Social Responses to Nature; Using Open Design to Empower Citizen Science in the Beekeeping Community.

Design content creation has traditionally remained within professional practice. Open Design employs accessible fabrication, enabling lay users to create and re-appropriate content. Citizen Science encompasses activities where communities gather contextual environmental data, for scientific/community purposes. The paradigm combination provides opportunities for communities and grassroots projects to create 'products' addressing personal and global issues. Combining Open Design/Citizen Science practices, empowers responses by fostering "innovations that are both good for society and enhance society's capacity to act" (Manzini, Coad 2015).

This paper presents a social design case study applying Open Design/Citizen Science to beekeeping. The *Bee Lab* project empowered participants to construct data gathering devices, addressing local/global issues, facing apis mellifera (the honey bee). The project yielded insights of; motivation, leveraging community and public engagement. Insights have been distilled into repeatable stages for analogous activities. The results present opportunities for organisations addressing the challenges facing *'social responses to nature'*, through social design.

Keywords Social Design; Open Design; Citizen Science; Community; Human Computer Interaction; Conservation

Relevance to Design Practice

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

Introduction

This paper explains a combined approach using Open Design 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 developing 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 15 years as a result of pesticides, GM crops, changing environment, weather diversity and disease management (Davies 2007). 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 (Anon 2013) . *Bee Lab* achieves this by including beekeepers in the design, creation, assembly and deployment of *openly designed* digital monitoring devices. This investigation provides lessons regarding: kit design for Citizen Science, removal of barriers, translation of user concepts into tangible outputs through research in-the-wild.

In *Design, When Everybody Designs*, Manzini & Coad (2015) define social design as "innovations that are both good for society and enhance society's capacity to act" (Manzini, Coad 2015). Manzini presents that "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, Coad 2015). This social shift extends design capabilities because the public can respond to their own issues providing for solutions for themselves, equalling social design. Manzini describes 'locality and openness', to be an important attribute in social innovation because "self-sufficiency to promote community resilience to external threats and problems" (Manzini, Coad 2015). 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 (Whiteley 1997). 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, Fuller 1972) . These eminent social design experts promote design interventions empowering users to be actively engaged in interventions that affect them. The authors define social design as: the creation of artefacts/systems that engage communities, to benefit themselves, other communities and wider society.

In *The Power of Making*, Charny describes that making "allows people to take care of loved ones, worship, mourn celebrate or demonstrate, it is a way of exercising (free) will" (Charny 2011) . Fixperts *(fixperts.org)* a social design brainchild of Daniel Charny is described "not as a social project [but] an open knowledge sharing platform", created as fixing and designing is a "valuable creative and social resource" (Charny 2015). Projects like Fixperts create online communities and unbox design processes, making them accessible to diverse audiences.

The authors believe that social design must align with sociologist Marcel Mauss's insights in *The Gift*, that "[t]here are three main obligations: to give, receive and reciprocate" (Mauss 1990) . The writers identify that social design needs to be community appropriate, enhance societies capacity to act and reciprocate to its audience, through accessible, or 'open' mechanisms.

What is Open Design?

Open Design (OD) emulates the "patterns" concept from the textile industry, enabling users to adapt 'designs' for fit and material (Kraft 2004). Open Design is not a new phenomenon as people have adapted products/materials from descendants' shared knowledge since fire making or warmth from animal skins was required. 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, Pfaff 2006). OD democratises processes, systems or products; enabling users to self-create and edit solutions using digital fabrication (Carson 2009). Digital manufacture enables lay users to *download* products and reproduce them in 3D with digitally enabled tools such as 3D Printing. Open Design compliments digital manufacture through the reproduction of physical goods through digital processes (Lipson 2013). In *Open Design: Contributions, Solutions, Processes and Projects* Tooze *et al* clarify Open Design 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" (Tooze, J., Baurley, S., Phillips, R., Smith, P., Foote, E. & Silve, S 2014) .

OD enables collaborative efforts by providing incentives and methods for the freely sharing design information (Vallance, Kiani *et al*. 2001). Whilst there are inherent problems in 'opening processes' including: repeatability, calibration, consistency, quality control, there are advantages of distribution, adaption and concept development (Carson 2009). Open Design projects currently (at time of writing) in practice include; design platforms *(openstructures.net)*, houses *(wikihouse.cc)*, firearms *(defdist.org)*, farming tools *(opensourceecology.org),* amateur CAD repositories *(thingiverse.com)* and more unpublished projects in development. These platforms and designs are enabling lay or non-technical users to be involved in designing and creating products, referred to as "user-designers" (Von Hippel 2005). With the advent of 3D printable electronic components, capable of producing far-more "functional objects incorporating electronic sensors that can be used in a number of ways" and user-designers will become more commonplace (Leigh, Bradley *et al*. 2012). Whilst digital fabrication offers design file repetition, not all objects require sole digital manufacture. Using mass-produced or 'off-the-shelf' components complimented by bespoke parts, form 'construction kits'. Kits are used in multiple territories including; toys *(lego.com)*, clothing *(threadless.com)*, flat pack furniture *(ikea.com)* and Airfix *(airfix.com)* models cheaper to manufacture for self-assembly. These examples could be adapted with Open Design elements, whilst still remaining viable as a kit of parts. Users have the capability to manipulate Open

Design for personal needs or manipulate outputs beyond a platforms comprehension.

What is Citizen Science?

The recording of seasonal events has been a pastime amongst natural historians, with records going back to the 1730s (Sparks, Carey 1995). 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, H.E.,Popcock, M.J.O., Preston, C.D., Roy, D.B. & Savage,J. 2012) . During the last 20, years 'environmental issues' have become more prevalent to the general public (Law Commission, Reforming the Law 2012). Citizen Science "involves the public in various aspects of scientific inquiry" via gathering local data, meaning the public can engage in protecting environments or species (Louv, Dickinson *et al.* 2012). Whilst 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, Pannell 1990). 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), Feeder Watch *(feederwatch.org)*, a programme for participants to catalogue birds on the feeders and the Elephant Listening Project *(elephantlisteningproject.org),* all relying on non-professional participation for data collection. Commercial monitoring still has exceptionally high value applications including: flood defence *(globalfloodds.com)*, wildlife inventory *(rspb.org.uk/webcams)*, and weather forecasting *(skyview.co.uk)*; but often relies on financial incentives for active participation.

In the *Use of Citizen Science Monitoring for Pattern Discovery and Biological Inference,* Hochachka *et al* comment that "the use of volunteer-gathered data for monitoring is not always appropriate" (Hochachka, WM. *et al.* 2012). The relevance for selecting a Citizen Science route is contingent on data collection requiring large geographic areas. Hochachka *et al* comment projects must "reinforce participants' awareness that the data that they provide [is] valuable" (Hochachka, Wesley M., Fink, Daniel., Zuckerberg, Benjamin. 2012) . Online projects like *ebird* and *feeder watch* "have not changed their model for two decades" (Wilderman 2007) . They are online systems that are broached from a top down system where an expert team is assembled, designs a CS project and recruits for public engagement. These models, whilst being scientifically robust, start with an institution and not always end users. The participants are motivated due to "interest, location or perceived value" not built around their prime personal interest, where the data could affect them personally and motivate them (Wilderman 2007) .

Combining Open Design and Citizen Science

Existing projects partnering OD and CS have included Open ROV *(openrov.com)*, 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)* have created a "guest sheperd's scheme", inviting ramblers and dog walkers to observe and report on sheep's welfare during activities (Blencowe 2013). The combination of Open Design and Citizen Science could enable community action by participants contributing to solving local or global issues through personal activities i.e. social design. With the Open Design/Citizen Science 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 the need for methodologies and processes to optimise user-designers' activities (Gershenfeld 2005). The *Bee Lab project* was initiated to explore what is required for non-technical users to create monitoring equipment using Open Design for individual need, whilst contributing to community challenges, beyond the smartphone. The combination of Citizen Science and Open Design can place the steering hands of projects in the community, building on Mazzini's approach to social design (Manzini, Coad 2015).

The Bee Lab project

Bee Lab builds on studies engaging beekeepers in the design of equipment, defining fabrication abilities (Anon 2013b), user led participatory design workshops and ethnography practices (Anon 2013) . Studies highlighted existing beekeeper motivation for data gathering from beehives. It created a strong case for OD to facilitate beekeepers sharing their data with each other and to strengthen ties as a wider community. We hypothesise that OD can provide positive uptake of Citizen Science 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 (Cramp 2011). Bees can visit 1,500 flowers and fly up to 500 miles in their life time, this work equates to a large percentage of pollination for our food chain: "without bees, McDonald's would only have the buns to sell" (Langworthy G 2009). 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). 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 grass roots study is "hobbyist[s] offer new insight to the custom requirements of products" (Bie Prett 2008).

Method

The project's initiation engaged beekeepers in design workshops (Anon 2013) , nationally through remote activities using design probes (Anon 2013b) and hackathons with beekeepers (Anon 2014) . A team of technologists, front-end developers, charities, urban and suburban beekeepers both professional and amateur were assembled from across the United Kingdom. The team ensured each field was validated according to extensive 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 pre-programmed, 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 (Anon 2014) . Our kits are intended to help beekeepers avoid over inspection 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 1999). 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 (Anon 2013) . 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 (The British Beekeeping Association 2012).

The functionality of 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 if further hive investigation is warranted. Beekeepers are encouraged to share data with each other through the Timestreams data-publishing platform (Blum, J., Flintham, M., Jacobs, R., Shipp, V., Kefalidou, G., Brown, M.,

& McAuley, D. 2013) . Timestreams, developed as part of a previous project, enables engagement with environmental data and media supporting data storage, visualisation and sharing. The Timestreams platform provides participatory sensing capabilities to support engagement with communities around their data. The system comprises components for mobile sensing and blogging through WordPress. Timestreams facilitates mass participation in Citizen Science activities, providing features to report and review sensor measurements, and manipulate their playback properties in order to remediate them in digital, web-based interpretations, or through physical artefacts. Researchers presented the *Bee Lab* sensor kits and Timestreams to beekeepers at a kit workshop recruited nationally via the British Beekeepers Association (BBKA) *(bbka.org.uk)* network, which took place at a central London studio. During the workshop, participants assembled kits, examined the designs, and provided functionality feedback. Participants had mixed skill sets, including architects, engineers and accountants, all with beekeeping experience and personal apiaries.

Figure 1. Bee Lab Kit assembly

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 amongst these merits was added value for a user's self-assembled object, or *the Ikea effect* (Michael I. Norton, Daniel Mochon, Dan Ariely 2011) : "look what I have made" (participant X). Participants described 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 only accurate to the first three postcode pre-fixes, as participants stated previous problems with hive vandalism and theft.

Figure 2. Deployment of Bee Lab Kit

The motivation of workshop participants was the individual data gathered from devices. During the workshops, participants expressed an interest in reviewing neighbours data to understand similar scenarios or possible disease conditions. The project partners were interested in the aggregated data and 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 sensors 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 categorised into either successful or challenging insights.

Successful Insights

1) *Plausible Engagement* was ensured as the BBKA has over 25,000 members in the United Kingdom, it is important to consider possible engagement.
2) *Aligning Motivation* of project participants with stakeholders' intentions, encouraging people to participate as enriching experiences and providing mutual benefit to both parties.
3) *Mutual Reciprocity* in data gathered, i.e. the individual data harvester benefits the community and vice versa.
4) *Environment Protection Procedure*, the participants were experienced in handling their bee colonies. 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.
5) *Data Protection Agreement*, the participants were willing to share their data as long as online presences were anonymised and they were not publically compromised as bad beekeepers.
6) *Digital Economy of Data*, the participants when questioned did not conceive their data would individually hold value, but saw the financial benefit of being part of a wider community.

Challenging Insights

7) *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.
8) *Deployment Procedures* were standardised, but it was hard to evidence and users could contaminate the data pool through negative actions.
9) *Constructional Liability*, the kits were low voltage, all safety protocols were adhered to during their assembly.
10) The *Quality Control Procedures* were based around technicians' abilities, for wider repetition these need to be embedded into kits themselves.
11) Data *Misuse/Abuse,* the project did not yield abuse.
12) *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 Open Design/Citizen Science process was created, the following actions and stages are repeatable. 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 organisation, the stakeholder is an organisation or wider community with a vested interest in the project and the user is the end user. At each insight stage, there are actions to explore project parameters and important topics that require attention, based on successful processes through research in-the-wild. The insights can be reordered, but are based in financial economic order, so have reduced barriers to entry. The results of this process have been reflected upon throughout each section as they inform each other and are not isolated.

Perceived Project 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 contextualise beekeepers' activities and current product usage, the Bee Lab project conducted in-depth observation(s) of "in the field" praxis of amateur beekeepers (Hammersley, Atkinson 2007). As Hammersley states "obtaining access to the data looms largely in ethnography" (Hammersley, Atkinson 2007). 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, Holyfield 1996a). Adhering to Fine's guideline, a seminar was conducted with the studies group, defining: study intentions, author's commercial practice and ethical codes of conduct. The seminar grounded the study within professional practice, building trust between gatekeepers and consolidating protocols continued throughout the study.

The repeatable stage from the project was 'Topic Identification' and 'Topic Review' with a wider audience, validating the decisions. Within the process, the design agent or end user define(s) what the issue or localities are. The intention of the topic review is to see the wider picture of the territory that is intended for exploration, this is very contextually based and can be a broad with specific lenses. It is important to not only consider the end user's perspective but also identify stakeholders that can be involved in the project. The topic review can include a literature review or initial informal discussions with the users to define interest areas for further review. This is a scoping exercise to define the relevant parties, users, NGO or organisation that will be interested in possible outcomes and interventions.

A) Identify topic / issue or locality for project(s).
B) Understand the 'perceived value' or impact of the topic area, to locate other parties/interest groups.
C) Identify pertinent expertise to define the challenge.

Project User / Stakeholder Review
In *Participatory Design in 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" (Carroll, Rosson 2007). 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, Rosson 2007). 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, Atkinson 2007) . Where necessary, researchers "go native", viewing the world through the eyes of those they are studying (Forsythe 1999). Ethnography can be used in design processes to provide observers with products' "context of use", presenting opportunities for future interventions (Kensing, Blomberg 1998). When "ethnography is applied to design, it helps designers create more compelling solutions" based on real world insights (Aiga 2013).

In *Community Technology,* Hess states that "community and technology form a bond, in isolation neither functions" (Hess 1979) . 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" (Hess 1979). It is also important to be wary of the community's hierarchy and how they want to be viewed by outside parties. All of the parties identify the active participants that could engage in an OD/CS activity:

A) Identify users / hobbyists active on location(s) / issue.
B) Identify stakeholders interested in accrued location / issue data.
C) Identify stakeholders interested in accrued location / issue.

Plausible Actions for Comprehending User / Stakeholder Review
A critical action is producing a research program, 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, Atkinson 2007). 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, Holyfield 1996b).

Design workshops include researchers/participants in questioning problems, situations or defining design territories. In *‘Developments in Practice’*, Suri identifies that the “design profession’s major strengths [are] the ability to create tangible expressions of ideas and to invent and exploit new tools” i.e. translating insights into tangible design outputs (Suri 2003). The ‘new tools’ Suri describes range from technologies to services, from construction to execution. Design workshops are a good tool for incubating design outcomes and translating insights as they “establish user needs, test product designs and evaluate final concepts” providing grounded tangible solutions (Lofthouse, Lilley 2006). Design workshops can also repeat elements at a distance by using cultural probes. A cultural probe is a research tool “completed by a participant in their own environment in isolation from the researcher” (Gaffney Gerry 2012). Cultural probes are “objects, physical packets containing open-ended, provocative and oblique tasks to support early participant engagement within the design processes” including photographs, maps or diaries (Boehner, Vertesi *et al*. 2007). Probes can be posted to participants’ locations, covering a large and wide sample area, which would be costly to individually interview. Design probes use visual mechanisms that can reveal richer findings and insights from their users. Probes enable users to construct a story from their point of view, building on Frankenberger *et al’s* theories of bringing “a narrative element into designing” (Frankenberger, E., Badke-Schaub, P., and Birkhofer, H. 1998) .

Key Topics that Require Identifying in User / Stakeholder Review:

- Data Reciprocity, data that both the stakeholder and the user want to discover and share.
- Required Motivation, identifying motivating factors for end user participation.
- Specific Community Required, ensuring the community is interested to engage in activities.
- Personal Interest Data, individuals might require different outputs from stakeholders providing participation motivation.
- Data Reciprocity, what will they/wont they be willing to share and the overall alignments of stakeholders / users.

Key Interests that Need Attention (User / Stakeholder Review):
The key factors to understand within the review are:

- Pertinent Measurands, is the captured measurement validated by all parties.
- Data Analysis, what procedures are required for accurate analysis and field use.
- Surrounding Issues, are there underlying issues that will impact on proposals.
- Alternate Audiences, who else can engage with the project.
- Economic Cost of Design, cost analysis of OD/CS intervention.
- Construction Capability, participants capability to assemble technology packages.

Technology / Scenario Review
To create effective design outputs, “designers must have an understanding of the characteristics and diversity of those” they design for (McGinley 2010). As previous *ethnography* work identified, beekeeping is a broad complex practice. In *Citizen Science Public Participation in Environmental Research* Bonney *et al* define Citizen Science project design parameters: “use multiple technologies, have inherent complexities and levels of engagement dependent on their goals and participatory requirements” (Louv, Fitzpatrick *et al*. 2012). 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 scrutinise design opportunities first hand with beekeepers. To understand the complex relationship between Citizen Science and beekeeping with the possibility of this leading to Open Design

opportunities, it was important to "humanise technology innovatively" (Roux 2011). 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, William 2001) . 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 (Anon 2013a) . The work yielded, three repeatable insights for the Technology / Scenario review.

All parties identify:

A) What is already known about location / issue?
B) Who are the appropriate experts?
C) What technological interventions already exist?

The actions include: a literature review or expert consultation and understanding the cost constraints of the opportunity in hand.

Key Interests (Technology / Scenario Review)
At the scenario review it is important to consider the following outputs; Accrued data, Required Data Analysis, Potential Digital Economy, Personal Data, Community Data, Stakeholder Data, Perceived Misuse / Abuse of issues that surround the topic?

A) Review user data requirements, which are appropriate to stakeholders.
B) Review parallel organisations / wider audiences interested in data collection.
C) Review data output requirements are appropriate to users.
D) Review the project constraints and turn-offs of the user community.

Project Participant Alignment Validation
Understanding the audience for Citizen Science activities is imperative as "the most important consideration is the motivations of participants" (Roy, H.E.,Popcock, M.J.O., Preston, C.D., Roy, D.B. & Savage,J. 2012) . 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 (Galloway, Hickey *et al*. 2011). 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" (Mauss 1990) . 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 programs can be designed and aligned accordingly.

In *Dusting for Science: Motivation and Participation of Digital 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" (Nov, Arazy *et al*. 2011). 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 (Jordan, Gray *et al*. 2011). 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's* needs because "protection of ones' self-interest is key to motivation", ensuring engagement (Clary, Snyder 1999).
2) *Motivation* requires clarification because "citizen science projects are inherently about partnerships, collaborations between

scientists and volunteers" (Louv, Fitzpatrick et al. 2012) .

3) *Community* needs to be established as "community and technology form a bond, in isolation neither functions", leading to negative uptake (Hess 1979).
4) Any participants detrimental fears need clarifying so they "do not cause problems later down the line", dissuading participation (Anon 2013a).

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, Rabeharisoa 2003). 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 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, whilst remaining transparent to all parties, with ownership residing with end users.

The important stages that design agent(s) and stakeholder(s) need to ensure alignment validation include the following:

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

Project Agreement Creation

In *Limits of Knowledge and the Limited Importance of Trust*, Sjoberg presents that "risks tend to be routinely denied or ignored unless or until they have been proven to exist" (Sjöberg 2001). 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, Pannell 1990) . Environmental tourism and increased footfall in areas of outstanding natural beauty, are becoming "increasingly significant" impacting on the surrounding area (Buckley 2000). 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:

A) Create user protection agreement, environment protection agreement, data protection agreement and deployment verification procedure. The agreements must be transparent and understood by all parties. These agreements should protect the data being collated, end user, organization(s) and the environment(s) they are operating within.
B) Ensure agreements are clearly understood, and subscribed to by all agents.
C) Important project elements that require understanding before the project is created and designed: Deployment Verification procedure, User Safety, Kit Diagnosis, Construction Liability, Part Accessibility, Repairable, Usability of Design, Constructional Validation Procedure, Potential Misuse/Abuse, Quality Control Procedure, Identifying Pertinent Measurands, Reciprocity in Data, Economic Cost of Design / Construction.

Deployment Intervention

The deployment of artefacts is "essential to move design out of the lab and making it into an unremarkable feature of everyday life" (Tolmie, Crabtree *et al*. 2010). Deployment is an "effective experiential method, where a group of users test products" (Milton, Alex., Rodgers, Paul. 2013) . Including the "public can help you question your assumptions, introduce fresh perspectives to improve your thinking, and provide an opportunity to reflect on your design practice and research" (Milton, Alex., Rodgers, Paul. 2013) . Deploying proposals for Citizen Science is different to 'design deployment' in the previous literature. In Dickinson *et al's Citizen Science Public Participation in Environmental Research*, they present "participant-centred approaches" (Louv, Dickinson et al. 2012) . Participant-centred "approaches enhance recruitment by appealing directly to participants' interests and motivations"

(Louv, Dickinson *et al*. 2012). Clary *et al* state that the "most effective satisfaction is highest when messages and benefits of volunteering match the volunteers' motivations" (Clary, Snyder 1999). Citizen Science projects create relationships and successfully deploy projects within communities; "participants connect with one another, sharing their data" and "stories, photos and insights about their experiences" (Louv, Dickinson et al. 2012) . The critical points for the *Bee Lab* deployment were:

1) *Quantity-quality trade-offs*; deciding where the bias of quality or quantity of data is balanced, i.e. how many people need to participate (Hochachka, Wesley M., Fink, Daniel., Zuckerberg, Benjamin. 2012)
2) *Lack of prior knowledge;* not relying on the prior knowledge of the participants (Hochachka, W M. *et al*. 2012).
3) *Health and Safety;* ensuring participants are safe during observations or data collection (Roy, H.E.,Popcock, M.J.O., Preston, C.D., Roy, D.B. & Savage,J. 2012)
4) *Design for doubt;* remembering that your volunteers are lay users so limit the possibility of doubt through practice or in the data accrued (Paulos 2009).

The lack of prior knowledge is something accommodated throughout the project with all the considerations for 'lay users' and the testing of the deployment. Making participants benefit from their accrued data created user motivation. The health and safety of participants was considered for assembly tools, not interrupting users' conventional practice. If beekeepers are associated with a club, or the BBKA, they are insured and have individual club risk assessments (The British Beekeeping Association 2012).

A) Create champions advocating the project amongst their networks, provide tools for this.
B) Consider deployment communities, are they capable of lifelong project sustainability.
C) Design for Doubt, continuously validate users throughout construction and deployment.

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 requires 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 something else? The data disseminated needs to align with agreements previously stated by all parties. The key insights from the project were to honour the previously created agreements.

Discussion

In the *State of Nature 2013,* 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" (Burns, Eaton et al. 2013) . 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 (Burns, Eaton *et al*. 2013). 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, Open Design and accessible content are evolving product creation for lay users. Products are no longer isolated in physical form and can be evolved to influence users 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 wider impact was the United Kingdoms, 2001 foot and mouth epidemic. Foot and mouth is spread by foreign contaminants transferred to footwear and carried over wide areas. In 2001, the South Downs recreation area (1600 km^2), located in East Sussex, was closed in order to stop the spread of the disease. The public's misunderstanding of their foot traffic wider impact, exacerbated its spread. The disease claimed many farms and "resulted in losses of £3.1 billion to agriculture" (DEFRA 2004) . Legislation determines how people engage with rare species and the countryside, but currently there are no legal considerations for CS/OD activities. Whilst 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 the pigeon parasite to other species (Robinson, Lawson et al. 2010) . 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 2013) . The only cure for this is for the "public to clean their bird feeders, regularly" as this act of kindness could erode species over time (RSPB 2013). Whilst this design space is exciting, the authors align with Papanek's views, avoiding the creation of "instant experts" that do not comprehend the wider impacts of their immediate actions (Papanek, Fuller 1972) .

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 their disposal and plausible misuse. In the "last five years, 12.5 million computers have been thrown into UK landfills" (Ewaste 2014) . Their users deem these computational items useful/valuable for work or pleasure. 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 what the general public output (Papanek, Fuller 1972) ?

The other consideration is the long-term OD/CS affect on behaviour change that could happen to its audience. A good example of participants gathering data and openly presenting it is the 'saving energy through street art' project in Brighton. In 2015 "an artwork sprayed onto the middle of Tidy Street in the British seaside town of Brighton helped residents cut their electricity consumption by an impressive 15%" (Tulloch James 2015) . Every 24 hours, the local residence had their energy consumption data sprayed onto the street in front of them. This evolved participants behavior through "not about forcing people to change, [but made] them aware of other choices" (Tulloch James 2015). This open, public approach of presenting gathered data, within the OD/CS context, could have an impact on how participants treat local wildlife.

A profitable example of Open Design is 'Open Desk', a "global platform for local making. You can use it to download, make and buy work space furniture" (Steiner 2015) . It is currently turning a healthy profit using organisations' digital fabrication tool down time. Successful businesses are being created through Open Design, so this space will become more plausible over time. The combination of an Open business and the natural environment presents a number of challenges. These challenges have been identified as; User motivation, Recruitment, Validation, Quality Control, Deployment, Ownership, Compliance, Opting out, False positive, Security, Misuse and Responsibility (Phillips, R & Baurley, S 2014) . The nature of Open Design and accessibility makes the engagement with the natural world complex.

The combination of CS/OD also 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 fulfill those needs (Clary, Snyder 1999) . Volunteers require motivation based on their needs if this is either for self-fulfilment or group recognition. There are stumbling blocks in the lifelong sustainability of this approach, hence why the alignment of the output is critical to the motivation of the participant(s).

A more controversial example of Open Design is the wiki weapons project. The wiki weapon project *(defdist.org)* has developed 'fully printable firearms', publishing the design files to create specific working components of an AR-15 Assault rifle. The Texas-based project wants to "change the way that we think about gun control and consumption and test the policy on how governments would behave if every citizen has near access to a firearm through the Internet?" (Wilson 2013) . The access to the design information is in the format of a Stereo-lithography Tessellation File (STL), a 3D printable file that can be appropriated but not openly 'edited' without a great level of skill. The access to the 'firearm' comprises one component (the lower receiver), the only component that requires a firearms licence, under current legislation (at time of writing). The project is not conversely interesting (to the authors) but it is intriguing that they are trying to inform government policy through design. Users downloading firearms has caught American federal gun laws off-guard as a "monolithic legal scheme erected with the belief that guns and gun components originate in industrial facilities" under professional, not lay user control (Jensen-Haxel 2011) .

Workshop participants clarified their motivation to participate, as they were active beekeepers with mixed experience. They were interested in accruing data that would improve their honey yield, their 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, rigor of gathered data and the technical competence of assemblers/users. The key to repeating this type of activity is finding participants with mutual interests i.e. a fisherman catches and weighs a fish, with the weight data of primary interest to the user but also to fisheries or nature organisations. The agreements identified earlier in the OD/CS process present an opportunity for different organisations to engage with this approach. The scrutiny and reliability is based around how freely those agreements are created, informed by relevant expertise.

Conclusion

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

1) *Create project champions*

Empower individuals to become advocates for the 'project'. They will be more powerful/influential within their community than external researcher(s) or organisation(s). Issue advocates resources to communicate and recruit, as their input will be exponential.

2) *Listen to desires, not just technological opportunities*

Throughout the project, researchers learnt from 'territory scoping' workshops and 'deployment in the wild' with users. Beekeepers freely expressed their desires for technological uses and applications. Whilst technological interventions are exciting, make sure that users/needs are aligned and avoid over-complicating simple exercises or experiences.

3) *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.

4) *Always think motivation*

Deploy your projects within different communities and allow them to self-select. Always consider that community-based projects are not solely about the 'project', but concern what individuals personally yield. Try to align personal end user needs with those of wider communities.

5) Procedure(s)

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

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 Open Design/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 who have a vested interest in the environment they engage with and preserving it for the future. During project dissemination there was an exhibition at the Victoria and Albert Museum, London. The exhibition launched a discussion with secondary school technology teachers, the output with 'cross curricular learning'. Kits could form the computing lesson, the data analysis could be the science lesson and the geographic contexts could form the geography lesson, an exciting possibility.

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