DBS 2 (2) pp. 197–215 Intellect Limited 2016

Volume 2 Number 2
 doi: 10.1386/dbs.2.2.197_1

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Social Responses to Nature; Citizen Empowerment through Design

ABSTRACT

Traditionally, design content creation has remained within professional practice and manufacturing industries. Open Design (OD) utilizes accessible fabrication, enabling lay users to create and reappropriate content. Citizen Science encompasses activities where communities gather contextual environmental data for scientific or community purposes. The paradigm combination provides opportunities for communities, grass-roots projects and social initiatives with opportunities to create 'products' addressing personal and global issues. Social design (SD) combines OD/Citizen Science practices, empowering responses by fostering 'innovations that are both good for society and enhance society's capacity to act'. This article highlights a SD case study that applied OD/Citizen Science to beekeeping. The 'Bee Lab' project empowered participants to construct data-gathering devices, embodying Manzini's SD approach. The case study aided motivated participants to address local/global issues, facing Apis mellifera *(the honey bee). The project yielded insights into*

KEYWORDS

social design
Open Design
Citizen Science
human–computer interaction
conservation
public engagement

motivation, community leveraging, public engagement for social good and more. Insights have been distilled into repeatable stages for analogous activities. The results offer applications for communities, design agents or organizations wishing to address the burgeoning challenges facing social responses to nature.

RELEVANCE TO DESIGN PRACTICE

The design landscape has evolved empowering non-designers and communities, outside of professional industry, to create physical content. The article presents lessons for opening design processes to lay users for Citizen Science purposes, defined through practice. The work engages volunteers, design agents and/or conservation agents for analogous activities.

INTRODUCTION

This article explains a combined approach using Open Design (OD) and Citizen Science applied to users already regularly collecting data. It explores existing 'Citizen Data Harvesters' (CDH) skills in order to unlock their data silos and develop community-wide knowledge exchange. The project explores encouraging greater public investigation of wildlife at a distance using digital technologies, specifically in situations where smartphones are inappropriate. Authors report on a case study, the 'Bee Lab' Citizen Science Project. The project is a response to recent trends complicating the practice of beekeeping observed over the last fifteen years as a result of pesticides, GM crops, changing environment, weather diversity and disease management (Davies, 2007, p. 25). The project builds on *reciprocal motivation* and the data-gathering experience of beekeepers in the United Kingdom, in the design and sharing of solutions to solve community and global issues (Phillips et al., 2014b, p. 54). 'Bee Lab' achieves this by including beekeepers in the design, creation, assembly and deployment of *openly designed* digital monitoring devices. This investigation provides lessons for kit design for Citizen Science, removal of barriers, and translation of user concepts into tangible outputs through research in-the-wild.

In *Design, When Everybody Designs*, Manzini and Coad define social design (SD) as 'innovations that are both good for society and enhance society's capacity to act' (2015, p. 24). Manzini presents 'social innovation has moved from the fringe to the centre of the political agenda', in which 'the classic tools of government policy on the one hand, and market solutions on the other, have proved grossly inadequate' (Manzini and Coad, 2015, p. 31). This social shift extends design capabilities because the public can respond to their own issues. Manzini describes 'locality and openness' to be an important attribute in design as 'self-sufficiency to promote community resilience to external threats and problems' (Manzini and Coad, 2015, p. 22). In *Design for Society*, Whiteley remarks that we are surrounded by 'consumer and market-led design', but not design for and with the society itself (1997, p. 15). Papanek, the infamous author of *Design for the Real World*, discerns that 'the designer[s] must now be combined with a sense of social responsibility' and should not be 'short-ranged' in their outputs (Papanek and Fuller, 1972, p. 53). These SD experts promote design interventions empowering users to be actively engaged in interventions that affect them. The writers identify that SD needs to be community appropriate, and enhance societies' capacity to act and reciprocate to its audience, through accessible, or 'open', mechanisms.

WHAT IS OD?

OD emulates the 'patterns' concept from the textile industry, enabling users to adapt 'designs' for fit and material (Kraft, 2004, pp. 274–89). OD is not a new phenomenon as people have adapted products/materials from descendants and shared knowledge since the dawn of fire making. The development of this phenomenon is that 'Weblogs and Wikis have been readily adopted in civil society and are transforming the way many of us access information', making information accessible (Hasan and Pfaff, 2006, p. 197). OD democratizes 'processes, systems or products; enabling users to self-create and edit solutions using digital fabrication' (Carson, 2009, p. 82). Digital manufacture enables lay users to *download* products and reproduce them in 3D with digitally enabled tools such as 3D Printing. OD complements digital manufacture through the 'reproduction of physical goods through digital processes' (Lipson and Kurman, 2013, p. 186). In 'Open design: Contribution, solutions, processes and projects' Tooze et al. clarify OD as a 'catchall term for various on-and-offline design and making activities. It can be used to describe a type of design process that allows for (is open to) the participation of anybody (novice or professional) in the collaborative development of something' (2014, p. 538). OD enables collaborative efforts by providing 'incentives and methods for the freely sharing design information' (Vallance et al., 2001, p. 2). While there are inherent problems in 'opening processes', including: repeatability, calibration, consistency and quality control, there are advantages of distribution, adaption and concept development. These platforms and designs enable non-technical users to be involved in designing and creating products, referred to as 'user-designers' (Von Hippel, 2005, p. 25).

WHAT IS CITIZEN SCIENCE?

The recording of seasonal events has been a pastime among natural historians, 'with records going back to the 1730s' (Sparks and Carey, 1995, pp. 321–29). Citizen Science is defined as 'the involvement of volunteers in science' and can provide an 'indispensable means of combining environmental research with environmental education and wildlife recording' (Roy et al., 2012, p. 4). During the last twenty years, environmental issues have come into greater focus for the general public. While wildlife and national parks are encouraging public engagement, 'biologists have pointed out for decades that protected areas are not playgrounds: [wildlife] parks are assets for tourism, but they are not tourism assets' (Buckley and Pannell, 1990, pp. 24–32). Citizen Science projects examples include eBird (ebird.org), a real-time online checklist program, cataloguing '1,000,000 bird observations monthly reported by participants' (Cornell Laboratory of Ornithology, 2013). Commercial monitoring still has exceptionally high value applications but relies on incentivizing participation.

COMBINING OD AND CITIZEN SCIENCE

Existing projects partnering OD and CS have included Public Laboratory of Open Science and Technology (publiclab.org) and Air Quality Egg (airqualityegg.com). Citizen Science activities are not always technological responses. Sussex Wildlife Trust (sussexwildlifetrust.org.uk) created a 'guest shepherd's scheme', inviting ramblers and dog walkers to observe and report on sheep's welfare (Blencowe, 2013). The combination of OD and Citizen Science could enable community action by participants contributing to solving local or global issues through personal activities – i.e. SD. With the OD/CS combination in mind increasingly, 'the greatest limitation [for personal fabrication] is neither cost nor research; it's simply the awareness of what's already possible', highlighting methodology and process requirements to optimize user-designers' outputs (Gershenfeld, 2005, p. 55). The 'Bee Lab' project was initiated to explore what is required for non-technical users to create monitoring equipment using OD for individual need, while contributing to community challenges, beyond the use of smartphones.

THE 'BEE LAB' PROJECT

'Bee Lab' builds on studies engaging beekeepers in the design of equipment, defining fabrication abilities (Phillips et al., 2014a, p. 54), user-led participatory design workshops and ethnography practices (Phillips et al., 2013b, p. 54). Studies highlighted existing beekeeper motivation for data gathering from beehives. It created a strong case for OD to facilitate beekeepers in sharing their data with each other and to strengthen ties as a wider community. We hypothesize that OD can provide positive uptake of CS through mutual reciprocity in gathered data and form new models of engagement, data gathering and responsibility for participants' surrounding area.

Beekeepers are stockholders of a completely wild and undomesticated creature, the honeybee. Bees can visit 1500 flowers and fly up to 500 miles in their lifetime. This work equates to a large percentage of pollination for our food chain: 'without bees, McDonald's would only have the buns to sell' (Henein and Langworthy, 2009, p. 25). Traditional beekeeping techniques 'avoid over handling, making it hard to witness signs of disease or negative impacts without opening beehives'; digital sensors can monitor without disturbing hives (Davies, 2007, p. 15). Hive monitoring systems and initiatives exist, such as The National Bee Unit (NBU) (nationalbeeunit.com) in the United Kingdom, but are closed systems with design improvements not openly shared. Presenting user led opportunities to control device inputs and outputs. The intention of using amateurs as the target audience of this grassroots study is 'hobbyist[s] offer new insight to the custom requirements of products' (Prettis, 2008, p. 84).

METHOD

The project's initiation engaged beekeepers in design workshops (Phillips et al., 2013b, p. 54), nationally through remote activities using design probes (Phillips et al., 2013a, p. 51) and hackathons (Phillips et al., 2014, pp. 1951–56). A team of technologists, front-end developers, charities, urban and suburban beekeepers, both professional and amateur, were assembled from the United Kingdom. The team ensured that each field was validated according to experience. The research processes helped capture users' ideal monitoring concepts within beekeeping contexts. The project was initiated with lo-fidelity processes that were cost-effective and defined the stakeholders' goals and motivations for participation. Authors and project stakeholders then translated research insights into tangible designs for hive monitoring kits, to support assembly by lay users. The kits, developed in collaboration with 'Technology Will Save Us' (techwillsaveus.com), include off-the-shelf components and adaptable parts/code that can be downloaded or purchased at electronics retailers. Project kit elements were preprogramed, ensuring audiences can edit functionality without compromising assemblies.

THE KIT

The 'Bee Lab' kit provides components to monitor the weight of an entire beehive, the weight of a beehive feeder (internal or external) and internal temperature, identified by beekeepers in our workshops to be of considerable importance (Phillips et al., 2014, pp. 1951–56). Our kits are intended to help beekeepers avoid overinspection and/or opening of hives and present early warning signs in relation to hive health. Knowing the 'weight of the hive and feeder is particularly important during winter months when opening a hive can be detrimental' (Yates and Yates, 1999, p. 42). Out of the box, the kits do not include some components traditionally found in sensing kits, such as wireless connectivity and GPS. During our workshops beekeepers reported concerns that wireless signals may cause problems for honey bees, as well as the highly sensitive nature of hive location owing to theft and vandalism (Phillips et al., 2013b, p. 54). A current requirement for attaining the British Beekeeping Association's (BBKA) 'Certificate in Beekeeping Husbandry' requires the maintenance of beehive records, aligning Citizen Science within the motivations of a hobby (2012, p. 8). The assembled kit not only records bee hive activity periodically (one-hour default and user editable) on removable SD cards, but also displays data *in situ* on an LCD, helping to determine whether further hive investigation is warranted. Beekeepers are encouraged to share data with each other through the Timestreams data-publishing platform (Blum et al., 2013). Researchers presented the 'Bee Lab' sensor kits and Timestreams to beekeepers at a kit workshop recruited nationally via the BBKA (bbka.org.uk) network, which took place at a central London studio. During the workshop, participants assembled kits, examined the designs, and provided

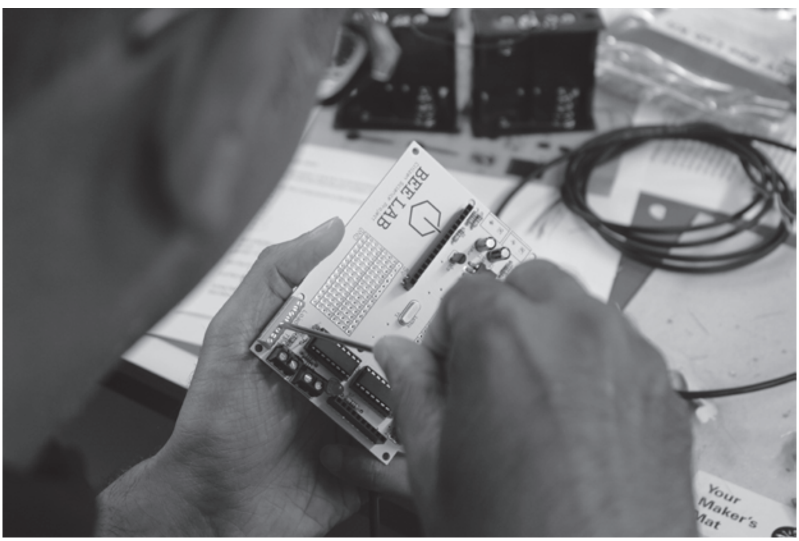

Figure 1: 'Bee Lab' kit assembly.

Figure 2: Deployment of 'Bee Lab' kit.

functionality feedback. Participants had mixed skill sets, including architects, engineers and accountants, all with beekeeping experience and personal apiaries.

The results of the construction workshop made it clear to researchers that user-assembly has merits, including providing users with an understanding of the kits and sense of ownership. Primary among these merits was added value for a user's self-assembled object, or *the Ikea effect* (Norton et al., 2011): 'look what I have made' (participant X). Participants described the reticence of fellow beekeepers to uptake technology, but this CS/OD approach will usually rely on self-selecting groups, rather than regulatory participation. Workshop participants clarified the need to keep beehive locations secret, so deployed locations were accurate to the first three post code pre-fixes, as participants stated problems with hive vandalism and theft.

The motivation of workshop participants were the individual data gathered from devices. During the workshops, participants expressed an interest in reviewing their neighbours' data to understand similar scenarios or possible disease conditions. The project partners were interested in the aggregated data and in increasing the public's knowledge of beekeeping. All stakeholders provided *mutual reciprocity* for the good of a community-wide challenge. Development project partners already opened their code and processes within their networks and 'maker community'. The 'Bee Lab' kits were deployed for three months with hackathon participants supported with troubleshooting by technical support partners. During the study, participants adapted the kits, changing the power units, adapting sensor functionality and removing sensors extending power capabilities. The deployment was later scaled to include 100 participants dispersed within the United Kingdom.

'BEE LAB' PROJECT REVIEW (RESULTS)

To understand repeatable lessons, the process was reviewed with all project parties and categorized into either successful or challenging insights.

Successful insights

- *Plausible engagement*: As the BBKA has over 25,000 members in the United Kingdom, and it is important to consider possible engagement.
- *Aligning motivation* of project participants with stakeholders' intentions: People were encouraged to participate for enriching their experiences and to mutually benefit both parties.
- *Mutual reciprocity* in data gathered: The individual data harvester benefits the community and vice versa.
- *Environment protection procedure*: The participants were experienced in handling their bee colonies. But what if they were not? Future projects engaging with 'openness' need to review the contextual environment it is situated within and protect against damaging it.
- *Data protection agreement*: The participants were willing to share their data as long as online presences were anonymized and they were not publicly compromised as bad beekeepers.
- *Digital economy of data*: The participants when questioned did not conceive their data would individually hold value, but saw the financial benefit of being a part of a wider community.

Challenging insights

- *Validation procedures* for construction, environment, quality and deployment. These elements are reliant on individuals ensuring they had constructed and deployed the technologies appropriately – a possible flaw.
- *Deployment procedures* were standardized, but it was hard to prove and users could contaminate the data pool through negative actions.
- *Constructional liability*: The kits were low voltage, and all safety protocols were adhered to during their assembly.
- The *quality control procedures* were based on technicians' abilities. For wider repetition these need to be embedded into the kits themselves.
- Data *misuse/abuse:* The project did not yield abuse.
- *User safety* was considered: Project users were experienced beekeepers. This requires attention for audiences unfamiliar to the context.

TRANSFERABLE OD/CS APPROACH

Based on the successful stages of the 'Bee Lab' project, an OD/Citizen Science process was created; the following actions and stages are repeatable (Figure 3). Throughout the document different parties have been defined as agents of Design, Stakeholder(s) and User(s). The agents can work in tandem; the design agent is a professional organization; the stakeholder is an organization or wider community with a vested interest in the project and the user is the end user. The insights can be reordered, but are based in financial economic order.

TOPIC REVIEW

When designing for people, communities or demographics it is important to understand the contextual information and ramifications surrounding perceived product requirements and users' aspirations. To contextualize beekeepers' activities and current product usage, the 'Bee Lab'

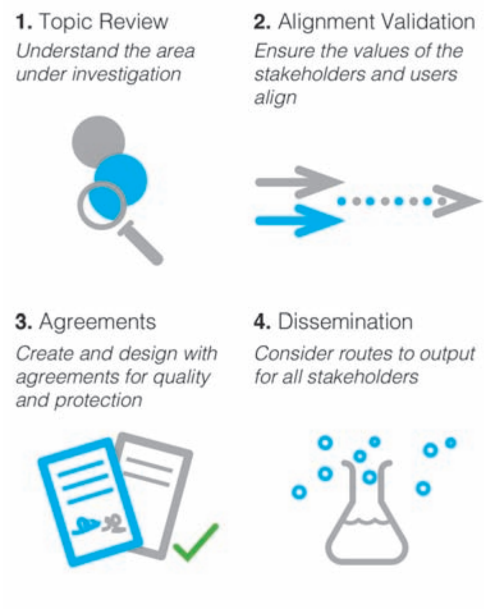

Figure 3: Process of repeatable stages.

project conducted in-depth observation(s) of ‘in the field’ praxis of amateur beekeepers (Hammersley and Atkinson, 2007, p. 3). As Hammersley states, ‘obtaining access to the data looms largely in ethnography’ (Hammersley and Atkinson, 2007, p. 120). To gain access, it was important to gain trust from the best and oldest respected beekeepers in the group. These gatekeepers and ‘experienced hands’ were regarded with a hierarchical status among novices within the group. In ‘Secrecy, trust, and dangerous leisure: Generating group cohesion in voluntary organizations’ Fine dictates that ethnography practice requires ‘trust and secrecy [to] operate by regulating information’ between parties, the observer and the observed (Fine and Holyfield, 1996a, pp. 22–38). Adhering to Fine’s guideline, a seminar was conducted with the studies group, defining study intentions, the author’s commercial practice and ethical codes of conduct. The seminar grounded the study within professional practice, building trust between gatekeepers and consolidating protocols. This scoping exercise should define relevant parties, users, NGOs or organizations that will be interested in possible outcomes and interventions.

In ‘Participatory design in community informatics’, Carroll and Rosson state, ‘in participatory design, the designer’s role is more nuanced and more complex. Ideally, all the relevant stakeholders participate in even the inner loop of design conception, and all continue to participate meaningfully as the design is specified, implemented, delivered, installed, and used’ (2007, pp. 243–61). It is the authors’ view to include users as ‘people have the right to participate in the design of technological artefacts and systems that affect their activities and experiences’ (Carroll and Rosson, 2007, pp. 243–61).

Within the ‘Bee Lab’ project, it was critical to review all of the stakeholders in the project to understand their participatory motivation and their agendas for the forthcoming output; practical ethnography was used for this.

Ethnography explores the dichotomy between 'what people say they do and what they actually do' (Hammersley and Atkinson, 2007, p. 4). Where necessary, researchers 'go native', viewing the world through the eyes of those they are studying (Forsythe, 1999, pp. 127–45). Ethnography can be used in design processes to provide observers with products' 'context of use', presenting opportunities for future interventions (Kensing and Blomberg, 1998, p. 167–85). When 'ethnography is applied to design, it helps designers create more compelling solutions' based on real-world insights (Aiga, 2013, p. 3). In *Community Technology*, Hess states that 'community and technology form a bond, in isolation neither functions' (1979, p. 43). The project started with the community, both urban/suburban beekeepers, enabling researchers to understand their approach, restrictions and opportunities for future development. Hess states that 'if you want to organize the group to look toward social ownership of basic productive needs' (1979, p. 24).

A critical action is producing a research programme, including appropriate processes. Ethnography, design workshops and cultural probes were selected for the 'Bee Lab' project. Design ethnography involves 'the researcher participating, overtly or covertly, in people's daily lives for an extended period of time, watching what happens, listening to what is said, gathering data to throw light on the issues that are the emerging focus of enquiry' (Hammersley and Atkinson, 2007, p. 597). To be effective, codes of conduct require clarification between the observer and the observed. In 'Secrecy, trust, and dangerous leisure: Generating group cohesion in voluntary organizations', Fine dictates that ethnography practice requires 'trust and secrecy [to] operate by regulating information' between parties, the observer and the observed (Fine and Holyfield, 1996a, pp. 22–38).

Insights

- *Data reciprocity*: Data that both the stakeholder and the user/stakeholder want to discover and share.
- *Required motivation*: Identifying motivating factors for end-user participation.
- *Specific community required*: Ensuring the community is interested in activities.
- *Personal interest data*: Individuals might require different outputs from stakeholders providing participation motivation.
- *Surrounding issues*: Are there underlying issues that will impact proposals?
- *Alternate audiences*: Who else can engage with the project?
- *Economic cost of design*: Cost analysis of OD/CS intervention.
- *Pertinent measurands*: Is the captured measurement valued by all parties?
- *Data analysis*: What procedures are required for accurate analysis and field use?

In *Citizen Science: Public Participation in Environmental Research* Bonney et al. define Citizen Science project design parameters thus: 'use multiple technologies, have inherent complexities and levels of engagement dependent on their goals and participatory requirements' (Louv et al., 2012, p. 71). The complexity of Citizen Science and designing for lay users presents challenges. Challenges can include: translating relevant issues and topics for further investigations that are mutually interesting for the user and wider audiences. To explore the tangibility of Citizen Science within beekeeping, it was important to actively scrutinize design opportunities first hand with beekeepers. To understand the complex relationship between Citizen Science and beekeeping with the possibility of this leading to OD opportunities, it was important to 'humanise technology innovatively' (Roux, 2011, pp. 22–25). The primary objective was to understand active beekeepers' and end-users' requirements, alongside project stakeholders.

The objective was to design, create and execute participatory design workshops involving end-users to develop and inform the concept generation stage. Involving 'end-users in research activities [can consequently] have diverse positive effects: on the quality or speed of the research and design process' (Sanders and William, 2001, pp. 110–19). Participatory design workshops make material accessible to participants that might be lacking relevant skills to articulate their concepts. This approach includes participants in the process of design. The 'Bee Lab' project undertook design workshops that created a larger viewpoint that was accessible to all (Phillips et al., 2013a). The work yielded repeatable insights for the Technology/Scenario review.

Repeatable stages

All parties:

- Identify what is already known about the location/issue and who the experts are.
- Review user data requirements that are appropriate to stakeholders.
- Review parallel organizations/wider audiences interested in data collection.
- Review whether data output requirements are appropriate to users.
- Review the project constraints and turn-offs of the user community.

ALIGNMENT VALIDATION

Understanding the audience for Citizen Science activities is imperative as 'the most important consideration is the motivations of participants' (Roy et al., 2012, p. 12). In 'A survey of ungulates by students along rural school bus routes', Galloway et al. describe the process of recruiting school children (living rurally) to document observed wildlife activity on their bus journey to school (2011, pp. 201–04). The project aligns free time with a considered activity and appropriate material. According to French sociologist Marcel Mauss, '[t]here are three main obligations: to give, receive and reciprocate' (1990, p. 10). Participants in Citizen Science activities give their time and receive accreditation or knowledge, and reciprocate gathered data. It is imperative to comprehend what participants receive for their activities, understanding motivation factors so that programmes can be designed and aligned accordingly.

In 'Dusting for Science: Motivation and participation of digital Citizen Science volunteers', Nov et al. highlight that 'the designers and leaders of such projects need to focus their recruitment and retention efforts on motivational factors that are more salient and have a positive relation with intention and participation' (2011, pp. 68–74). The Citizen Science motivation survey of Jordan et al. also found a behavioural change in participants documenting plant types, increasing their knowledge and engaging in more peer learning (2011, p. 1148). The key result from the 'Bee Lab' project was that participants were already motivated to understand their apiaries for personal reasons. Providing them tools to share their data aligned the participants with other parties and their community. There are four important considerations for understanding participants' motivations:

1. Answer *Individual* needs because 'protection of ones' self-interest is key to motivation', ensuring engagement (Clary and Snyder, 1999, pp. 156–59).
2. *Motivation* requires clarification because 'citizen science projects are inherently about partnerships, collaborations between scientists and volunteers' (Louv et al., 2012, p. 12).
3. *Community* needs to be established as 'community and technology form a bond, in isolation neither functions', leading to negative uptake (Hess, 1979, p. 82).
4. Any participant's detrimental fears need clarifying so that they 'do not cause problems later down the line', dissuading participation (Phillips et al., 2013a, p. 53).

Alignment validation is key to the successful uptake of future projects. Callon defines that recruitment is important to create 'co-production of science and society', engaging new audiences (Callon and Rabeharisoa, 2003, pp. 193–204). It is therefore important to validate motivational alignment with future participants based on a test recruitment. To repeat 'Bee Lab's' process, project creators must ensure that both stakeholder(s) and end user(s) are aligned in both intentions and outputs, motivating participation. Note that measurands, data and outputs might not correspond and can be layered to suit each party, while remaining transparent to all parties, with ownership residing with end users.

Repeatable stages

- Ensure plausible engagement from all parties and that the opportunity holds value worth pursuing.
- Validate project data alignment with stakeholders, locally and nationally.
- Validate project user motivation for gathering accrued data.

AGREEMENT CREATION

In 'Limits of knowledge and the limited importance of trust', Sjöberg presents that 'risks tend to be routinely denied or ignored unless or until they have been proven to exist' (2001, pp. 189–98). It is critical to build trust understanding and embracing risk primarily with all the parties. The CS/OD process puts a great degree of trust on all parties and the situated environment. It is imperative that the lay 'public do not view the environment as a playground' (Buckley and Pannell, 1990, pp. 24–32). Environmental tourism and increased footfall in areas of outstanding natural beauty are becoming 'increasingly significant' impacting on the surrounding area (Buckley, 2000, pp. 437–44). The 'Bee Lab' project did not require a heavy-handed approach to protecting users' 'physical self' as they were experienced beekeepers, but the hive interior and technology was carefully considered.

All parties:

- Create user protection agreement, environment protection agreement, data protection agreement and deployment verification procedure. The agreements must be understood by all parties, protecting data, end user(s), organization(s) and environment(s) they operate within.

- Ensure agreements are clearly understood and subscribed to by all, as they are embedded quality control.

DISSEMINATION

Dissemination is the action of delivering the material that has been collated. The audience and the form of accessibility to that audience is important, but also how the output has been validated. The audience needs to be identified as it could be a community, informal, formal or require validation by other means. It is important to carefully consider the purpose of the accrued information: is it for scientific purposes, to engage a community or for something else? The data disseminated need to align with agreements previously stated by all parties.

DISCUSSION

In the *State of Nature* report Burns et al. present that people should 'act to save nature both for its intrinsic value and for the benefits it brings to us [as humans] that are essential to our well-being and prosperity' (2013, p. 7). Burns et al. highlight that 'what we do know about the state of the UK's nature is often based upon the efforts of dedicated volunteer enthusiasts contribut[ing] their time and expertise [to] species recording', so they should be mutually motivated in investigating personal needs to participate (2013, p. 7). The lessons from research in-the-wild can be applied to wider fields, although detrimental factors encouraging people to monitor wildlife/environments require constant expert scrutiny. The defining element of combining OD/CS is the social empowerment for communities to solve their own problems. The initial hypothesis of using OD for positive CS applications can create *mutual reciprocity* in gathered data, forming new opportunities for engagement. Locating *mutual reciprocity* is the fundamental element to motivate participation. Digital fabrication, OD and accessible content are evolving product creation for lay users. Products are no longer isolated in physical form and can be evolved to influence user outputs. The repeatable formula is that participants should be pre-motivated to collect and 'reciprocate data', packaging individual needs within community and project requirements. Prior to project consideration and deployment, the wider impacts require clarity.

An example of a wider impact was Britain's 2001 foot and mouth epidemic. Foot and mouth is spread by foreign contaminants transferred to footwear and freely distributed. In 2001, the South Downs recreation area (1600km^2), located in East Sussex, was closed to reduce the spread of the disease. The public's misunderstanding of their foot traffic's impact exacerbated its spread. The disease claimed farms and 'resulted in losses of £3.1 billion to agriculture' (DEFRA, 2014). Legislation determines how people engage with rare species and the countryside, but currently there are no legal considerations for CS/OD activities. While foot and mouth is an industry-based example, species erosion can be created in back gardens, through bird feeders. *Trichomonas gallinae* is a common parasite to pigeons. Studies in 2012 documented a '30% reduction in green finch numbers' due to the transmission of parasites to other species (Robinson et al., 2010, p. e12215). The Royal Society Protection of Birds state that *Trichomonas gallinae* 'is spread as birds feed one another with regurgitated food during the breeding season, and through food and drinking water contaminated with freshly regurgitated saliva' (RSPB, 2014). The cure relies on the 'public to clean their bird feeders, regularly' as this act of kindness could erode species over time (RSPB, 2014). While this design space is exciting, the authors align with Papanek's views, to avoid creating 'instant experts' devoid of comprehending wider impacts of their immediate actions (Papanek and Fuller, 1972, p. 12).

With the rise of accessible digital fabrication technologies, the responsibility of creating OD/CS objects is heightened as design agents and stakeholders are not just responsible for their creation and environmental impact, but also for their disposal and plausible misuse. How would CS/OD packages be received over time as they potentially hold less value? How do design agents avoid wasting precious resources? Papanek is famous for stating that designers must 'design responsibly' but who controls the general public's output (Papanek and Fuller, 1972, p. 14)? The CS/OD combination relies on volunteers. In 'Understanding and assessing the motivations of volunteers: A functional approach', Clary et al. describe that 'people come with needs and motives important to them' requiring opportunities to fulfil those needs (Clary and Snyder, 1999, pp. 156–59). Volunteers require motivation based on their needs if this is either for self-fulfilment or for group recognition. There are stumbling blocks in the lifelong longevity of this approach, hence why the alignment of the output is critical to the motivation of the participant(s).

'Bee Lab' workshop participants clarified their motivation to participate, as active beekeepers with mixed experience. They were interested in accruing data to improve their honey yield, bee husbandry and aid in foreseeing problems, minimizing over inspection. Opening a process does not always create positive effects; elements within OD projects need clarity concerning users' inputs and outputs ensuring accuracy/repeatability, rigour of gathered data and the technical competence of assemblers/users. The key to repeating this type of activity is finding participants with mutual interests – that is, a fisherman catches and weighs a fish, with the weight data of primary interest to the user but also to fisheries or nature organizations. The agreements identified earlier in the OD/CS process present an opportunity for different organizations to engage with this approach. The scrutiny and reliability is based on how freely those agreements are created, informed by expertise.

CONCLUSION

In order to maximize the potential for our findings to inform future design activities of this type our conclusions have been distilled into an ordered framework for planning OD/Citizen Science activities:

Create project champions

Empower individuals to become advocates for ventures. They will be more powerful/influential within their community than external researcher(s) or organization(s). Issue advocates resources to communicate and recruit.

Listen to desires, not just technological opportunities

Throughout the project, researchers learnt from 'territory scoping' workshops and 'deployment in the wild' with users. While technological interventions are exciting, make sure that users/needs are aligned and avoid over-complicating simple exercises or experiences.

Open 'Design' or assembly

Designing artefacts/systems takes time, reliant on expertise to deliver tangible, economic results. If you are engaging audiences to create/design 'openly' then carefully consider project stages where they are 'designing'. Question user's skill base? Do they need support/resources? What is the output and are validation procedures required? When opening a process, consider whether 'design' phases are appropriate for the audience.

Always think motivation

Consider that community-based projects are not solely about the 'project', but concern what individuals personally yield. Try to align personal user needs with wider communities.

Procedure(s)

The procedures (validation, assembly, deployment and environment/user protection) protect forthcoming project(s), but also protect participants and environments.

FUTURE WORK

The 'Bee Lab' project did highlight that aligning the interests of participants with stakeholders and wider issues are important for the success of OD/Citizen Science projects. The process of alignment and data reciprocity is critical to the presented model and warrants further investigation. Repeating the model with wider audiences, for example, fishermen with a vested interest in the environment they engage with and preserving it for the future could prove fruitful. Develop cross-curricular learning (in schools), kits could form the computing lesson, the data analysis would create science, maths or geography lessons.

ACKNOWLEDGEMENTS

The authors would like to thank the volunteers at supporting activities, project partners and their donations in kind: The British Beekeeping Association (www.bbka.org.uk), social innovation from Wolf Ollins, The Honey Club (www.honeyclub.org), and Technology Will Save Us (www.techwillsaveus.com). This work was supported by RCUK through the Horizon Digital Economy Research (www.horizon.ac.uk) grant (EP/G065802/1).

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SUGGESTED CITATION

Phillips, R., Brown, M. and Baurley, S. (2016), 'Social Responses to Nature; Citizen Empowerment through Design', *Journal of Design, Business & Society*, 2: 2, pp. 197–215, doi: 10.1386/dbs.2.2.197_1

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Image: Blue Morph,James Gimzewski and Victoria Vesna

Technoetic Arts: A journal of speculative research

ISSN 1477-965X | Online ISSN 1758-9533
3 issues per volume | Volume 11, 2013

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