SISSA - International School for Advanced Studies Journal of Science Communication
ISSN 1824 - 2049 http://jcom.sissa.it/

RECEIVED: June 10, 2013
PUBLISHED: November 05, 2013

Article

Combining citizen science and public engagement: the Open AirLaboratories Programme

Hauke Riesch, Clive Potter and Linda Davies

ABSTRACT: *Citizen Science (or "Public Participation in Scientific Research"), has attracted attention as a new way of engaging the public with science through recruiting them to participate in scientific research. It is often seen as a win-win solution to promoting public engagement to scientists as well as empowering the public and in the process enhancing science literacy. This paper presents a qualitative study of interviews with scientists and communicators who participated in the "OPAL" project, identifying three potential flashpoints where conflicts can (though not necessarily do) arise for those working on citizen science professionally. We find that although participation in the CS project was generally valued, it does not seem to overcome continuing (and widely reported) concerns about public engagement. We suggest that enthusiasm for win-win situations should be replaced with more realistic expectations about what scientists can expect to get out of CS-style public engagement.*

1. Background and introduction

The concept of promoting public engagement in science through involving members of the public in scientific research — often labeled "Citizen Science" (CS hereafter; the term was coined independently in the mid 1990s by Rick Bonney in the US and Alan Irwin in the UK[1]) or "Public Participation in Scientific Research" (PPSR) — has received enthusiastic support over recent years.[2,3,4] This enthusiasm derives from several sources, reflecting different aims and aspirations often associated with CS. First, it can be seen as a win-win situation where a project simultaneously delivers public engagement (PE hereafter) as well as scientific research, solving some of the problems often identified with getting more scientists into communicating science by making it worth their while scientifically.[5] CS can also help monitoring the local environment where otherwise resources are scarce,[6] again coupled with a PE aspect of empowering people to take ownership of their local environment.

Second, CS, by involving the public directly in the production of scientific research, can help in teaching not only in terms of generating evidence but also in demonstrating how science is done, thereby enhancing public understanding of the processes of science, its inherent uncertainties, the methods it uses to arrive at conclusions and the practical skills scientists need to acquire in order to reach their conclusions.

Third, CS projects can enhance democratic "ownership" of the domains it investigates, environmental CS projects for example engage the local public with environmental concerns that are relevant to them and thus enhance civic engagement in local environmental matters; similarly medical CS projects can enhance patients' and potential patients' ownership of their own medical history through encouraging self-reflection on biomedical data and empowering them to take active control over it (see also Prainsack[7] for a critical discussion of "crowdsourcing" in genetics research). In the process, through educating about science and scientific thinking, CS also often aims to enhance public decision making and — in the environmental sciences at least — a more general sense of "Earth stewardship" that goes beyond the local environment.[8]

The extent to which these varied aims are ultimately realised and can be demonstrated is an active area of research. Taking the claim that CS can enhance public understanding of the processes of science, Brossard et al.,[9] in their investigation of a CS project from the Cornell Ornithology Lab, found that very little learning about "the scientific process" took place through involvement in the project, although an earlier investigation by Trumbull et al.[10] found that CS at least offers participants a forum for discussion these issues.

Other aspects in which CS enhances informal science learning fare better, with several studies having found that participation raised science literacy at least in context-specific measures.[11,12,13,14] On this basis it is fair to say that, despite possible misgivings over CS really teaching about scientific method, traditional science learning in terms of raising scientific literacy in the context of the CS project is indeed enhanced through participation. The evaluation of these more traditional learning outcomes of CS emerge from more traditional ideas of what PE is and what it should deliver. Public Understanding of Science research has over the past 20 years often dismissed what it termed the "deficit model" of public understanding, which — as the caricature has it – intends to increase the public's "science literacy" in the expectation that they will become more knowledgeable and crucially more supportive of it.[15] While many arguments have also been made to reconcile deficit model ideas with science communication understood as a two-way dialogue, these efforts concentrate mostly on new or controversial sciences[16,17] or the defence of PUS surveys,[18] and there are complaints that in science policy circles, despite the rhetoric, the deficit model has never really been abandoned.[19] Conceptions of PE have shifted over the years as research on public understanding of science has moved through its various paradigm shifts from deficit to dialogue to upstream engagement and "third mode" engagement[20] and finally attempts to reconcile them. However, old definitions have not disappeared and therefore many different ideas of what PE is and should achieve continue to exist side-by-side. This appears particularly clear when scientists and science communicators themselves are asked about how they perceive PE, where researchers have identified a shift between interpretative repertoires[21] or clashing narratives[22] and where ideas about deficit, dialogue and "third mode" PE can exist alongside each other.[23] At the same time, recent theorising about PE seems to foreground policy relevance to the exclusion of modes of PE that have other, more educational, goals.[24] Although we do not intend to rehash this particular debate here, we would at least like to suggest that, if taken as a mainly "informal science *learning* activity" (as CS is analysed for example by Bell et al.[25]), it is entirely appropriate to take science literacy learning outcomes as one of the indicators of success, and that for this reason some of the criticisms of deficit model fail to hit the mark. Therefore we might need to step away from a simple dichotomous understanding of PE as either "deficit" or "dialogue", which seems to be something of a growing — if still small — trend in science communication studies that focus on informal learning.[26]

As part of formal (school) science education, citizen science has also been discussed as a way of enhancing student knowledge of the nature of science, as well as "democratizing science",[27] although there is an ongoing debate on whether CS is as workable for school science as for informal science education.[28,29]

The contextual or dialogue turn in PUS which foregrounds public lay expertise as an important element in the dialogue which needs to take place between science, experts, and the public, is similarly seen to be supportive of the CS agenda. This mode of understanding CS is often tied up with the third aim in the list we outlined above, i.e. that of furthering public ownership of the local environment and empowering members of the public to get into an effective and equal dialogue between lay-experts and experts. Within this interpretation of CS, which is more closely related to Alan Irwin's[30] independently coined use of the term, CS is anything but a traditional deficit engagement project and instead works by furthering the policy dialogue by giving people an expert's stake in processes such as evaluating local environmental conditions.[31] The more programmatic end of teaching science and how science is done within the context of science literacy that characterises approaches to CS as outlined in the previous paragraph are, within this literature, sometimes seen as not quite aligned to the aims of what they see as citizen science.[32]

Thus, analyses which foreground the dialogue aspect of CS, such as Hemment et al.,[33] see the value of the concept in the public contribution towards science and (arguably more importantly) the science and environmental policy process. In this vein, initiatives such as the "Extreme Citizen Science" group at University College London aim "to develop and contribute to the guiding theories and methodologies that will enable any community to start a Citizen Science project that will help them deal with issues that concern them",[34] thus foregrounding the value of CS to community concerns above the aims of informal science education or, indeed, that of science itself.

There are many other concepts that are relevant to CS and which are occasionally discussed alongside it, particularly within science communication — science shops for instance, involve the public in setting research agendas, so that there is a "working relationship between knowledge-producing institutions, such as universities, and citizen groups that need answers to relevant questions",[35] though these don't usually involve public participation in the actual science. Similarly, the concept of upstream engagement involves the public in contributing to debates on science policy and research directions.[36] More tangentially perhaps, the "open science" movement has been connected with CS because of its emphasis on making publicly funded science (and raw data) publicly available to everyone, so that interested amateurs could potentially work on the data themselves. One of our interviewees (see our companion paper to this study[37]) even complained that CS and open science are too often conflated.[38] While these conceptions of CS are also valuable, they are less relevant to our case in this paper, but see Toogood and Everett[39] for a discussion of the wider concepts connected with CS and how they fit in with OPAL.

CS is thus clearly a contested term with multiple origins reflecting different conceptions of what it is and should deliver and how success is judged. There is currently little debate about the extent to which the different elements of CS, such as the PE and knowledge production objectives interact and what this could imply for project design, enrolment, validation and implementation. It is unclear, for instance, how far a project designed to maximise the breadth of participation by members of the lay public in community monitoring can also be effective as a vehicle for data collection and science engagement or even as a democratic empowerment tool that enhances people's participation in science and the science policy process. What may be a good outcome for the scientist whose primary concern is successful science, may not be so for members of the public for whom good PE (or maybe just having a fun day out) might be more important. A desirable outcome for science policy advocates in environmental decision making might in turn be mediocre in terms of the science produced, or fail in enhancing the science literacy of participants.

These questions are rarely posed, let alone addressed, in debates about CS, its potentialities and limitations. This may be due to the nature of the projects themselves and the considerable logistical challenges they face but it may also be due to a lack of clarity because of a deeper ambiguity concerning what CS is and how it can best be promoted at a time when our epistemic culture is becoming increasingly heterogeneous.[40.] Additionally there is also a general ambiguity within science communication studies over what PE is and should be in the first place.[41]

In a social science literature that has so far concentrated on assessing the learning and science policy outcomes of CS, the voices of scientists and science communicators themselves have been little heard(see also Bonney et al.'s call for more research in this area[42]). Focusing on the UK's Open Air Laboratories (OPAL)[43] Programme, a particularly innovative and encompassing programme with a combined outdoor learning and CS component, we draw on a series of interviews with the scientists and communicators involved to offer an empirical analysis of the challenges they faced, and thus aim to open up some of the potential conflicts anticipated in this section to further research. The paper compares their experiences in order to identify three potential flashpoints that we argue will need to be taken account of in the design of future CS projects if they are indeed to be win-win scenarios for both scientists and the participants.

Drawing on semi-structured interviews with some of the senior and junior scientists and science communicators involved in this programme as well as our own lived ethnographic experience (one of the authors was instrumental in setting up and managing OPAL but deliberately played no role in conducting and analysing the interviews), we aim to identify some of the challenges involved and offer some reflections on the tensions and flashpoints that need to be navigated when designing and working on a hybrid CS project.

Although there are as yet no studies we know of which have examined the experiences of the professionals involved in CS initiatives, we can partly form a view of the scientists' evaluations of CS through the literature they publish themselves reflecting on their experience.[44,45,46] Such papers provide a rich source of scientists' reflections on the process of engaging in CS. While these studies hint at some of the more problematic aspects of CS work, they are usually limited to one particular type of project and often only include the authorial voice rather than those of all those involved. This limits the sociological density of description of CS projects because these papers are written usually for a specific purpose, a specific audience and privilege a Principle Investigator's point of view that might be at odds with the lived experience on the ground, especially by more junior and therefore institutionally less powerful actors.

2. The Open Air Laboratories Programme

Typical of many CS projects, but arguably unique in its ambition and scope, the Open Air Laboratories (OPAL) is a portfolio of projects in the UK that funded by a National Lottery Grant that has been running since 2007. It was set up with the aim of enhancing environmental knowledge and attitudes (as well as other goals, discussed below) by involving members of the public in the production of science. On the surface, OPAL looks like a classic piece of CS (in Bonney's sense of an informal science learning event). Under the direction of mostly university-based scientific teams, participants help gather data in areas such as biodiversity and air, water and soil pollution (since the interviews were conducted, a seventh OPAL survey (on tree health) has been launched in May 2013). Six national research teams (two teams at Imperial College London and one each at UCL, the Open University, the Natural History Museum and the Met Office) were commissioned to design a series of national surveys on soil, air, water,, biodiversity and , climate.

Data collected by public participants can be submitted to a national database that scientists and the public can access for analysis and interpretation or collected directly by scientists. So, for example, one survey involves identifying soil properties such as pH and soil type in small (20cm x 20cm) pits and counting and identifying earthworms. Results are then entered in the OPAL website, with the locations given through either postcode, ordinance survey grid reference or smartphone GPS applications. In addition to self-motivated participants who use survey packs/instructions given to them by OPAL or downloaded from the website, the project also employs a number of regionally based "community scientists" who organise field days with local community groups and schools (particularly targeted at "hard to reach" groups), where they help with and supervise participants with the surveys as well as educating about environmental issues. Educational materials and interactive tools are provided to help with practical tasks such as species identification.

The national surveys are supported and delivered through nine regional centres at Imperial College London and the universities of Hertfordshire, Plymouth, Nottingham, Birmingham, Newcastle, York and Central Lancashire who employ the community scientists mentioned above. Most of these regional teams also run their own, smaller scale citizen science research and education projects alongside the national surveys: For example the Hertfordshire group runs a survey of orchards and Birmingham runs a series of studies on urban birds, bats and bees. These regional CS projects tend to be smaller in terms of the amount of participants they reach as well as being more intense with how participants are engaged; the Birmingham group for example is training a group of about 20 members of the public with accredited bird-ringing skills. The data collected by participants are used by the research teams to produce scientific research in the form of published papers and PhD (and some MSc) projects. Some but not all of the research students funded through OPAL are also working on CS projects both on the national and regional level, but are not (again with several exceptions) required to engage directly with the public, though most do so voluntarily. Scientist also carry out research without involving the public in the data collection but they share their findings with local people through local events, workshops and regular bulletins on the website and through publications aimed at the lay person.

Although CS is a major component of OPAL, this knowledge production component is overlaid with various other ambitions, notably an outdoor learning aspect designed to connect people to their local environments and a PE component which aims to provide the public with opportunities to contribute to the resolution of environmental issues. OPAL also involves non-academic partners that help with the delivery and design of national surveys such as the Field Studies Council and Royal Parks as well as associate partners, Defra (the UK government department for Environment, Food and Rural Affairs) and the Environment Agency. OPAL also provides support for the biological recording community: Grant schemes for natural history societies, new recording software ("Indicia"[47]) and interactive tools from habitat data to online photographic identification services ("iSpot"[48]) have been set up to support both experienced naturalists and those new to biological recording. While roughly 50% of the grant goes towards research, the remainder is directly used for community engagement. The need to engage people and communities previously little involved in, or aware of, their local environments is clearly a major part of the OPAL mission and this is achieved either through direct approaches to communities and the data collection activities described above, through leafleting or events or via the local authority or other collaboration with voluntary networks. This is reflected in the range of professional communicators involved in the Programme.

3. Scientists' and science communication practitioners' experience: flashpoints and trade-offs in CS

Drawing on a series of 41 semi-structured interviews with OPAL professionals (42 in total, with one interview involving two participants), we have compared reflections on the experience of being involved and personal assessments of the Programme in terms of its ability to meet the ambitious goals outlined above. Interviews lasted between approximately half an hour to an hour, and were, with the participants' permission, recorded, transcribed and then analysed qualitatively for emerging themes. In the discussion below, interviewees are signified by a unique number as well as the seniority of the interviewer, whether they work in a regional or national project (or one of the other institutions that are OPAL partners such as the Field Studies Council) and whether they are employed as scientists or science communicators. 17 interviewees were senior partners (i.e. permanent academic staff or project leaders for the non-academic partners), the rest (25) were junior (i.e. temporary academic staff such as postdocs and postgraduates as well as temporary science communicators). 14 interviewees worked on a national project, 23 on a regional project and 5 "others". 30 worked as scientists (either as full-time staff or postgraduates; this includes 5 social scientists), 10 were working purely as science communicators (and 2 "others"). Some interviewees were hired both as scientists and science communicators (9), these are classified as "scientists" for the purposes of this paper (going into more detail of the interviewees' positions would compromise anonymity). Questions put to the interviewees included their assessments of how CS has worked from their point of view, how they see PE and its aims, and whether they were happy with how OPAL has contributed to both the science and the PE as they interpreted it. The analysis presented here concentrates on how the interviewees viewed the relationship between the science and PE element that characterises this type of CS by identifying three themes that we feel need to be theorised further if future CS projects are to be successful. Quoted excerpts from the interviews were chosen as salient examples of the discussions we had concerning their opinions on their work on OPAL, PE and CS. The three sets of issues identified below were not part of the interview protocol as such but rather represent thematic categories that crystallised during the analysis.

Despite strong support for the OPAL Programme amongst our interviewees, and considerable collective enthusiasm for the new, more publicly-engaged sort of science it promotes, many recognised an inevitable tension between successfully engaging with lay publics and ensuring reliable data collection. For some, there has been a direct trade-off between meeting the PE objectives of OPAL and its effectiveness as a form of collaborative science and many interviewees admitted they had underestimated the amount of effort that they would need personally to invest in a project designed to kill "two birds with one stone" (29 junior, regional, scientist). Various other tensions were expressed and we present here a series of 'flashpoints' in order to capture these.[49]

Breadth vs. depth

One often cited value of CS is that it can mobilise a much greater recording effort by larger numbers of participants than could be afforded if undertaken by professionals alone**.** But achieving this wide reach may require the standardisation of methods and a more limited individual engagement of participants with scientists. Typically a decision needs to be made at the outset of a CS project concerning what the scientific added value of the public contribution should be. As one of our respondents put it, “do we get lots and lots of simple data or [...] lower amounts of more complex data?” (2 junior, national, scientist). OPAL is designed to achieve both though the inclusion of several types of CS projects in the portfolio. The national surveys that are core elements involve large-scale participation (as of 7 June 2013 the earthworm survey generated 4410 field surveys[50]), while the regional projects (such as the Birmingham group’s bird research[51]) are typically focused on close engagement with smaller groups of participants.

Both these modes of engagement bring their own unique advantages and disadvantages. Asking large numbers of the public to participate means that vast quantities of data can be collected in many different biophysical settings. This generates a much wider geographical coverage than is usually feasible. Although the data recordings are often straightforward (in the OPAL earthworm survey case, alongside more detailed recordings such as species identification and soil type, participants are also asked to record the simple presence of earthworms), having such a wide geographical spread of observation is advantageous for the scientists involved:

> just the abundance of earthworms is, is... because then we can relate earthworm abundance to soil PH; to habitat type. And that’s never been done on such a large scale, so that’s valuable (1 junior, national, scientist)

Or, as another senior scientist put it:

> Has it been useful? Yea [...] it allowed us to look at big scale, big pattern, big picture patterns, it’s not highly scientifically rigorous, so it will always have those limitations, but strength of numbers helps overall overcome some of those limitations (30 senior, national, scientist)

A further advantage is that data can be gathered from places that are often inaccessible to scientists, such as private back gardens: “we gain access to areas that we wouldn’t otherwise access” (31 junior, national, scientist).

There are however limits to what type of data we can ask of the public; surveys that require sensitive or expensive equipment or handling dangerous substances are not suited for mass-participation CS.

The value-added for the regional “depth” projects is the lay expertise and effort provided by the individual participant, who will be able to bring their own lay knowledge or their own perspective on the science being performed. This does not mean that only lay experts can contribute to such CS projects. However if they are not already lay experts, members of the public need sufficient training or supervision to carry out more intensive tasks. In this mode of CS, participants can become research assistants, trained and/or supervised by the professional scientists and as such able to play a role as active collaborators within projects**.** In some cases, for example when it is felt that the layperson has contributed substantially to the eventual outcome, co-authorship of the resulting scientific publications may even be offered (as reported by one of our interviewees, 3 senior, regional, scientist).

The trade-off between depth and breadth was theorised into a general classification of CS by one of the interviewees:

> We've always viewed it as a pyramid, [...] where you have the broad base at the bottom, which is you can engage a lot of people in science communication and fairly simple, go out there and tell us what birds you find kind of approaches. So communication followed by data generation if you like[...]. And then you can gradually move further up until at the top of the pyramid you've got very in depth projects which inevitably, with smaller communities, and whereby the communities themselves, whoever they may be, whether it's naturalists or local housing associations, could be anything like that, who are actually informing the science direction, so a true collaborative project, whereby the public are steering the direction that scientists are working on. (16 senior, national, scientist)

Career Science vs. PE

As outlined above, one of the main reasons for the recent enthusiasm for CS is that it seems to offers a way to combine good science and extensive PE. The involvement of research-led universities and public research institutions in OPAL suggested confidence that this could be achieved through the Programme. Indeed, one of the aspirations and hoped for outcomes of OPAL was that by demonstrating the benefits of integrating PE with scientific research it would motivate senior scientists to continue to engage with the public. The added value of CS for the public is that they participate in real science, which the interviewees thought has made a real difference to individual motivations: "I think the fact that we are doing something with the science data has been a real hook to get people doing the surveys" (17 junior, national, sci. com.). Interviewees also recognised that the fact that the public gets to meet and interact with practising scientists was an attraction. The science side of OPAL was also seen as a major success, and the data collected by the Programme were regarded as important in advancing scientific research.

However, it was also recognised that trying to be both at the same time has led to conflicts, both at an institutional and a personal level. To start with the institutional, most OPAL sub-projects were embedded in public research institutions such as universities. While there is a growing recognition that these institutions need to be more public focused and open towards community outreach and engagement, in practice (and naturally) they remain focused on research.

> Within the university context I would say [OPAL's remit] is slightly more tricky. [...] The university likes doing public engagement and outreach and

> those kind of knowledge exchange activities; the way we get money and funding as an academic is research councils and peer reviewed publications and REF and this kind of stuff (39 senior, regional, scientist)

The need for OPAL to straddle the different institutional requirements of universities and the project funder has brought a large amount of stress onto some individual researchers on the project:

> As far as I can see the institutions took the lottery money to do research and the lottery put up with that because they were paying for outreach. And essentially the kind of the people like me [...] get caught in the middle having to satisfy both of them really (28 junior, national, scientist)

Though most interviewees were not as negative in tone as this particular interviewee, many were willing to acknowledge a clash of interests between the funding organisation and the universities and research institutions, within which individual OPAL projects were embedded. The overall aim of one partner was not necessarily that of another, and those administering OPAL needed to negotiate these tensions very carefully.

These differing institutional aims and how exactly OPAL fitted into them, also in turn created tensions for the individual scientist having to justify investing time in activities other than science. Although PIs generally allocated less than 10% of their time to OPAL work and were given PhD studentships so they could continue with their research, there was a general worry about the way promotion panels and reviewers would view this diversion of effort even for some of the more established academics:

> *Respondent*: Well I haven't had my appraisal yet. But I have a pretty good idea of what they're going to say [laughs].
>
> *Interviewer*: You expect that to be a problem?
>
> *Respondent*: I expect it to be an issue, yea. Which is awful really. It is awful that you can't do that kind of work and get credit for it on its own, without having to justify all the time why you haven't done any publications. (26 senior, regional, scientist)

A few scientists made this point by talking about "pounds per paper" spent on OPAL, and how they fear this might go down with university management. Though in the quote below this did not reflect their personal experience because plenty of papers came out of their research for OPAL, it was nonetheless something that clearly worried them:

> I know this well enough from our promotion panels, when we pick up a CV, if it's got a shedload of money on it and no output, people will think the money's been wasted. Yea? So I have half a million pounds extra on my CV, if I don't have academic papers for it, it looks like I've squandered half a million pounds (3 senior, regional, scientist)

The OPAL management team has tried to minimise these impacts by encouraging the appointment of "community scientists" to take on the role of the PE work. OPAL community scientists are working within the regional centres and help in disseminating and getting the word out about OPAL in their local region as well as organising field trips with hard to reach community groups (such as certain schools, young offenders or asylum seekers), where they include and guide them in both national and regional OPAL activities. They are usually the public faces of OPAL in that they have most contact with the public, and though senior scientists also often go out meeting the public directly, the community scientists are the main driver in organising, planning and disseminating OPAL activities at this scale. The precise role of the "community scientist" is very varied owing to the bottom-up organisational structure of OPAL that let each region develop their own projects. Several regional teams have hired community scientists in a hybrid role that combines research work on the local project with being a community scientist. These can be postdocs or PhD students. In two regions, the community scientist was recruited to the department's PhD program later on.

Hybrid communication and research roles however were not unproblematic, and some interviewees have struggled in straddling the two elements of CS:

> it's several roles rolled into one. I mean it's essentially, for two part time jobs I, they're not they're two full time jobs to do them properly I'd say really. And if you're not going to do it properly, then.... you know if you do it fifty percent you don't necessarily get fifty percent done, you might only get twenty percent done (28 junior, national, scientist)

> I'm probably doing more science than I'm probably supposed to be now so that, because I'm not an arsehole what I do is then just extend my hours so my holidays my weekends disappear, my evenings disappear (4 junior, regional, scientist)

As was pointed out in some interviews, a strict separation of engagement and research roles inevitably diminishes the extent to which the public have been able to work alongside senior scientists, which was identified by many interviewees as one of the strong advantages of OPAL and CS generally.

The balance between science and PE that needed to be struck by OPAL was therefore a very fine one, and it was sometimes felt that universities' institutional structure has not yet adapted to the new challenges faced by CS:

> OPAL is ahead of the game here, you know, we're doing stuff that we'd like to see happening much more widely, but we're doing it in a framework that doesn't recognise the value of part of what we're doing. (30 senior, national, scientist)

Moving into full-time PE remained a career option for junior OPAL scientists, however these were not perceived as particularly attractive, because this sector is (perceived to be) blighted by low wages, no job security and little career progression[52]:

> they're getting paid 15, 16 grand a year, they're usually young, they're very enthusiastic, they know quite a bit, they don't know as much as an academic but they're very good at outreach, but they only do it for a small period of time

> because first of all generally they're funded by a grant so they [...] don't know if they're going to be employed or not. And also the kind of wages they're getting you get to 28 and they go "I'm tired of living with my mum, I can't afford to possibly get on the housing ladder, I can't possibly afford to have children" so they leave. So there are those sorts of jobs, but they are not particularly well thought of. It's not a career. (4 junior, regional, scientist)

As noted above of course, there was also traffic going the other way in terms of career development, where community scientists took up PhD studies and therefore used their OPAL PE work to develop their scientific careers.

Deficit vs. Dialogue

One of the paradoxes of many PE-focused CS programmes is that despite having a stated mission to empower amateurs and untrained volunteers, their success often requires considerable oversight by professionals. An important aspect of this is the process through which people are enrolled and recruited to work on CS projects and the extent to which advance training needs to be given to participants before they can become effective 'citizen scientists'. Since the earliest criticisms of top-down science and the deficit model of understanding it embodies, there has been a general nervousness about the idea of transferring knowledge from professional scientists to amateurs. For our interviewees, this was a flashpoint more implied than articulated directly, and it came for example in the form of being unsure of what to make of the academic PUS literature and its often negative and caricatured depictions of deficit models when they pick it up Nevertheless, there are hints throughout the transcripts of a need to think more openly and honestly about the need for knowledge transfer within even the most publicly engaged CS project.

If there is any conceptual conflict between the "knowledge deficit reduction" and the conception that science communication needs to be a genuine two-way contextualised dialogue between scientists/experts and the public(s), then it was certainly not recognised by our interviewees. Under OPAL, knowledge and information transfer is an important and widely acknowledged feature of the Programme. There was a general feel that people simply do not know as much about the environment and science as a whole as they should: "it's amazing how many people out there are really ignorant of anything around them, you know..." (25 junior, regional, scientist). The assumption was that, by learning more about science and the environment, participants would become more enthusiastic about, and empowered in relation to, environmental science and environmental protection:

> I think it is important to learn about nature and the environment and maybe they [participants] have a bit more... you know like ownership of the local area and stuff [...] It's trying to get a general sort of message across (6 junior, other, sci. com.)

However, these more traditional deficit style assumptions about the value of PE were often qualified by our respondents. Scientists should "not be seen as dogmatic" (1 junior, national, scientist) about their science, they need to acknowledge lay and local amateur expertise where it exists and they must continue to be responsive to different audiences and their different and varied needs. Moreover, they must acknowledge that PE is a two way dialogue. This in a sense echoes previous research on scientists' and science communicators' discourse on PE, e.g. Burchell[53] found a switch between interpretative repertoires between deficit and dialogue talk.[54] However we found the discourse within OPAL to be more nuanced and, importantly, informed: Many interviewees were aware of discussions within science communication studies surrounding the critique of deficit models, but often struggled to find them particularly relevant to their own work. Instead their views were better reflected by van der Sanden and Meijman[55], who see dialogue *as a method of* pursuing deficit reduction aims, and therefore the two should not be thought of as competing aims. This is also echoed by growing discontent noted above within the PUS discipline about whether the deficit/dialogue divide has any practical relevance,[56] though it has to be noted that even there, attempts at reconciliation involve concepts like upstream engagement which are more applicable to new and controversial sciences such as GM crops rather than the more inoffensive conservation and environmental science that OPAL engages in.

Contrasting science communication as imparting knowledge to uninformed members of the public with science communication as a dialogue that informs both parties was also problematic. Many lay members of the public were very well informed and could "run rings around many of the scientists when it comes to sort of specifics of what they're interested in" (31 junior, national, scientist), and of course participants of OPAL also included not-so lay members of the public such as retired university professors. On the other hand, many people came to OPAL with the intention of learning something new and as such also often lacked the confidence in their survey results (which is what OPAL scientists feel explains the relatively low number of returns from the amount of survey packs they hand out).

There was however a more deep-seated ambiguity within OPAL concerning the extent to which the Programme had broken through a lay-expert divide. "Breaking barriers" was also one of the recurring themes within the interviews about what motivates the scientists and communicators to do PE. But in order for this to work in practice, OPAL pursued an at times traditional education programme in which participants needed to be told what to look out for, how to do it, and why they are doing it. Surveys were designed to stand alone and did not need to be supervised and many survey results submitted came from people who had carried out the survey without support but many groups wanted to be supervised. In this instance rather than breaking a barrier between experts and lay publics, the effect was to maintain a sense of distance between 'the experts' and 'the public'. Projects like the national surveys promoted a clear sense of the expertise of the scientists directing them and the status of the participants who needed to 'follow instructions' and get to learn about science where surveys were led by community scientists. This divide, it was argued, should be seen as desirable and it is what participants want:

> some of the literature that I was reading about motivations for being involved in biological recording and monitoring was about the enjoyment of being part of the scientific process, and I think that requires a expert-lay divide because that's what you're bringing to it as the expert (38 junior, regional, scientist)

Overall, our interviewees were often much more clear about the engagement goals of OPAL; they saw it as an education project working through dialogue and empowering the public to "take control of their environment", but with the scientists/experts firmly in control. However, there were also some isolated opinions that aimed to move beyond these boundaries and conceptualise a vision for OPAL that simultaneously educates and involves the public as equal partners in the science and even science policy project:

> *Respondent*: I think it's a combination of [the data, education and policy aims of CS] that uses synergies that give you a net benefit almost. And I think that's the sort of thing... and there is a period or a trend in the environmental policy science systems that refers to this integrated view of the environment with the public being part of it, and I think that helps to build a...
>
> *Interviewer*: right, so it's building up a kind of integrated public policy...
>
> *Respondent*: exactly, where science, policy makers and the public is connected in a way that brings a more realistic view of the reality of the problem and the solutions. (11 senior, national, scientist)

4. Discussion and Conclusions

The three flashpoints identified above point to tensions felt by OPAL scientists and communicators about fitting research and various PE objectives together in CS. Because PE and research are different activities with their own (sets of) goals and modes of operation, this suggests that if CS is to be a successful combination of both, careful thought needs to be given to what precisely we want to get out of it, who benefits from it and how, and how it should be organised in practice in order to pursue both the institutional and personal goals behind such projects. If not conceptualised carefully the PE and science side of CS can pull in opposite directions, as argued by one interviewee (4, junior, regional, scientist). Therefore being clear about what the goals of a CS projects are, and how they are best pursued, will help in the design of the project as well as help in anticipating potential difficulties a project may face.

None of the three flashpoints are necessarily unique to CS as PE practice, though we would argue that CS can feel them particularly acutely both due to its hybrid and often still somewhat undefined nature, but also because it aims at a much closer relationship between science and PE than most other PE activities. Thus for example, every PE programme will face the choice of either engaging many people more superficially or fewer people more intensely, but in CS there are added complications around research design and how to conceptualise the public value-added to the science (often in a way that could have not been done by scientists alone). Because science and PE are so intimately intertwined in CS, decisions made on the PE side of the coin also affect the science.

Similarly, in any scientist-led PE activity trade-offs will have to be made in terms of balancing scientific and academic careers with spending time on PE (for professional scientists), while those wishing to develop PE into a main career, the limitations in terms of funding, short-term contracts and relatively low salaries are constraining factors for non CS PE as well. However CS as a purported win-win scenario can easily portray itself in a manner that skips over these worries — after all the scientists will get science out of it, rather than merely participating in PE, and therefore these worries can end up being downplayed when they should not be. Performing hybrid research and communication roles left people feeling often unable to give both sides of CS the attention they deserve without having to work extra hours, and possibly damaging future academic careers. Separating research from communication roles however removes the advantage for the public of interacting with genuine scientists. Again, because research and PE are intimately intertwined, this is a more intractable problem for CS because it is not possible to separate communication from science activities, and scientists are therefore not in a position to back out of their communication activities: A scientist can cancel a public lecture or say no to appearing on radio if they felt they need to concentrate on their science, but no is not an option when the science itself relies on the performance of effective communication activities.

Finally, the deficit vs. dialogue choice that needs to be made in the design of CS projects needs also to be made explicit in formulating the goals of any PE project, yet the “breaking barriers” rhetoric of much PE sits uneasily within a strictly hierarchical project design that relies on the experience and expertise of the professionals as well as the strict boundaries they need to set up in order for the projects to function. The nature of the engagement in CS is that members of the public enter into a constructive partnership with the scientists overseeing the research, and in this it differs from other one-way PE activities. Unlike science shops or upstream engagement however, this public contribution stays within strict parameters defined by the experts (unless the CS project is specifically designed to involve the public in the planning and setting up of the research questions as in the “co-created” CS as described by Bonney et al.[57])

The general appraisal of CS as seen from the scientists and science communicators then is that it is definitely worth doing, but also that it is not paradigm changing in the way PE gets done. Despite often enthusiastic rhetoric to the contrary, CS as a form of PE is not immune to the problems faced by PE in general and that therefore the “win-win” scenario that is often hoped for with CS is rather muted. On the contrary as outlined here there are good arguments to be made on why CS might be particularly vulnerable to these problems.

On the positive side however, there are plenty of factors that make CS a particularly worthwhile form of PE (and of science and/or monitoring): The interviewees were certainly very enthusiastic — despite some of the problems encountered along the way — about their contribution to OPAL and about how the Programme produced worthwhile scientific results. Among many of the senior scientists, participation in

OPAL has certainly increased the likelihood that they would participate in PE in the future because of the personal satisfaction they got out of communicating with the public, although some also reported that the experience may have demonstrated that PE is after all maybe not an activity they are particularly suited to, which in itself is of course also a valuable learning outcome. The flashpoints in this paper we would argue are reminders of the difficulties that need to be addressed if we want to get to this stage and that CS is no panacea for these: the happiest participants were those who felt little career pressure, knew how to involve the public in a way that complemented their science and had clear ideas of what they wanted to get out of doing PE.

Acknowledgements

We wish to thank the OPAL scientists and communicators for their time and opinions. Special thanks go to Laura Gosling and Roger Fradera for their support, both in relation to OPAL and the production of this paper. The study was funded by the Big Lottery Fund through the Changes Spaces programme and the Open Air Laboratories (OPAL) project.

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Authors

Hauke Riesch is a lecturer at the Department of Sociology and Communications at Brunel University. His research interests are the public understanding of science, especially risk and the environment, science blogging, popular science and the sociology and philosophy of science. Email: hauke.riesch@brunel.ac.uk.

Clive Potter is Reader in Environmental Policy at Imperial College London. His research interests include issues around stakeholder and public engagement in public policy decisions relating to rural land use and biosecurity.
Email: c.potter@imperial.ac.uk.

Linda Davies joined in Imperial College London in 1999 from a background in environmental policy. Her doctoral thesis and research are focused on biological monitoring and urban ecology. She has worked on a number of ecological projects including the UK National Ecosystem Assessment. She proposed the concept for the Open Air Laboratories (OPAL) programme in 2005 and led the partnership that delivered it from 2007 to 2013. She is a founder member and Director of the European Citizen Science Association. Email: linda.davies@imperial.ac.uk.

HOW TO CITE: H. Riesch, C. Potter and L. Davies, "Combining citizen science and public engagement: the Open Air Laboratories Programme", *JCOM* **12**(03) (2013) A03.