Testing a Grassroots Citizen Science Venture Using Open Design, “the Bee Lab Project”

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Abstract
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 presented approach uses design workshops to provide insight into the design of kits, user motivations, promoting reciprocal interests and address community problems. This paper signposts issues and opportunities in the process of designing Citizen Science tools for communities using Open Design to solve individual problems, including: downloadable design for social/local change, laypeople creating technology and repairable kits.

Author Keywords
Open Design; Citizen Science; Workshops; Beekeeping; Apiology

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous. General Terms: Design, Human Factors

Introduction
This paper describes a method combining approaches from Citizen Science (CS) and Open Design (OD) applied to people engaged in collecting offline data.

The approach appropriates digital technologies and encourages the use of existing skills, in order to unlock data silos, develop community-wide knowledge exchange, and facilitate greater public investigation of wildlife at a distance (specifically in situations where smartphone use is inappropriate). Here we report on a particular case study involving the approach: 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 [1]. The project's research objective is to understand the requirements for lay users creating Citizen Science monitoring tools from Open Design plans; to comprehend the pitfalls and opportunities and subsequently use aggregated individual bee hive data to contribute toward community bee health insights. The project builds on the notion of *reciprocal motivation* (project stakeholders motivated by giving and receiving), and data gathering by beekeepers in the UK, to form stronger community bonds with each other and design and share their own solutions to personal, community, and global issues [2]. *Bee Lab* achieves this by including beekeepers in the design, assembly and deployment of *openly designed* monitoring devices. This investigation provides insights regarding the design of kits for Citizen Science in general, removal of application barriers, translation of user concepts into research in the wild or Internet of Things devices, and including users in Open Design processes.

Previous work

Open Design (OD) methodologies build on models of *patterns* from the textile industry, enabling users to adapt designs for fit and material choice [3]. OD compliments digital manufacture through the reproduction of goods via digital processes, lowering entry points to industrial manufacturing processes. OD democratises processes, systems or products; enabling users to self-create and edit solutions using digital fabrication, enabling collaborative efforts providing incentives, and methods for freely sharing digital design information [4]. Whilst there are inherent problems of repeatability, calibration, consistency and quality control with opening processes, there are advantages of distribution, adaption and development of concepts [5]. Digital manufacture enables lay users to *download* products and reproducing them with digitally enabled tools. Citizen science (CS) is defined as "*the involvement of volunteers in scienc*e" providing an *"indispensable means of combining environmental research with environmental education and wildlife recording"* [6].

Bee Lab builds on studies engaging beekeepers in the design of equipment defining fabrication abilities [7], user led participatory design workshops [2] and ethnographic findings. These studies highlighted existing beekeepers motivation for beehive data gathering showing a strong case for OD. We hypothesise that OD can provide positive uptake of Citizen Science through mutual reciprocity in gathered data forming new models of engagement, data gathering, and responsibility for participants' surroundings. Beekeepers are *stockholders of a completely wild and undomesticated creature, the honeybee* [8]. Traditional beekeeping techniques avoid over disturbing hives, making it hard to witness signs of disease or negative impacts without opening beehives, digital sensors can monitor avoiding disruption or over-handling [9].

Hive monitoring initiatives exist such as *(www.nationalbeeunit.com)* in the UK, but are closed systems with design improvements not openly shared, presenting user led opportunities to control device inputs and outputs. Timestreams [10], 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. Users can view and respond to local and global data from environmental sensors and media whether in fixed locations or in mobile situations. Timestreams is a platform for capturing sensor data from communities' local environments, reporting to a cloud-based social platform 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 in order to remediate them in digital, web-based interpretations, or through physical artefacts.

Method

The project's initiation engaged beekeepers in design workshops and nationally through design probes [7]. These processes captured users' ideal monitoring concepts within beekeeping. Insights were translated by researchers with feedback from users into tangible designs for hive monitoring kits (*Bee Lab* kits), supporting assembly by lay users. We hosted a second workshop to test the effectiveness of the kits, and the willingness of Beekeepers to collect and share data with each other. We presented the *Bee Lab* kits and Timestreams to 10 beekeepers at a *Bee Lab* kit workshop recruited nationally via the British Beekeepers Association (BBKA) network, taking place in central London. During the workshop participants assembled the kits, examined designs, and provided feedback on functionality. The participants had to be taught how to solder and correctly identify electronic components. The workshop included participants with mixed skills including engineers and accountants all with beekeeping experience and their own beehives. The workshop presented the wider picture of the *Bee Lab* project and the day's activities, staff overseeing kit assembly (Fig 1.) and Timestreams presentation. During the day many extension kits were discussed with participants, highlighting the complexities of any software guide or system that would replace the technicians' personal knowledge in a remote setting. Kits were verified by technicians at the end of the day to ensure technologies were functioning appropriately. *Bee Lab* kits, developed in collaboration with 'Technology Will Save Us'[1], translated prior design workshop outcomes into packages containing off the shelf components and adaptable parts that can be *downloaded* or purchased at electronics retailers. These kits could easily have more OD elements for future applications; the main importance is tangible outputs. Elements of the kits are pre-programmed for mixed audiences to edit functionality without compromising assemblies. The *Bee Lab* kits provide components to monitor measurands identified by beekeepers in our workshops, including beehive total weight, the weight of hive feeders, and hive internal temperature.

Results

The kits are intended to aid beekeepers avoid over inspection of hives and present early warning signs in relation to hive health. Knowing the weight of the hive

[1] www.technologywillsaveus.org

and feeder is particularly important during winter months when opening a hive can be detrimental [11].

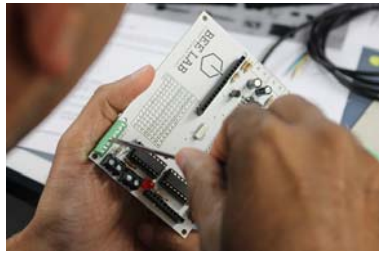

Figure 1. User making a *Bee Lab kit* during a workshop

Out of the box, the kits exclude some components traditionally found in sensing kits i.e. wireless connectivity and GPS. During our workshops beekeepers were concerned about wireless signals causing problems for honey bees and highlighted the sensitivity of hive location owing to theft and vandalism [2]. The functionality of the assembled kit not only records bee hive activity periodically (hourly by default, but user editable) on removable SD cards, but also displays data *in situ* on an LCD, aiding to determine if further investigation is warranted. This helps the attainment of the British Beekeeping Association's (BBKA) 'Certificate in Beekeeping Husbandry', which requires the upkeep of beehive records, aligning Citizen Science within the motivations of a hobby [11].

During the *Bee Lab* workshop we experimented with providing the kits fully disassembled to our participants (Fig 2.) along with paper instructions. Technicians provided soldering lessons, aided electronic components identification, and validated participant's component selection. The workshops demonstrated merits of user-assembly, including providing users with a greater understanding of kits, and a greater sense of ownership. Statements by participants during the workshop, in keeping with *the Ikea effect* [12], such as 'look what I have made' indicate the added value of user-assembled objects. However, users tended to report a preference for partial assembly in order to reduce the time and skill required for assembly. Such partial assembly limits aspects of *openness* but could aid more quality control parameters. A major pitfall for repeating this type of activity is the required skill and knowledge level users require in kit assembly. Design and computational opportunities are not just in scenario context but also in supporting systems or software that validate users' correct assembly.

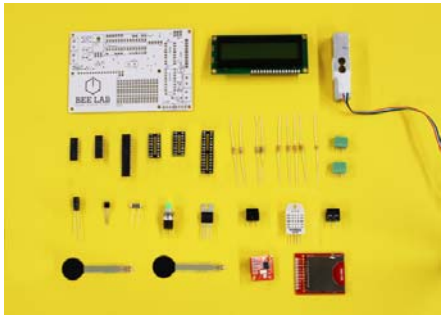

Figure 2. *Bee Lab Kit*, components

During the *Bee Lab* kit workshop we saw that participants often copied each other, rather than using provided instructions. This highlights the value of participant meet-up in OD. Extension kits and added functionality were discussed with workshop participants. They would prefer to remove components in order to optimise battery life. The workshop

highlighted new methods of open hardware assembly avoiding assembly pitfalls of OD with the LCD (screen) assembled first then each subsequent electronic component introduced by the LCD, as participants construct the device gaining understanding and confidence in their creation. Participants described reticence of fellow beekeepers to use new technologies, but this OD and CS approach will usually rely on self-selecting groups, rather than statutory participation. Workshop participants also discussed keeping beehive locations secret, so deployed device locations would only be accurate to the first three pre-fixes of a postcode, either online or in person to avoid previous problems with beehive vandalism or theft.

Discussion

Workshop insights present opportunities for OD/CS, but detrimental factors of encouraging the pubic to actively monitor wildlife require constant scrutiny. The defining element of combining OD/CS is the empowerment of communities to solve problems whilst aiding a higher cause. The hypothesis of using OD for CS applications can create mutual reciprocity (individual, benefits group and vice versa) in gathered data forming opportunities for motivation. Pitfalls in combining OD/CS in practice were; user skill required for assembly, troubleshooting device problems & when to cost effectively 'open' or provide user 'edit-ability' without compromising projects. Aggregating data was discussed with participants. They highlighted the deployment time required for CS data to become valuable (to them) was substantial, although they placed high economic value on accessing other users' data. Insights to counteract pitfalls of OD/CS from initial *Bee Lab* workshops for similar activities include:

- Transparency for users in gathered data, user anonymity and the reciprocity of community or subsequent data that is accrued.
- Closed assembly elements can protect overall OD outcomes, with accessible software.
- Understand relationships between personal motivations and community requirements.
- Kit assembly processes providing users' with integrated validation and assembly feedback.

Digital fabrication, OD, and accessible designs are evolving elements in product creation and use, which users can engage with. Products are no longer isolated in physical form but designed processes can dictate when and how users influence project outputs. Workshop participants clarified their participatory motivations as active experienced beekeepers interested in accruing data to improve honey yield, bee husbandry and aid in foreseeing problems (minimizing over inspection). Opening processes does not always create positive effects; elements of OD projects need clarity concerning users' inputs and outputs ensuring accuracy, repeatability, rigor of gathered data and the technical competence of users. The workshop participants demonstrated they could construct OD equipment for CS. Throughout workshops beekeepers commented on how devices would aid their honey production, monitoring in winter months (when inspection is troublesome) and save them money, motivating factors for participation. Finding personal interests or activities that can contribute to global accomplishments could be replicated in other areas mutually providing stakeholder benefits. The work starts to identify when a project should be closed to particular user inputs and points towards integrated platforms with assembly verification tools (either visual

or smart/software based) aiding users for positive outputs.

Future work

The *Bee Lab* workshop highlighted territories for project success. Assembly kits must prioritize user experience, giving users successful feedback, ensuring positive encouragement and progression. Workshops require repetition with less technical support ensuring home users are able to assemble a basic kit. We plan to hold future workshops for users to discuss their data either virtually or in person with entomologists. Future plans for kits will include instructions featuring goals and validation procedures encouraging assemblers. The deployment of the Bee Lab kits is an ongoing study.

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