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Making Sense: Empowering participatory sensing with transformation design


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ABSTRACT This paper demonstrates the value of transformation design in participatory sensing and describes how design can inform awareness and develop actions for change to tackle environmental issues. Recent research advocates for participatory sensing (open data capture through digital platforms) using technology that can assist and inspire citizens in driving environmental change. This paper examines a study aimed at overcoming some of the challenges

associated with the sustainability and impact of environmental participatory sensing. Our approach merges the fields of participatory sensing and design, and explores how transformation design can add an important dynamic in the framing of participatory sensing. It conceptualizes the way that communities increase awareness of environmental issues and take action to effect positive change. We present a study conducted across three European cities with citizens who were concerned about environmental challenges. Our contribution describes an approach and range of methods for supporting action and change.

KEYWORDS: participatory sensing, transformation design, urban environmental challenges, citizen science, making sense

Introduction

 We have reached a point where our increasing population has led to very real, complex, and rapidly growing urban challenges. In Europe, 75% of the population lives in urban environments, and this is expected to rise to 80% by 2020, and though there are benefits to living in a city, urban dwelling citizens are more likely to be exposed to health diminishing pollutants (European Commission 2010). A study conducted by the Apekom group, found that citizens of 25 European cities were exposed to PM2.5 levels well above the recommended limit outlined by WHO (Pascal et al. 2013). Air pollution in Europe is responsible for more than 400,000 premature deaths each year (European Environmental Agency 2015). However, air pollution is not the only matter of concern as 30% of the European population is exposed to noise levels exceeding what is deemed healthy limits (WHO 2017). Continuous exposure to noise can have detrimental effects on health including: increased in blood pressure, illness or fatigue from sleep deprivation, and decreased capacity for learning and creativity caused by stress (European Commission 2015). In the main, citizens are becoming increasingly aware of these environmental issues, yet they can often feel helpless when it comes to tackling them (Bunyan et al. 2016).

However, the use of digital devices as sensing technologies, with the platforms and systems that underpin them, present new opportunities for citizens to measure and observe the environment in ways that were not possible before. The augmentation of these technologies has led to a desire for some to engage in *participatory sensing*: a social and open practice of data capture, analysis and sharing through digital devices and platforms (Ganti et al. 2011; Bria et al. 2015). Participatory sensing and public engagement in the formation of environmental information through citizen science increases the possibility to understand how scientific information comes into being and how it is used in decision making (Hacklay 2017). This field

emerges from participatory digital culture and is building upon existing traditions in citizen science which enlist the public to engage in the collection of information on the natural world. Research demonstrates, that those who have first-hand experience of environmental problems are more likely to take steps towards environmental protection (European Commission 2008). Nevertheless, participatory sensing has to date largely focused on the technology and only gone as far as building the digital databases and networks to support environmental sensing. Critically, there is a gap in mechanisms and methods to foreground environmental and social issues, needs and challenges before technology interests and capabilities. We contend that addressing aforementioned gap is one way to leverage digital advancements and publicly created, and open, data for grassroots movements to increase their awareness and to address urban environmental problems. To this end, contemporary use and understanding of design, with a focus on how it can enable transformation, has much to offer in this debate.

Therefore, this paper explores the merging of the fields of participatory sensing and design, specifically the concept of transformation design (Burns et al. 2006; Sangiorgi 2011), to examine how citizens across three cities in Europe (Amsterdam, Barcelona and Pristina) have been addressing shared environmental concerns through a process that brings participatory sensing and design together. Using a case study methodology, nine pilots (three in each city) are assessed and discussed in regards to underpinning principles of transformation design, which examines socially progressive design work within communities (Sangiorgi 2011). These principles are considered more broadly as a theoretical framing for participatory sensing and design as a way to address environmental challenges at a grassroots level. The results of this study contribute to a growing demand for the relationship between participatory sensing, and the social contexts in which they are situated, to be discussed (Maisonnueve et al. 2016). This paper argues for a design-led approach to developing methodologies for participatory sensing in urban environments. To conclude, the authors present insights from the nine case studies and the value of transformation design in the delivery of the pilots.

Pathways to Environmental Awareness: Approaches in Participatory Sensing

Participatory sensing is a field which is still in its relative infancy. Its proliferation is due in part, to an increase in affordable and accessible digital devices. It is a new form of citizen inquiry made popular through advancements in ICT and global social networking. However, the practice of citizen inquiry is not new, nor is the notion that citizens can assist in informing scientific data sets. These activities have a long history of occurrence in the field of citizen science, defined by Bonney et al. (2009) as the process of enlisting ‘the public in collecting large quantities of data across an array of habitat and

locations over long spans of time' (977). However, those who seek to understand citizen science have recently noted that citizens can have a greater influence on science through their participation (Cooper 2016).

In traditional citizen science interventions, the questions, goals, engagement and operational strategies stem from the project instigators, who can also train users or provide them with technology (Wiggins and Crowston 2011). This approach allows for established organizations or institutes to benefit from the data collected by citizens, whilst the citizens themselves rarely make use of the data for their own purposes. One reason for this could be that collated datasets are not typically available in a form that is accessible. In contrast, grassroots initiatives show issues at a local level, where goals and strategies are negotiated by groups of citizens who gather around the issue or share a common purpose with a need to gain access to technology and acquire the skills to operate it.

These emerging challenges have led to a rising interest in the use of design in the evaluation and development of citizen science and participatory sensing technology (Tangmunarunkit et al. 2015), and the use of design in the development of collaborative citizen science initiatives (Lukyanenko et al. 2016; Ishigaki et al. 2015). Through a study on technology tools for grassroots approach to waste management, Offenhuber and Lee (2012) highlight the importance of informal bottom-up initiatives in delivering change. They demonstrate the lack of uptake from hierarchically imposed legislation and argue that design allows for communities to involve themselves in the process without feeling the weight of top-down legislation.

Although promising, the vision of truly bottom-up empowerment heralded by those who instigate participatory systems is hard to achieve. Several studies on user engagement with participatory sensing platforms have revealed a number of technical and social issues that can hinder the appropriation of these practices at the grassroots level (Balestrini et al. 2015; Balestrini et al. 2014). Lack of technical skills among users, difficulties with the usability and robustness of the sensing devices, a perceived lack of social interactions and purpose among community members, and problems with data reliability and meaningfulness have too often led to user disengagement with the platform (ibid.).

Furthermore, there is a gap between the prolific use of technology to capture data on environmental issues and recognizing the complex social systems in which they exist. Knowledge exchange and co-creation are crucial components for environmental awareness and action and bringing in transformation design can offer a new framing and can evolve methodologies and technologies from a product focus to a more holistic approach. The next section examines this in more detail through describing the evolving subject of design and how it is can tend to the challenges within participatory sensing.

Instilling Change: Widening the Scope for Transformation Design

Design, which has been shifting in definition and application was once thought as a way to give form to objects and graphics but is now a way to describe processes for problem solving and even approaches to understanding complexity of systems and environments (Buchanan 2010). This shift allows design to explore areas such as participatory sensing. Existing collaborative, co-created approaches in participatory sensing have recognized the potential role of citizens as more than passive data gatherers. The number of truly co-created projects, however, remains very small. To this end, design offers a way of envisioning futures, developing and testing solutions, and knowledge and practice for creating change.

Design is a way of thinking about the connection between individuals and the designed world. It has developed progressive and collaborative practices, which are design-led and aim to employ generative approaches (Sanders 2002). Concurrently, there has been an increased interest in uniting science and technology studies and participatory design (Le Dantec and DiSalvo 2013). This is crucial, as it is argued in this paper that new approaches in this area of participatory sensing must take into account the social dimension of people using new technologies that address an area of concern specific to their community.

The forming of communities is a strategic design action which identifies appropriate coalitions and strengthens these groups through shared interests, values and visions developed through sharing of ideas and conversations (Manzini 2015). Similarly, co-design is a critical component, as it provides the theoretical understanding of the value of co-created knowledge and actions for change. By exchanging knowledge and expertise, and sharing it within the community, the co-design process creates concrete, feasible ideas for tackling collective issues because it reflects the knowledge and experience of those who are most impacted by the challenge at hand. In this context, those who share matters of concern can range from citizens, academics, environmental experts, makers and those in local government. It is to this end, that the concept of transformation design comes into play.

In transformation design, the participatory process is devised to support grassroots movements and influence wider society, to initiate systems remodelling towards more sustainable approaches (Baek et al. 2010). The application of design is a way of organizing the process of enabling solutions for radical change (Baek et al. 2010; Björgvinsson et al. 2010). It is argued that technology can enable bottom-up social innovation, providing communities with the tools to devise solutions to their unfulfilled social needs (Baek et al. 2010). The outcomes of these social innovations are wide in scope and can range from an idea to new policy agreements, from a public intervention to widespread social movements (Björgvinsson et al. 2010). One

approach of specific relevance in the context of participatory sensing is *transformation design*: an approach advocated by the Design Council UK to ‘tackle social and economic issues through design-led innovation’ (Burns et al. 2006). Further research into transformation design reveals an unpacking of the concept for assessing participatory sensing. Namely, seven key principles introduced by Sangiorgi (2011) positioned new practices across areas of design, organizational development, and community action research. These themes include:

- **Active Citizens:** where the users become the designers and the producers working in partnership with professional experts, academics and policy makers.
- **Building Capacities and Project Partnerships:** understanding that sustainable transformation requires a certain amount of trust, which is built through communication and a culture of participation. This denotes the inclusion of people in the process of change and continuous learning.
- **Building Infrastructure and Enabling Platforms:** is the purposeful devising of structures and platforms that support participation, with focus on the sustainability and long-term action and impact to maintain and develop it.
- **Evaluating Success and Impact:** understanding the specific methods and tools used for measuring the long-term impact and legacy of the process and interventions.
- **Intervention at a Community Scale:** harnessing the collective power of the community and using a community-centred approach and community-driven solutions, so that communities become the catalyst of interventions for large-scale and transformative change.
- **Redistributing Power:** participation in a design process requires a shift in the distribution of power for all stakeholders in regards to decisions, directions and production.
- **Enhancing Imagination and Hope:** supporting and enhancing the ability for communities to imagine new possibilities, and building a shared vision based on seeing the future in a new light and collectively working towards shared objectives.

This overview of the central concepts which underpin transformation design is aligned with participatory sensing as it is apparent that the human ability to co-create is central to solving global challenges at a local level (c.f. Manzini 2015; Ehn et al. 2014; Mulgan et al. 2007). It is through collaboration with those who share matters of concern to create appropriate courses of action, new environments and objects that can be the first step in research solutions to increasingly complex problems. The themes are areas for which the opportunities and challenges of participatory sensing, and in turn design, can be considered. The following discussion presents these

themes in relation to the findings from a study into a participatory sensing project delivered across Europe.

Methodology

To tackle these increasingly complex issues, this research employs an interdisciplinary approach. Therefore, a case study methodology has been selected as it embraces complexity and allows for a deeper understanding of interactions and uniqueness within specific context (Stake 1995). This is of great importance, as this paper includes nine pilot studies that occurred across Europe. All pilots worked with the public, driven by those people's need to address pressing environmental issues, and all had very different contexts. To capture the richness of these various case studies, a pro forma was constructed to glean the practical information alongside the context, strategy, aims and objectives, methods and tools, participatory process, sensing strategies, equipment and materials, findings, outcomes, and limitations. The case studies also reflected the impact of each pilot, demonstrating the collective action, mechanisms for sustainability and policy implications that the pilots had on their local governments. The case studies were initially formed through the collection of existing literature and written and visual documentation produced by the organizations leading on the pilots. Once the case study information had been gathered and analyzed through one of the themes above. The case study was then validated through a reflective conversation with those leading on the pilots. Using the framework of transformation design, the case studies were then analysed specifically to understand the role of design within these instances of participatory sensing. In the following discussion, we present the details of the case studies and a framework of participatory sensing developed through an analysis of the findings. We also discuss how transformation design exist and was crucial to the development of the pilots.

Making Sense Case Studies

The Making Sense approach was informed by previous experiences with partner organizations, and research into other participatory sensing platforms and projects. Apart from providing opportunities to engage with and improving existing tools, or developing new ones, Making Sense aimed at building actionable knowledge, supporting campaign orchestration, connecting networks and creating methods to foster collective awareness on environmental issues. The key participants involved ranged from: 'community organizers' who initiate the project and bring citizens together; 'project team' who lead on the process and facilitate activities; 'community members' who participate and drive the project with their collaborative efforts; external experts; data visualizers; government officials; and, the wider public. Participants collectively formed diverse communities and work together in various ways throughout the process to collectively

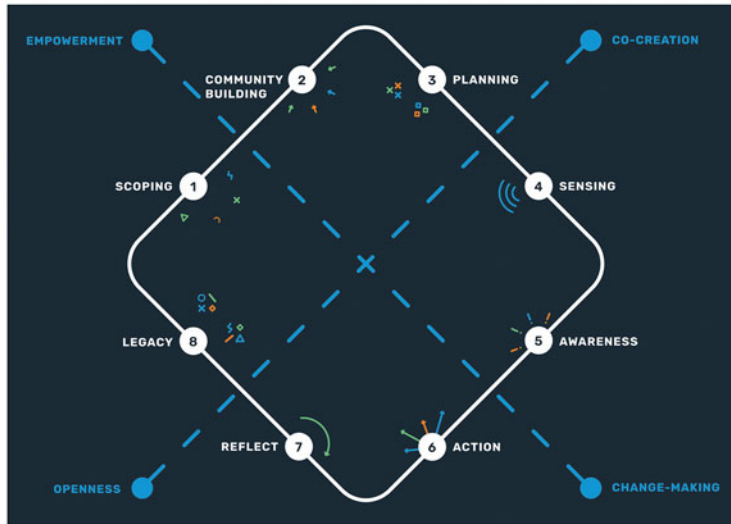


Figure 1. Visualizing the overarching principles and iterative phases of the Making Sense process.

promote awareness and devised actions to address shared urban environmental concerns.

Figure 1 visualizes the Making Sense approach; this framework was devised through a reflective and co-creative process with all the Making Sense partners (Making Sense 2018). It represents the phases informed by the overarching principles, cutting across the framework. It also demonstrates the process and serves as a reminder that it is not a strictly linear pathway, but one of reflection-in-action. Tools and materials employed during the project were co-designed by transdisciplinary partners and invited experts (c.f. Sanders 2017).

Figure 1 demonstrates the reflective nature of the project and the way in which the process moves through the stages summarized below:

1. **Scoping** is when the important issues are discovered, mapped and discussed by the key participants.
2. **Community Building** is when the participants come to a shared understanding of the issue, the goals of the project, and how it will be organized and documented.
3. **Planning** is when participants collectively decide on the project goals, on sensing strategies and on protocols for collecting data.
4. **Sensing** is when everyone collects data on the issue.
5. **Awareness** is when the data is collated and analysed and discussed amongst the community.
6. **Action** is when participants work together to propose and deliver courses of action.

7. **Reflection** is when participants reflect on the process and consider what worked well and what could have been improved.
8. **Legacy** is when participants look towards the future and making plans for lasting impact.

To discuss the relevance of transformation design in participatory sensing we will first give a brief overview of the nine case studies that were conducted as part of the project [Table 1]. The discussion which follows examines principles of transformation design in the practice of participatory sensing in Making Sense. Drawing on examples from the nine pilots, further details are given within each of Sangiorgi's (2011) themes of transformation design.

Discussion: Underpinning Transformation Design in Making Sense

These case studies are discussed in relation to the transformation design principles proposed by Sangiorgi (2011), and insights from this process are used to consider the relationship between practices of participatory sensing and conceptions of transformation design. These themes are: active citizens, building capacity and project partnership, building infrastructure and enabling platforms, evaluating success and impact, intervention at community scale, redistributing power and enhancing imagination and hope. These themes are used as an evaluation construct to present insights from participatory sensing activities below.

Active Citizens

Unlike most citizen science and participatory sensing projects, self-organizing communities need to negotiate common goals and shared purposes themselves. Within the Amsterdam Urban Air Quality pilot, the community members were formed around their residency in areas of high air pollution. Prior to the pilot this community organizers had been actively engaged with the issue, they had already attended meetings within the community on the topic and had been in contact with the municipality. For the pilot, this community came together with experts on air quality from the national official measurement organization, a university, and project leads from Making Sense. The contact between the experts responsible for the measurements, with the people that lived in the pollution everyday was a successful way of exchanging views and insights.

The community members co-created measurement strategies for monitoring local air quality together. The measurement strategy directly addressed: the questions the community members wanted answers to, the environmental issue they wanted to measure and why, and where the sensors would be placed [Figure 2]. After the pilot was completed, some community members were still actively

Table 1. Making Sense pilot case studies

<i>Pilot Title</i>	<i>Summary of Case Studies</i>
Amsterdam Urban Air Quality	For this pilot, 25 local residents measured air quality in this region of the city. They used existing information from the Dutch environmental defence organization (Milieudefensie) which stated that the Valkenburgerstraat and the Weesperstraat in the heart of Amsterdam were the most polluted streets of the city. Sensors were deployed in the residents' homes and collected data on NO ₂ , particulate matter, humidity and temperature. This data was analysed and interpreted in collaboration with experts and residents.
Amsterdam Smart Kids Lab	The Smart Kids Lab started as an installation at a festival, where children were invited to conduct their own measurements on soil, liquid and air. From this, an online platform that demonstrated how to perform the tests at home or at schools was developed. This led to the production of an online resource for creating DIY sensors in classrooms. Three schools took part in the pilot.
Amsterdam Gamma Sense	This pilot scoped the possibility of designing a new online platform which could be used by citizens to monitor gamma radiation and access others' observations and information on gamma radiation. Gamma Sense was created in response to the issues of information distribution during nuclear disaster. Using daily and readily accessible technology, such as smartphones, laptops or tablets, citizens can measure levels of gamma radiation in their surrounding environments.
Barcelona Community Champions	The first pilot in Barcelona, citizens tested technologies and methodologies in participatory sensing with focus on use of technology and methods for understanding data. The pilot examined noise pollution in the city, as this had been deemed the most pressing challenge by the citizens during an open session hosted by Making Sense Barcelona. As a result of the pilot, the citizens formed into cohort of 25 community champions who would have a level of understanding and skills which they could pass on to future participants.
Barcelona Fab Kids Lab	A group of 15 Kuwaiti students between the ages of 9 and 14 explored the effects of climate change on local environments with members of Making Sense team and community champions. Using the Smart Kids Labs activities developed by Making Sense in Amsterdam, they involved the children in processes of analogue and digitally-led sensing to demonstrate how pollution can affect local bird species.

(Continued)

Table 1. *(Continued).*

<i>Pilot Title</i>	<i>Summary of Case Studies</i>
Barcelona Gracia Sounds	The Plaça del Sol in the area of Gracia, Barcelona has historically suffered from people loitering, drinking and creating high levels of noise in their neighbourhood. The Making Sense team and the community champions from the first pilot, collaborated with the local residents to evidence the problem. Equipping residents with the technology and through a program of activities to support them in data literacy, the group were able to speak out on their ongoing problems with noise pollution and get the recognition from media and government that they needed to take steps towards resolution.
Kosovo Season 1	Kosovo is one of the most polluted regions in Europe. Making Sense in Kosovo investigated the air pollution by empowering young people and affected communities to jointly break the institutional silence around air pollution through evidence-based campaigns and actions. For the first pilot, a committee of young people aged 17-30 were recruited to plan, organize and run the pilot. This committee collaboratively designed the measurement strategy as well as the actions and protests that were arranged as a response.
Kosovo Season 2	The second pilot had the same committee members as the first, with the same focus on a participatory and democratic process of designing and conducting the pilot. They decided to focus on a primary school in Pristina for air quality measurements. Additionally, pupils from the school, their parents, carers and teachers took part in the process.
Kosovo Season 3	The third pilot had the same committee members as the first two, as well as the same collaborative and participatory process. This time, air quality sensing was focused on areas around aging power plants. This pilot covered the spring and summer season where the previous two pilots covered autumn and winter so that measurements were taken at all seasons throughout a year period across the three pilots. This pilot also included the measurement of bio-indicators, mapping lichen diversity as an indicator of environmental stress.

involved in the issue of air quality. This included meeting with the Municipality to discuss their air quality data from their sensor; signing up to a future pilot on noise pollution as they see both air and noise quality linked to traffic; and campaigning to the local council to prevent a parking lot being built in their area using data from the pilot.

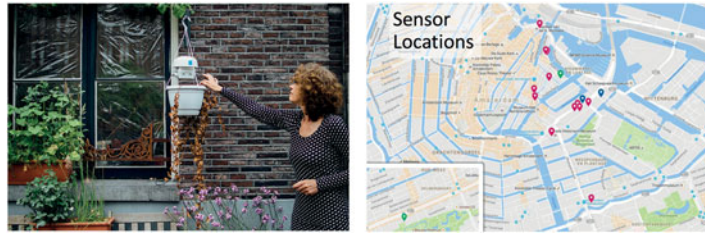


Figure 2. Active Citizens. Installing the NO₂ sensor (left). Map of sensors in Amsterdam (right).



Figure 3. Building capacity and Project Partnership. Discussions with affected residents in Barcelona.

Building Capacity and Project Partnership

The Gracia Sounds pilot in Barcelona directly built on a previous pilot, as such, Community Champions from the previous work were key in bridging the two, designing and implementing the subsequent Gracia Sounds pilot. Gracia Sounds took place with residents from an area in Barcelona that had been struggling with the issue of noise pollution for some time. During the pilot, there were several workshops, meetups and events to encourage participation and the development of learning and knowledge in areas such as sensors, data visualization and interpretation. Initially, the community members from the Plaça del Sol wanted the Making Sense project team to ‘fix’ the issue of noise pollution in the square and it took time and effort on both sides to build trust and see that the Making Sense process was designed to give the community members the tools and skills to encourage change themselves [Figure 3].

The themes emerging from the studies around community engagement with Making Sense are aligned with those reported in the citizen science and environmental justice literature: the success of a pilot intervention has been linked to factors such as providing training and skills through community coordinators, and following an approach that is context-specific, iterative, and adaptive (Pollock and Whitelaw 2005). Furthermore, the fundamental role played by community champions to ensure the sustainability of community based environmental stewardship and civic action has been signposted in previous reports (Conrad and Daoust 2008; Conrad and Hilchey 2011; Pollock and Whitelaw 2005).

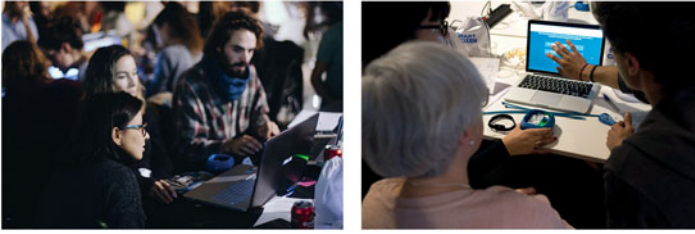


Figure 4.

Building Infrastructure and Enabling Platforms. Learning the sensor onboarding process together.

Building Infrastructure and Enabling Platforms

To date, most low-cost sensors for environmental monitoring lack the robustness required to produce reliable data. As a result, users struggle to keep the sensors calibrated, which is crucial to obtaining reliable measures. This can lead to random readings that have a negative impact on the quality of the data and consequently the trust people have in the sensors. Making Sense attempted to mitigate these issues, exemplified in the Community Champions pilot in Barcelona.

The Community Champions in the first Barcelona pilot were a specific group of community members, comprised of those with high interest and variable technology skills, citizens who were attracted to the campaign by the issue of noise pollution, but also had a desire to use and form a better understanding of sensing technology. There were also those who had a variable interest and high technology skills. Within this group there were those with a background in sound engineering, coding, and technology enabled visualization. These individuals sought to work towards solutions for the noise pollution issue in the city. The pilot was structured to strengthen the community through the sharing of skills and interest, and the regular workshops and social media allowed for the community champions to form a strong network of community members.

This sustainable infrastructure was composed of technology skills around sensor building, installation and onboarding processes and understanding of data as well as through other skills such as mapping and understanding noises. The intention was for the community champions to support other participants in following pilots, and to continue building the network of participatory sensing activities. Indeed, the Community Champions in the first Barcelona pilot continued their involvement in further pilots. Specifically, the third pilot in Barcelona, Gracia Sounds. For this pilot, the Community Champions took a more active role in onboarding and supporting the new community members [Figure 4].

Evaluating Success and Impact

Citizens feel empowered when they understand evaluation and can connect it in a way that has relevance to their lives (Fetterman,



Figure 5. Evaluating Success and Impact. Documentation of collection of bio-indicators.

Kaftarian and Wanderman 1996). To move participatory sensing beyond primarily technological practice and towards a transformational endeavour, new approaches to collective assessment to action and impact were introduced. Primarily, this can be seen in the use of indicators as complementary forms of information to the data gathered from the sensors (Coulson et al. 2017).

During the third Kosovo pilot a committee member put forth a proposal to study the impact of air quality on bio-indicators. Initially, the proposed research study was presented at a community members meeting where the study was democratically voted on. Once approved, a small group of members collected lichen samples from trees growing near three main power plants, in close proximity to five most populated areas of Kosovo, where air quality samples were also being collected as part of the pilot [Figure 5]. This research was based on an existing study titled 'European Guidelines for Mapping Lichen as an Indicator of Environmental Stress' (Asta et al. 2002). This process helped to inform the community members on the impact of air pollution on other living organisms. It had them design their own research strategy and consider the implications of their endeavour, and how they could contribute to existing scientific knowledge.

Intervention at a Community Scale

Deciding on the scale of interventions and participation is a high-level choice to be made at the beginning of any participatory sensing project. It may be that this is a process that comes about organically from within a community. The benefits of community level participation are that they are large enough to enact change but small enough to be representative of individual interests (Sangiorgi 2011; Meroni 2008).

The main participants of all the Kosovo pilots were young people aged 17-30, and the second pilot they were involved in was based around a primary school located in the centre of Pristina. Making measurements in and around the school was a strategic means to link air quality to the health effects on a vulnerable group, and to engage with people impacted by that: the children, their parents, the school and the wider community and society. A digital bootcamp

and non-formal environmental education events involved the young people as well as children from the school and their parents, carers and teachers. As a consequence of the measuring activity happening at the school as well as the events organized as part of the pilot, a Green School Committee was created, comprised of parents and teachers who wanted to be active in the area of reducing air pollution. This community is continuing to meet after the conclusion of the Making Sense pilots.

Redistributing Power

Within the Kosovo pilots, there was a deliberate strategy to shift the power and decision making to their citizens. Over 53% of Kosovo's population is under 25 and face many challenges, from unemployment, to corruption and lack of visa liberalization. The participants in all of the Kosovo pilots were comprised of young people that were concerned with the air quality in the city and wanted to work towards creating change in their local environment. One main objective of the first Kosovo pilot was to create, consolidate and empower a youth-led environmental movement that promoted and functioned under direct democratic principles. The idea behind giving them a role within the project, a title and the right for equal decision, was to not reduce the participants merely into volunteers, instead giving them ownership of the project.

The internal governance of the pilots was distributed between the Making Sense project team and the community members and all decisions regarding the pilot, including measurement strategy, sensors and actions to be taken were made by consensus. They had several meetings as part of the process which were safe spaces where everyone could voice opinions or concerns. Finally, they organized several ways in which everyone could communicate, including Facebook, WhatsApp and Google Docs.

Enhancing Imagination and Hope

In the very last event for the Barcelona Gracia Sounds pilot, the citizens and Making Sense project team decided to create an event in the Plaça del Sol where the main issue of noise was coming from. Full size stand up silhouettes of the residents of the plaza were placed around the square to encourage understanding from the users of the square that they were affecting the residents' lives. There was also a large box placed in the square with details of the pilot and about the impacts of noise. There were debates and activity tables providing a space for co-creation of proposals to improve the quality of life in Plaça del Sol. The themes of the tables were: architecture and design, urbanism and the social, collaborative economy, health and participation and an open theme. Children also participated in the creation of proposals using the Lego Serious Play methodology to encourage creativity and collaboration [Figure 6].



Figure 6. Enhancing Imagination and Hope. Using creative techniques to unpack issues.

The discussions from the tables generated a wide variety of ideas to improve quality of life in the square. Physical ideas included replacing the stone floor with sound absorbing materials and creating moss vertical gardens to protect facades of the buildings. There were also ideas for using the square for different short-term purposes, such as using mobile urban furniture. A calendar of silent events throughout the year was proposed, such as yoga classes and silent cinemas. At the end of the pilot the citizens felt that they had been heard by the media and that they had a chance for real change if they continued to work together.

Conclusion

This paper has looked at how the application of design in participatory sensing has enabled citizens to address environmental issues and take action to effect positive change. This in turn offers an advancement in the emerging field of transformation design, moving it further towards collaboration with citizens and a greater emphasis on the role of open technology and data. Central to this is co-creation and design by citizens, as opposed to being users of products and services designed by a private company or government agency. For sustained engagement and to allow citizens to take matters into their own hands and attain change, a new approach which combines participatory sensing with strategic co-creation must be formed. It is here, that new conceptualizations of design for transformation can add value to the participatory sensing field.

Additionally, design is utilized for the development and evaluation of participatory sensing is a burgeoning area of research. The insights obtained from the case studies demonstrate that the community aspect of participatory sensing, where communities are addressing issues of importance with new technologies, must be taken into account in this new approach to research and practice. Change and action through design principles should also be prioritized within participatory sensing and citizen science.

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Biographies

Saskia Coulson is a postdoctoral research fellow at the University of Dundee, where she works on interdisciplinary projects that put design at the centre of collective inquiry. She currently works on WeObserve, a H2020 Coordination and Support Action for citizen observatories for environmental monitoring. Previously projects include H2020 Making Sense and AHRC Design in Action. Her doctoral research was funded by the ESRC and sponsored by V&A Museum of Design Dundee. Her research interests include design for social innovation, citizen science and design-led research.

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Michelle Scott was a post-doctoral researcher on the Making Sense project at the University of Dundee. Previously she was based at the Centre for Sustainability at the University of Otago in the Energy Cultures project. She has a PhD in HCI from Madeira Interactive Technologies Institute and is interested in encouraging individual behaviour change as well as collective action for change towards more sustainable living.

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