minority, while there is a lack of studies on the social mechanisms that push non-experts (i.e. citizens) to invest energy, time and (sometimes) money in collaborative initiatives on the ground of scientific research. In this review, merging the views of a water scientist and a social scientist, the attention given to community-based rain measuring domain has brought some relevant point to the forefront. First, the strong inadequacy of outdated theoretical framework based on the so called «homo oeconomicus» paradigm: the assumption of a social actor merely driven by external motivations accordingly to his/her utility function is largely unfit to represent the complexity of engaging behaviours of thousands of people.

Secondly, to justify why at given moments an individual would move in the opposite direction of what is assumed by the classic economic theory, a 2x2 matrix based on Social Identity theory and new media mechanisms is taken into account, providing more solid theoretical tools to trace some of the recent evolutions in CS: Rational egoism, Group Leadership, Social and Individual advocacy are the four ideal-types of motivations in CS engagement generated from different combinations between two latent dimensions, the “Ego-context” tension and the “social values *vs* personal utility” balance.

The third and last point moves forward to what we have called CS 2.0: as the Internet of Things and its applications (i.e. wearables, smart sensors, networks of objects, and derivates) is raising more and more attention and enthusiasm in today's public debate, new methodological issues are just around the corner. Participative practices may in fact be more exposed to uncertainty than traditional CS initiatives, mainly due to the absence of a standard measuring instrument. To prevent, or at least minimize, what could possibly be the most undesirable side effect in Citizen Science 2.0, a multi-method approach – based on both community supervision and trustworthy power users – is needed. The problem of measurement or, to put it in another way, whether and with what extent to trust in numbers is an epistemological node at the intersection of science and sociology that still seems largely undervalued. Further multiperspective field-works are required to cast a light, and successfully tackle, the challenges arising within the Citizen Science 2.0.

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Figure captions

Fig. 1 – Citizen Science timeline: an infographic of the CS phases between XVII and XXI centuries

Fig. 2 – Scientific interest on CS measured as a number of publications containing the locution "Citizen Science" in the period 1990-2015 (Number of papers on the y-axis; years on the x-axis). Source: ISI Web of Science.

Fig. 3 – Online public interest on CS in the period 2004-2015. Source: Google Trends.

Fig. 4 – From self-interest to public engagement: a model of action. Source adapted from 46 and 47.

Fig. 5 – Ideal types of citizens engaging in science.

Fig. 6 - Each project listed in tab 5 is classified according to the social engagement mechanism adopted by the project proponent (x-axis) and innovativeness level of the enabling technology (y-axis)

Tab. 1 - Citizen science projects for participative precipitation monitoring

Tables

Project	Year	Summary	Refs
Coop	1890	Citizens provide observational meteorological data	33
CoCoRaHS	1998	Citizens upload information about precipitation amount measured by manual gauges	34
Rainlog	2005	Citizens upload rain measures	35
Weather Underground	1995	First commercial weather service providing real-time weather analytics via the Internet	50
PING	2012	Citizens upload information about precipitation amount and type	51, 52
UKSnowMap	2014	UK citizens tweet a snow rating which are then shown on a map	53
Vehicle data	2013	Rainfall estimation using moving cars as rain gauges	54
WaterView	2015	Rain measures are taken via imaging sensors	55