Exploring Open Design for the application of Citizen Science; a toolkit methodology

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Abstract

The manufacture of mass produced quality assured products has previously remained within professional practice. Digital manufacture presents opportunities for producing products in low volumes, catering to bespoke requirements. This phenomenon can benefit parties where the manufacture of goods has previously been financially unobtainable, i.e. non-government and charitable organisations. Open hardware (accessible electronic components) can complement digital manufacture, enabling bespoke products to become intelligent, with the ability to sense, monitor, record and produce data. This paper tests an Open Design / Citizen Science toolkit drawing from practice based research and supporting ethnographic activities.

The study documents design workshops with *The Sussex Wildlife Trust* and *Cornell Laboratory of Ornithology*, conservation and wildlife experts. The papers research contribution is a design toolkit, identifying insightful opportunities for Open Design through Citizen Science. The study showcases new prospects for organisations to engage with the public. The prospects form 'reciprocal relationships' via members of the public fabricating monitoring devices and gathering data. Users' individual accrued data can meet wider community needs and address local or national conservation challenges. The emphasis of this study has focused on accessible wildlife monitoring, beyond the valuable but limited versatility of the smartphone, extending Citizen Sciences reach.

Keywords

Toolkit, Design Methodology, Design Workshops, Citizen Science, Open Design

Open Design (OD) enables collaborative efforts by providing incentives and methods for freely sharing design information (Vallance *et al.* 2001). This type of potentially complex activity can be underpinned by systems enabling people to easily access or create design information to make personal artefacts. OD is not a new phenomenon; with transferable design information from the textile industry known as "patterns" (Kraft 2004), users can purchase/download a textile pattern, tailoring outputs to meet personal aesthetic, fitting or material requirements. Whilst different tailoring techniques require more skill, the principle of adapting core templates remains constant. Patterns have supported economic rationales, for example the make-do-and-mend movement during the Second World War, where the public were encouraged to extend garments' lifetimes (De la Bédoyère 2002). A progression from individuals editing blueprints with varying skill is the creation of online platforms, equipping users with editable parameters and community support.

Open Structures *(www.openstructures.net)* is an online platform that "explores the possibility of a modular construction model where everyone designs for everyone on the basis of one shared geometrical grid" (Lommee 2012). The system adheres to a grid, where users apply parallel measurements unifying individual parts. Created parts can then be used in multiple assemblies, forming an 'open' and editable repository of parts (Lommee 2012). The same Open Design methodologies have been applied to scientific equipment by Tekla labs *(www.teklalabs.org)*, "a global community for research quality Do-It-Yourself laboratory equipment" (Nilsson Lina *et al.* 2012). Whilst opening processes can have negative effects, such as calibration issues, trust, conformity to standards and accurate assembly reliance, the process can enable a lower financial entry point, aiding communities to respond to their own issues (Phillips. R *et al.* 2013).

Digital manufacturing is changing the accessibility to make bespoke alterations to products at their digitally created source. The economist John Maynard Keynes stated “it is better to ship recipes than cake and biscuits” (Heskett 2005). Digital manufacture is the “reproduction of goods through digital processes, lowering the entry point to industrial manufacturing processes” (Carson 2009). 3D printing or “additive manufacture is one example of digital manufacture” (Igoe Tom & Mota Catarina 2011). 3D printing is lowering the entry point to manufacture as equipment is becoming cheaper and more widely available, through online services, or in local Fabrication Laboratories or ‘Fab Labs’.

Fab Labs are “small scale workshops with modern computer controlled equipment” open to members and the public (Massimo Menichinelli 2011). Fab Labs also offer support to construct more elaborate or technically challenging products like electronics or ‘open hardware’. Open hardware are components “whose design is made publicly available so that anyone can study, modify, distribute, make, and sell the design or hardware based on that design” (Gibb 2013). The key offerings of Digital manufacturing are: “the ability to produce downloadable products, bespoke product outputs and design freedom, i.e. complex geometries that cannot be created by traditional manufacturing processes” (Hague 2006). This paper does not discuss mass-customisation, acts of user misuse or intellectual property within Open Design.

The recording of seasonal events has “long been a pastime amongst natural historians, with records going back to the 1730s” (Sparks & Carey 1995). Commercial monitoring equipment has been used within industry and keen amateurs to address documentation and conservation issues. These monitored events have included earthquakes, weather, air quality and even domestic gas leaks for preventative, protective and documentary purposes. Commercial monitoring yields data that when translated can inform policy or local issues, but can be expensive for average people to purchase or engage with. Citizen science is “broadly defined as the involvement of volunteers in science” (Roy, H.E. *et al.* 2012) providing an “indispensable means of combining environmental research with environmental education and wildlife recording” (Roy, H.E. *et al.* 2012). Citizen Science currently utilises smartphones GPS for accurate geographical locating or in-built or plug-in sensors. Top-down Citizen Science models “let the public engage but rarely do the participants dictate possible directions or witness scientific ramifications” (Mueller & Tippins 2012). Grass roots activities “can play a major role in studies, often initiating the surveys leading to professional attention and intervention” (Heiman 1997). The process of including volunteers “might not just include data collection but in fact lead to a more rounded, educated and aware community” (Phillips, R., Baurley, S. & Silve, S, 2013). Citizen Science can be used to gather data encompassing many scenarios; this paper is interested in Citizen Science within nature and wildlife.

During the last 20 years environmental issues have had more media coverage and agencies have created “enhanced environmental legislation” (Law Commission, Reforming the Law 2012). Whilst 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). The following examples illustrate scenarios created with positive motives but caused negative effects to wildlife: the RSPCA has advised that ‘Sky Lanterns’ (flammable balloons released at events) can cause “ingestion, entanglement and entrapment to wildlife” (RSPCA 2013). The public feeding of Mallard ducks with “white bread, causes problems, as excess starch makes them lethargic, leading to health problems” (Furness 2013). Over feeding Mallard ducks can also cause “over-populations of males in environments leading to forced mating” (RSPB 2013). Recent research has also shown “that baleen whales [are] affected by military mid-frequency sonar” (Goldbogen *et al.* 2013).

These activities highlight the fragile complexity of ‘involving the public in wildlife’ and reinforce the care required within this design space, deliberations that have been considered within the toolkit. Non-professional lead users are already creating monitoring devices, for example: a child of 14 fabricated an earthquake warning system for “under one hundred US dollars per unit” using open hardware (Galant 2012). The paper’s interest is how ‘Open Design’ can enable ‘Citizen Science’ for lay users. This could evolve user’s experiences with wildlife and their surrounding environment beyond the smartphone.

Toolkit Design

The process of design is complex, with factors including careful attention to manufacturing processes, design aesthetics and functionality, user interpretation and more. Design toolkits are “interface[s] that enables trial and-error experimentation and allows the customer to take an active part in product development”, deconstructing challenges that users without design experience can engage with (Franke & Piller 2004). The practice of “collective creativity has been around for 40 years, going under the name of participatory design” (Sanders & Stappers 2008). Participatory design can enable “bottom-up innovation, where concepts come from grass roots rather than manufacturers or producers of goods” (Wuytens & Willems 2010). Toolkits have “externalised different consultancies processes” for others to use, “targeting intended audiences” (IDEO 2003). Containing design processes within toolkits gives “users constraints, guiding participants to an output or discussion” (Lockton 2012). Toolkit material needs to ascertain factors whilst considering wider ramifications as “one [Citizen Science] solution does not fit all” situations (Roy, H.E. *et al.* 2012). Insights from prior research studies have been collated and prioritised, including ethnography, public engagement (Phillips, R., Baurley, S. & Silve, S 2013), design workshops (Phillips, R *et al.* 2013) and design probes (Phillips, R., Baurley, S. & Silve. S 2013).

The toolkit comprises 150 printed cards streamlining prior findings from lay users creating sensor-based technologies. The toolkit has an information hierarchy *(Figure.1)* that builds on the knowledge of the expert or lay design user. The toolkit translates users’ knowledge into scenarios or briefs using “card sorting” and “storyboard creation” (IDEO 2003).

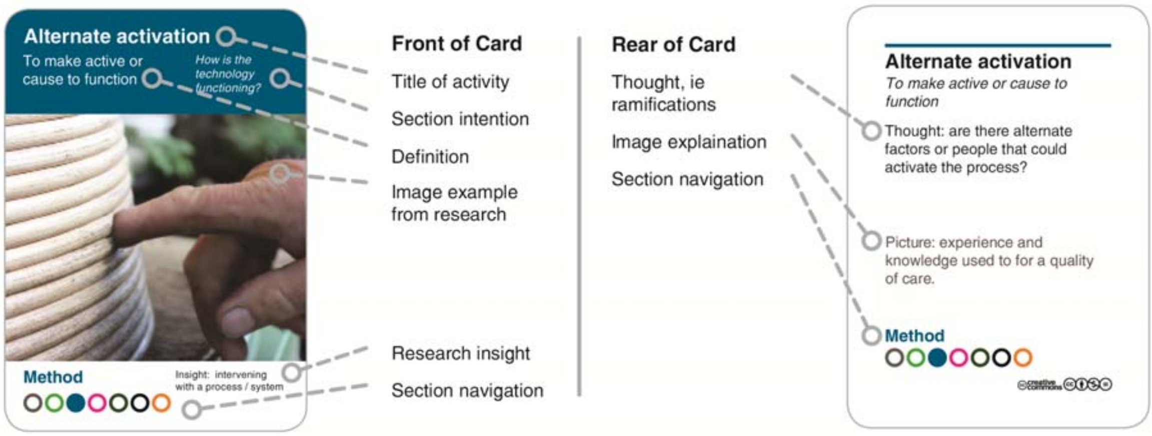

Figure 1: Navigation and hierarchy of information on toolkit cards, 2013.

The toolkit creates a workflow *(list.1)* for discussion on and around the following topics:

- *Scenario*, the situation for monitoring
- *Technology*, monitoring technologies that could be used
- *Method*, the process in which the device is used

- *Output*, the output from the device
- *People*, participants involved in activity
- *What is success?* The positive intention of the device
- *Funding*, how this venture might be financed?
- *Challenges*, potential issues Citizen Science and Open Design projects could encompass.

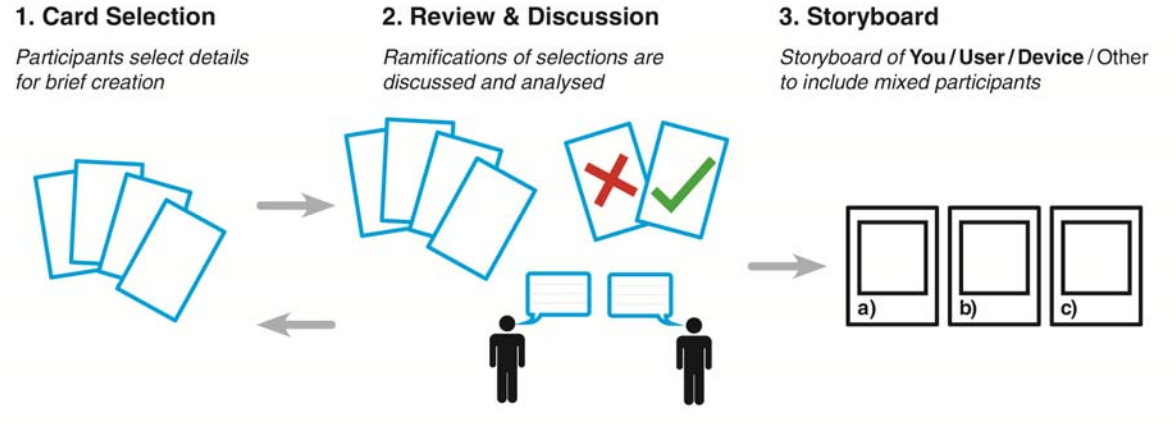

Figure 2: Process of toolkit workshops, 2013.

The toolkit enables participants to make selections, drawing on their knowledge, interest and project intentions *(Figure.2)*. The cards can form discussions within groups, prioritising intentions and recognising relevant topics to their organisation. The informed discussion is then interpreted into narratives to engage parties unfamiliar to the process of design. The process of creating narratives aids the conceptualisation and scenario building involved in creating ideas; this can be achieved through storyboards. Storyboards help participants to get “a grip on context and time by forcing them to attend to diverse aspects, integrate these aspects and confront the implications that could be postponed with abstract considerations” (Van der Lelie 2006).

The storyboarding process uses A6 cards *(Figure.3)* as single cells to capture narratives from viewpoints of “You/User/Device/Other” intended to help participants create a rounded narrative. The single cells allow participants to reorder created narratives. During previous research the ‘touch points’ of Open Design were defined as open and closed inputs and outputs, categorising how participants define *‘how ‘open’ open design is’?* Open inputs and outputs can then be defined at different points in the narrative, discussing the participants’ intentions *(Figure.3).*

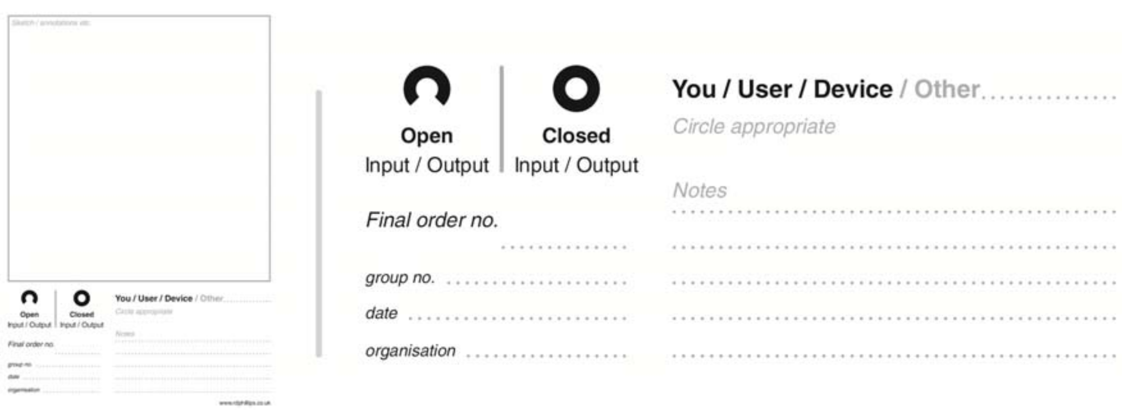

Figure 3: Storyboard card and documentation details, 2013.

To test the toolkit, a workshop with Seren partners *(www.seren.com)*, a customer experience consultancy, was executed involving service designers, brand consultants and UX designers (Seren 2013). The test critiqued the process, experience, system and delivery of the toolkit. Workshops were initiated by introducing Open Design / Citizen Science and digital manufacture, following (*Figure.2)* format. An initial presentation, introduced contemporary examples: Public Laboratory of Open Science *(Plots, www.publiclaboratory.org)*, Open Structures *(www.openstructures.net)*, Little Bits *(www.littlebits.cc)* and Airfix *(www.airfix.com)*.

Workshop 1

The Sussex Wildlife Trust *(www.sussexwildlifetrust.org.uk)* (SWT) is a conservation and charitable organisation managing over 4500 acres of nature reserves within Sussex in the United Kingdom. The SWT is renowned for their environmental education programme and is supported by over "33,500 members", some of whom volunteer (Sussex Wildlife Trust 2013). The SWT run extensive "wildlife courses on birds, mammals, flora and ecology attracting paying participants within and external to their membership" (Russell 2013). The SWT currently engage volunteers for monitoring with their "part-time shepherds project," training hikers, dog walkers, joggers as "volunteer shepherds" observing sheep in visited pastures monitoring the health of livestock (Blencowe 2013). SWT are active on social media platforms, 'tweeting' video content from their video nest bird boxes, showing familiarity with the positives of accessible technology.

The SWT's headquarters comprise meadows, ponds, woods and viewing points with classrooms educating the public about environments, demonstrating experience with public engagement and school participation. SWT collaborate with The Sussex Bio-diversity Centre *(www.sxbrc.org.uk)* (SBC) who "collect, manage and disseminate wildlife data, providing an information service for the whole of Sussex" (Anonymous 2013b). The SBC are active in habitat /species data across Sussex, involved in many species inventories. Their background places SWT as experts of wildlife conservation and protection. Prior to workshops SWT were interested in Open Design and Citizen Science for two initial upsides:

1) Volunteers/public could construct and deploy devices as charitable donations.
2) Digital manufacture responds to low volumes with low investment, presenting pilot project opportunities.

The workshop participants included SWT volunteers, species experts and staff from the SBC *(www.sxbrc.org.uk)* involved in the 2013 "State of Nature" report ascertaining "60% of the 3,148 UK species assessed have declined over the last 50 years and 31% have declined strongly" (Burns *et al.* 2013). The State of Nature highlighted that "out of 6,000 species assessed, more than one in 10 are thought to be under threat of extinction in the UK," highlighting the necessary inclusion of local populations in their surrounding wildlife (Burns *et al.* 2013). Workshop participants used commercial monitoring, for example "bird ringing, cataloguing species for the purpose of migration," but were unfamiliar with design processes and workshops (RSPB 2010).

Workshop Findings

The toolkit guided participants through brief creation in the territory 'beyond the smartphone'. The charity was unfamiliar with creating products as finances are too restricted to pursue such activities. Open Design can offer opportunities of low-investment product creation by designers or volunteers, generating products contributing to topical issues or local/national public engagement. Initial conversations explored education, involving new and secondary audiences within wildlife issues. The SWTs initial fears centred on 'not replacing nature with a screen'. The SWT safeguards such a broad range of species that it was looking to identify accessible frequently observed wildlife.

Participants wanted to include everyone within their Citizen Science brief, putting the experience and participant reward central to their focus. The application of “gamification” was discussed in comparison to Cub Scout badges, issued for completion and documentation of activities (Deterding et al. 2011). Rewards could link to social networking, promoting issues within wildlife, making participants young ambassadors for their environment. Participation could broaden engagement for audiences who would not usually participate, e.g. people who cannot physically access their wildlife sites. The SWT was concerned with people handling wildlife, in particular endangered species, but saw great value in concepts produced on demand by the public. The discussion addressed device creation and data sharing as ‘the next stage in charitable donations’ *(Figure.4)*. SWT members could donate accrued data, rather than donating funds demonstrating a “digital economy” (Chamberlain *et al.* 2012).

Figure 4: Card sorting and brief creating with The Sussex Wildlife Trust, 2013.

Users of the devices would need to be trained in how to track, to not disturb, and to place devices achieving positive results. Public liability issues were also discussed: how, in an open world of product creation, can charities create a product that puts its users in a foreign environment yet not place liability upon the organisation itself?

The SWT knew they had to place monitoring activities within "the critical age of influence” before 12 years old (Bird 2007). Before age 12 “contact with nature in all its forms, but in particular wild nature, appears to strongly influence a positive behaviour towards the environment" (Bird 2007). The SWT explored families playing games to explore wildlife in Sussex, and saw the advantage of collaborating with local social clubs. Collaborations would align Citizen Science outputs alongside hobbies mutually benefiting from gathered data. Several product storylines were created from the workshop, reviewing species that participants could easily witness. Their motivations were not just to ask research or Citizen Science questions as intended, but to create an open process of data gathering to engage diverse audiences. When the notion of success *(list 1)* was discussed, the most important goals were ‘educating and engaging the public in the environment that surrounds them’.

Whilst otter experts were present, otter activity in Sussex is rare and could disappoint observing participants. The SWT were interested in everyday species sightings, and highlighted the practical problems of people finding and disturbing habitats. The discussion of product creation also changed the tone of ‘who to include, and when’?

Discussions included connected learning strategies that the SWT could offer to schools: this practice could include the creation of digital devices in technology lessons with outputs used in geography or biology lessons, creating ‘connected education’. This could subsequently encourage family participation, possibly lead to national interconnected communities as a translation of “language exchanges” or “pen pals” amongst schools.

The SWT were adamant not to remove participants from the outdoor environment but, instead, enhance their experiences. This enhanced experience could educate participants and possibly recruit them as ‘ambassadors for wildlife’ among their peers. Whilst SWT’s motivations were not solely scientific, they were interested in developing understanding, educating and engaging the public with data gathering was a subsidiary outcome.
The SWT were interested in outputs that participants could “take home” either physically or digitally, for example, a 360 camera view of a bird’s flight path translated as a child’s memento. They were interested in the concept of a ‘nature street’, establishing competitions on identifying species amongst certain age groups, creating community competitions. The charity would use data gathered to gain feedback from people visiting locations in their custody as they currently have limited feedback processes.

Slow worm habitat creation and monitoring was explored purely as a species that is “abundant and protected in the UK”, whilst outside the remit of ‘community monitoring’ and directed towards public engagement (Anonymous 2013a). In Sussex there is an abundance of starling flocks moving in unison, creating beautiful swarms; the SWT were interested in participants capturing movements and volumes. Outputs could not only create mapping and conservation data but also interpret ‘captured activity’ into physical ‘things’, bespoke to the viewer or capturer. The SWT workshop highlighted the following lessons for further development; protocol creation to avoid detrimental factors participants might have on the monitored environment, reciprocity in data collection for participants’ efforts including multiple audiences and new models of charity donations from ‘conservation data’.

Workshop 2

The Cornell Lab of Ornithology *(www.birds.cornell.edu)* (CLO) is a world leader in the “study, appreciation, and conservation of birds” (Cornell Lab 2013). They use “technological innovation to advance the understanding of nature and to engage people of all ages in learning about birds and protecting the planet” (Cornell Lab 2013). The CLO has been at the forefront of Citizen Science programmes and projects since 1966 and continues to create “online tools enabling people to share and explore their data” (Cornell Lab 2013). The CLO houses the Macaulay library *(www.macaulaylibrary.org)* with a mission: “to collect, preserve, and facilitate the use of wildlife recordings for science, education, conservation, and the arts” (Cornell University 2013). Their Citizen Science projects have engaged international audiences leading to prominent scientific findings in ornithology and wildlife; developing models, methods and practices replicated worldwide.

CLO’s projects have included eBird *(www.ebird.org)*, a real-time online checklist program, cataloguing “1,000,000 bird observations monthly reported by participants” (Cornell Laboratory of Ornithology 2013b), Feeder Watch *(www.feederwatch.org)*, Backyard Bird Count *(www.birdcount.org)*, YardMap *(www.yardmap.org)* and the Elephant Listening Project *(www.elephantlisteningproject.org),* all relying on user participation for data collection.

The CLO has a visitor centre accompanying Sapsucker Woods, a “230 acre forest with ponds, ferny swamps, and abundant wildlife with over 230 bird species documented on their trails” (Cornell Lab 2013). Their visitor centre has a yearly footfall of 40,000 people. The CLO’s active role in Citizen Science activities, public education and documentation positions them as experts within the “execution, administration and development of Citizen Science projects” (Cornell Laboratory of Ornithology 2013a). The toolkit built on the CLO’s experience, informing discussions within the territory of Open Design.

The workshop was held twice with mixed participants from the CLO, including education and technical teams from the eBird and Elephant Listening projects *(Figure.5)*. The participants had a different briefing to Sussex Wildlife. The CLO were familiar with Public Laboratory of Open Technology & Science *(www.publiclab.org)* and Public Library of

Open Science *(www.plos.org),* organisations that embrace 'open' practice. Participants were guided through the same card sorting *(list 1)* process as previous groups *(Figure.2)*. Initial feedback identified the toolkit did not start with a Citizen Science question as previous "models" have (Wilderman 2007). The concept of starting with a design opportunity, technological application seemed strange to the group but it raised interesting further research questions:

- When does a technology push create bad Citizen Science projects?
- What is more important, answering a Citizen Science question, or engaging and educating the public with positive motivations?
- How can users and organisations engaged in Citizen Science activities mutually benefit each other?

Figure 5: Card sorting and discussions with Cornell Laboratory of Ornithology, 2013.

The workshop process highlighted the CLOs' interest in using participants' existing hobbies or activities to facilitate future projects. For example anglers could gather water samples for scientific use and protecting their favourite spots presenting 'mutual gain and reciprocity'. Whilst this could be considered 'on the fringes of Citizen Science', is this also an opportunity to connect an approach with an opportunity, communities with a solution? The groups applied the toolkit to existing projects they already run, reviewing how they could use Open Design to nurture new audiences. Initial discussions stated the CLO would 'open' all of their processes if they could guarantee quality control of the products participants assembled or adapted.

During discussion local 'fab labs' or maker spaces could be used to provide verification processes. Using a local fabrication or maker space could remove some skill elements but it should be seen as a verification process, not a process for cheap labour in assembly. The validation of a process or production route could be the USP of that particular company/fab lab (over a home user). Resulting in Fab labs not just providing construction files or equipment but validating user created outputs or products for other organisations.

The consensus of workshop 2 discussions was that, even though the "3D printing of electronics" (Leigh *et al.* 2012) is becoming viable Open Design products for Citizen Science would be effective as 'a kit of parts', using conventional and digitally manufactured components. The workshop discussions raised the following questions: What motivations are required for users to assemble/construct products to participate in Citizen Science activities? Conventionally these have been "educational" or within users belief in the 'ideal' of the project (Nov, Arazy & Anderson 2011). What is the required bridge for appropriate technologies to be constructed by the layperson? This 'bridge' is currently being explored in 3D printing by Auto desk *(www.autodesk.co.uk)* and their "creature creator app" (Autodesk 123D 2013). The app creates parameters for lay users to change diameters and forms. These simple software applications could be designed and deployed to compliment more complex digital technologies, for example monitoring devices.

What is the data consistency and rigour provided from construction kits? This would need to be explored in more depth as this depends on the nature of the project and its intention(s). The last question is the consistency or quality control procedures that need to be in place to help validate the users' construction back to the agency or organisation that is exploring Open Design and Citizen Science relationship.

Closing project elements

One element critical to Citizen Science projects is the "gathered data" (Louv, Dickinson & Bonney 2012). This collation, editing and distillation are usually completed by project providers, not the citizen. The gathered data, when harvested, is controlled by a central entity which can then create diverse data sets for multiple applications. There was a fear relating to the data from 'open' monitoring devices sensing 'bird movements' would direct end users to particular spots for viewing, with limited consideration to the possible footfall. In 2011 the Royal Society of the Protection of Birds *(www.rspb.org.uk)* (RSPB) documented "two wildlife photographers fined £1100 for disturbing a pair of nesting white-tailed eagles on the Isle of Mull" (RSPB 2011). This case could have been amplified by multiple users sharing information online. Would local custodians or 'youth ambassadors' stop this kind of activity? At what point do you close project elements?

There was an interest in empowering communities to respond to their own problems and the CLO disclosed that they do not usually initiate projects from the bottom up, due to their 'complications'. In discussion it was made clear that Citizen Science projects can require large internal administration or funding, purely to process data. The concept of selling the data to ensure longevity of a project was discussed, raising ethical questions such as who would profit? How would organisations ensure that the project was transparent and not exploit a core set of 'community approved values', whilst ensuring charitable protocols? Using local knowledge to influence the outcome and influence the motivation for participation was a key interest the CLO workshop.

The CLO were intrigued at combining activities that were either 'during an activity or hobby', integrating citizen science beyond active participation but into activities that require passive participation. These hobbies could include parties that are already active in that 'monitoring space' for example air monitoring and para gliders. The CLOs' main concerns were approval processes verifying Open Design processes from the bottom up. These processes could include many more aspects at the software creation stage of the project. These processes could have pay walls to maintain their upkeep, as long as goods and plans are accessible.

Insights for wider areas

The workshops raised insights and questions that can be applied to multiple areas:

- What should be the priority of Open Design Citizen Science projects, the technical value in data collection or the inclusion of the public in design and adaption of proposals?
- Can a kit, assembled device or service self-diagnose arising problems, assembly orientation or troubleshoot?
- The opportunity for organisations without design/development knowledge to use toolkits as a brief-making tool with outputs that target experts to construct/develop or design devices.
- When does public engagement become Citizen Science and vice versa and what is the defining goal?

- When in the process do you enable users to openly adapt projects for wider uncompromised use?

Discussion

Digital manufacture and Open Design have opened opportunities in fields of product creation by lead users. An example of such product creation is DIY Drones *(www.diydrones.com)*, a “product platform that has enabled lead users to collaborate, communicate and develop as part of a community” (Anderson Chris 2012). 3D printing has been well publicised and widely received as “the next industrial revolution”: whilst it offers opportunities, it also needs to be facilitated for lay users (Anderson 2010).

The Toolkit investigated the relationship from a ‘design opportunity’ perspective to help organisations that previously might not have considered opportunities in Open Design and Citizen Science. Could this collaboration create technological pushes rather than pure scientific questions? Which element is more important? With the design of ‘construction kits’ (the most cost effective, accessible solution), when do you exclude people and how can this be addressed in future proposals?

The motivation of ‘project volunteers’ remains critical, whilst Citizen Science projects primary goal has been scientific knowledge does Open Design present alternate opportunities? Could the gathering of data be mutually beneficial to all parties? The construction of a motivation to participate could not only be the collated data but also take the form of positive ‘reciprocal outcomes’. For example, the preservation of anglers fishing locations through participants cataloguing the weight of their catch, or parents giving children kites to record live air quality readings in their recreation locations.

The topic of self-financing projects was discussed (complying with charitable protocols) but raises questions of when charities/schools could create a profitable system enabling a Citizen Science project to sustain its self without compromising openness or their intention. Cross-curricular school lessons were alluded to throughout both workshops. These lessons could combine technical making and scientific analysis in computing lessons with data insights in scientific classes; the bigger issue is… how could schools afford this?

When is ‘open’ a problem?

The design of goods can be complex, in this case relying on the lay assemblers skills to create accurate outcomes from ‘open designs’. Solutions discussed in all workshops included kits like the child’s toy Lego *(www.lego.com)* that are accessible to lay people but can be developed upon by skilled users for higher complexity (LEGO 2013). A proposed structure could draw from design parallels like Twine *(www.supermechanical.com)* or Littlebits *(www.littlebits.cc)* both interactive ‘plug and play’ systems. Designing ‘*when to close a project’* was a high priority workshop output. The toolkit workshops yielded common themes for further work including; scientific rigour of accrued data, quality assurance of user assemblies and negative legacies or detrimental effects of misunderstood data.

The larger concept of ‘open’ is when parties want participants to develop and when or if closing processes can ensure quality. The advantages of establishing an Open Design Citizen Science project are product distribution, adaption, lower financial entry and extending an organisation’s capability. The opening of project stages could still require protocols ensuring quality control and scientific rigour. These stages could be co-ordinated on a case by case or parameter basis. Protocols could be designed to unify procedures but these would require complex databases or technical skill. That ‘technical skill’ could be out of reach to charities and organisations that would benefit from ‘opening a product’. There is also the question of when and if collated data could be used for negative use or profiteering by alternate parties?

The toolkit raised wider discussions for the Open Design and Citizen Science relationship but it still needs to be applied on a case by case basis. When parties are creating kits (either for download or assembly) what processes need to be closed, regulated or controlled ensuring a positive project outcome? So how does a process enable adaption and development without compromising data collection but still engage the lay or unskilled user? The opening of Citizen Science projects has already created equipment, for example: The Public Laboratory of Open Science (*www.publiclab.org*) and Open ROV (*www.openrov.com*) but can you include the lay public in equipment construction through Open Design and not just opening the construction to technical users?

Conclusion

Workshops presented opportunities for digital manufacture and Open Design's use in Citizen Science. The work presented possibilities for alternate parties to benefit from parallel development, i.e. product adaption from a base of interchangeable components. There were fears from both workshops, not relating to the sharing of data but to the possible misrepresentation if reviewers were not familiar with data findings, leading to panic or detrimental outcomes. Validation protocols could be included in an Open Design and Citizen Science platform that optimises outputs. This platform could be informed by local manufacturing or 'fab labs', with modes including, creator, end user and organisational administrator. The end user could create and input/output but the administrator could control or advise on project parameters ensuring rigour and quality control. Another issue is providing a process for motivating open development. Do designers or technology providers bid for work? Are there protocols for open intellectual property that can sustain a project or venture?

The toolkit highlighted the viability of the Citizen Science/Open Design territory and that workshop parties were very willing to explore it. The data from the 'territory partnership' could lead to organisations collaborating, extracting useful data from each other, if the projects scope is mutually beneficial. The main problem is trusting the public and possible data profiteering that companies could exploit. Reciprocity in the collected data could prove a powerful motivation for both parties (end user and organisation) to participate in activities… the bigger question is. What information holds value for individual users and organisation(s) alike? The workshops found the following priorities for Open Design use in Citizen Science projects: user/developer motivation, scientific question(s), technical cost, support processes and protocols for public inclusion or education. The toolkit was a practical tool in understanding the pitfalls, benefits and opportunities of this relationship leading to research insights that were applied to other areas.

The toolkit work resulted in the *Bee Lab* project *(www.beelab.org)*. The *Bee Lab* project applies Citizen Science and Open Design to beekeeping, enabling participants to construct monitoring devices gathering reciprocal data, motivating participants and third parties. The project is a collaboration between; The British Beekeepers Association *(www.bbka.org.uk)*, social innovation from Wolff Olins, The Honey Club *(www.honeyclub.org)*, and Technology Will Save Us *(www.technologywillsaveus.org)*. The work was supported by RCUK, Horizon Digital Economy Research *(www.horizon.ac.uk)* grant (EP/G065802/1).

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