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Shut up and take my environmental data!

A study on ICT enabled citizen science practices, participation approaches and challenges

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Abstract

Citizen Science initiatives have been around since the 20th century in numerous fields, from astronomy to health monitoring. In recent years, social changes mediated by the development of information and communication technologies have pivoted new types of civic actions, which have enabled an expansion in the breath of citizen science applications. This civic technology has become a genuine interactive and inclusive opportunity for engaging citizens in the continuous collection of data relevant to science, governance, businesses, communal living, as well as individual concerns. This article presents the practices, trends and challenges of 108 ICT enabled citizen science projects. In addition, we present a palette for participation in ICT enabled citizen science that depicts the shapes civic participation is currently taking in different contexts. We discuss the potential uses of this palette for improving the engineering of ICT citizen science platforms to better fit the needs of volunteers and build opportunities for active engagement.

Keywords— ICT; citizen science; civic technology; participation; technology use; practices; challenges

1 Introduction

What do applications like Wikipedia, Fold.it, Waze, Ushahidi, and Galaxyzoo have in common? The answer is "people" whom drive these civic technologies from their operational core. The activities that people carry on these platforms ranges from data collection, usage and classification all the way to dissemination and, represent a deliberative act of public participation via information and communication technologies (ICT) services. These activities hold a historical background tightly linked with human nature and humans' inherent curiosity that has led us to try to observe and understand our surrounding nature and society since ancient times. For example, during the prehistoric age people would use tally marks on caves, wood, bones, etc. as a counting aid to monitor animal populations. During the 20th century, it became clear that public participation was key for sustainable development, as international treaties and declarations started declaring it as a mean to enhance social development [1], environmental management [2], sustainable development [3], decision making [4] and science advancement [5], [6].

Having people carrying (monitoring) activities for a common good (e.g. research), became popular and became known as "citizen science". Due to the technological development of the last decades, this interaction between experts and citizens for monitoring purposes grew in reach, receiving multiple names in different fields [7], from the well-known citizen science to collaborative mapping, community monitoring, science 2.0, crowdsourcing, contributed geographic information, crowdsensing, participatory sensing, citizen sensing, among others.

The development of ICT has broadened the world's horizons in many ways. In particular, ICT tools have pivoted the development of new types of civic actions such as activism, mobilizations, public campaigning, community monitoring [8] and the web science [9]. As a result, fields such as civic technology and digital civics have emerged to support the design and use of technology to enhance public participation and dialogue [10]–[12].

Societies are heading towards a future that will increasingly involve partnerships mediated by ICT between citizens, communities and civic authorities to enhance civic engagement in planning, management and maintaining their living environments [13]–[15]. Already during the last decade ICT enabled monitoring applications have started booming across the world with applications in several domains, particularly in environmental monitoring (see section 3.1). For example, FixMyStreet[1], supports city development by allowing citizens to report and track issues in their towns (e.g. broken pavement). Ushahidi[2] helped the Kenyan government in 2007 to map violent acts across the country, and has been used in more than 10 countries for handling different issues since then. eBird[3] was launched in 2002 to gather basic data about bird distribution across the globe. By now eBird has collected hundreds of millions of observations from most countries in the world. Finally, Safecast[4] was launched as citizens' initiative to monitor the radiation levels in Japan after the nuclear accident in Fukushima in 2011. By now, it has become the largest monitoring network in history. In short, ICT enabled citizen science has been actively supporting citizen-driven data collection for a variety of purposes including scientific research [16] and crisis communication [17], [18], whilst serving as means for inclusive engagement, education, and public outreach [19]–[21]. However, despite the

[1] http://www.fixmystreet.com
[2] http://www.ushahidi.com
[3] http://www.ebird.org
[4] https://blog.safecast.org

outstanding success of these monitoring initiatives, there has been a limited attempt to study their day-to-day practices and their link with technology.

The contribution of this article is two-fold. Firstly, we highlight key results from a state-of-the-art study about ICT enabled citizen science projects. This study was carried by Lappeenranta University of Technology and the Finnish Environmental Institute during 2015 – 2016 [22] and it systematically reviewed practices, trends, and challenges of 108 ICT-enabled citizen projects reported in academic literature. Secondly, we present a framework for participation in ICT enabled citizen science that depicts the shapes civic participation is currently taking in different contexts. We then discuss the potential uses of this framework for improving the engineering of ICT citizen science platforms to fit the needs of volunteers and civic authorities. In order to build opportunities for active engagement in community monitoring initiatives.

2 Methods

The overreaching methodological approach of this study is thematic analysis (TA), which is "*a method for identifying, analyzing and reporting patterns (themes) within data*" [23]. The phases of this study are detailed below. Systematic review techniques [24], [25] are used as part of these phases to select relevant literature as data source for the analysis.

A. Phase 1. Familiarization with the data

In this stage, a systematic literature review study was performed to find literature reporting ICT-enabled citizen science initiatives. The objective of this literature review was to find out about the current state of the art of the trends, practices, and challenges of ICT enabled citizen science projects. This phase was part of a larger research initiative by Lappeenranta University of Technology and the Finnish Environmental Institute during 2015-2016 and its part of a published as a report by Palacin et al. [22], also the mined data is openly available at [26]. The literature corpus was created using the following steps: (1) Searching IEEE Digital Library, ACM Digital Library, Science Direct/Scopus, Web of Knowledge, Springer Link for articles matching the search string keywords such as 'citizen' 'citizen science' 'observatory' 'environment' 'engagement'. (2) Reading the metadata of 828 studies and include the ones with relevant link to this study. As a result, 70 papers were selected as relevant. Secondly, in this phase we also created a corpus of ICT enabled citizen science projects. (1) First we read in depth the 70 relevant papers and record each mention to an ICT enabled citizen science project. As a result, 108 projects were recorded. (2) Then each of the projects was further investigated by visiting its websites and reading its publications.

B. Phase 2. Generating Initial Codes

The entire literature corpus (70 papers) was classified according to common features such as research type, approach, relevance, and domain. In addition, the data gathered about the 108 ICT enabled citizen science projects was organized into major codes/categories, which are presented in table 1.

Codes per Project
Project title, environmental focus, participation model, domain, focus-domain, country, description, type of data measured, year of start, activeness, contact, website
Stakeholder, activities description, techniques to engage
IT platform, description, application type, goal, services use, detail IT infrastructure, social media
Problem or limitation, cause, solution proposes
Best practice, process
Recommendations
Standard in use, description, issuing institution, website

Table 1: Codes from Each ICT Enabled Citizen Science Project

C. Phase 3. Searching for Themes

In this phase, the literature corpus, the 108 projects data and the codes from the previous phase were re-analyzed iteratively to identify major themes, minor themes and sub-themes based on the differences and similarities in the data.

D. Phase 4. Reviewing Themes

This phase involved the refinement of themes by looking at the similarities and differences between themes and the data. Six major themes were found: domains of application, technologies, practices, stakeholders, challenges and recommendations. These major themes served to organize the lower level themes.

E. Thematic Analysis: Phase 5. Defining and Naming Themes and Sub-themes

A final mapping was completed by visually representing the major themes, minor themes and sub-themes.

3 Findings

This section presents the key findings from the report by Palacin et al. [22] and discusses their relevance. These key findings include a recollection of monitoring domains, data collection approaches, practices, stakeholders, volunteer's motives extracted from the studied projects.

3.1 Monitoring Domains

The 108 participatory sensing projects were classified into eight sub themes based on their monitoring domain. Those monitoring domains are presented in figure 1 and table 2. Most of the projects were focused on some level of environmental monitoring such as species, water, streams, snow, sea, biodiversity, air, spectrum, and global monitoring. Also, there were a significant number of projects focused on city management issues and tools for creating monitoring projects from scratch.

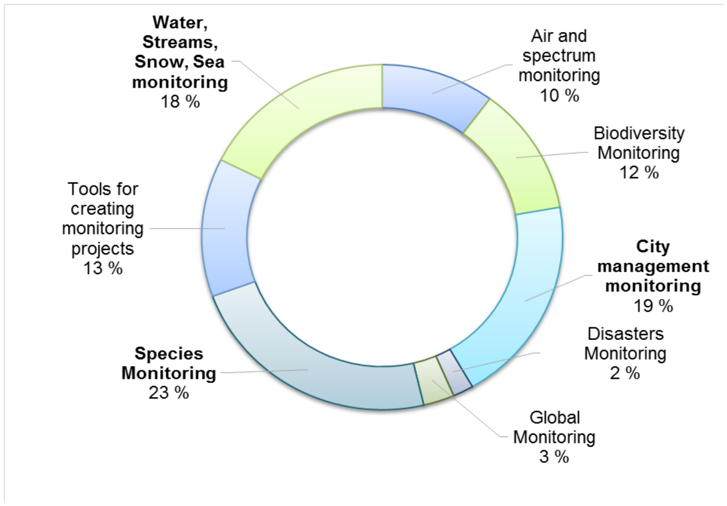

Figure 1: Domains of application

Domain	Description	Examples
City management	City issues monitoring projects, such as transportation, bike routes, land usage, and energy consumption	FixMyStreet, SeeClickFix, VizWiz, Waze, CiclePhilly
Water, streams, snow, sea	Collect data about water quality, precipitation, streams, lakes, snow, ice, and sea environments	CURA H20, Järviwiki, Brooklying Atlantis, LAKEWATCH, , CoCoRaHS
Biodiversity monitoring	Focus on monitoring biodiversity: flora, forests, mountains, biosphere, and trees.	Plant Watch, Leaf Watch, iNatural, Mountain Watch,
Air and spectrum monitoring	Gather data about air quality, noise, sounds, and radiation, especially in cities.	Common sense, SafeCast, Noise Tube, CitiSense, Bucket Brigades
Global monitoring	Monitor and report environmental variables to governments, also, projects that collect astronomy and climate-change observations.	Galaxy zoo, Spring watch, GLOBE at Night
Disaster monitoring	Monitor and detect early possible disasters, such as floods and earthquakes.	iShake, Did you feel it?
Tools for creating monitoring projects	Allow the creation or integration of monitoring initiatives, such as plug-and-play tools, image classification components and sensors-monitoring components.	Glassnost, Ushahidi, CitSci, Public Lab

Table 2: Domains of Application: Descriptions and Examples

3.2 Data Collection Approaches

ICT enabled citizen science projects are a clear example of a data intensive sociotechnical systems as they are:

- Used by multiple users: from citizens (collecting data), scientists (extracting patterns from the data available) to organizations such as companies (creating profits from the available and open data),
- Highly available in multiple platforms,
- For collecting, analyzing and disseminating data about certain phenomena of interest,
- From a wide variety of data sources, data types and data locations.

The technologies in use for data collection among the studied projects are presented in Table 3. These technologies range from automatic devices (such as sensors) to intentive means (such as web surveys) depending on the level of human interaction they require to capture data.

Approach	Interaction
Sensors	Automated
Social Media	↑
Mobile Apps	
Websites	
Interactive Voice Responders	↓
Surveys	Intentive

Table 3: Data Collection Technology Spectrum

This spectrum of technologies is reflected on the two data-collection modes (opportunistic and participatory) [27], [28]. Mobile devices and sensor networks have enabled growth on monitoring projects, because they provide constant and accurate measures of specific variables. As a result, the so-called opportunistic data collection has steadily risen since 2000. Also, the use of mixed approaches (participatory and opportunistic) have increased since 2010 (Figure 2).

a) ***Opportunistic data collection*** or device-centric data collection: A participant is an automatic sensor carrier, and "*sensor sampling occurs whenever the state of the device matches the application's requirements described in a sensing task*" [29] (e.g., Waze route tracking when driving or a mobility tracking app [30] ; and

b) ***Participatory data collection*** or user-centric data collection: A participant is an active data provider and is actively involved in the collection process by a prompted experience where the participant decides to record observations. This approach requires intentive interactions (e.g., reporting security issues with Ushahidi webpage).

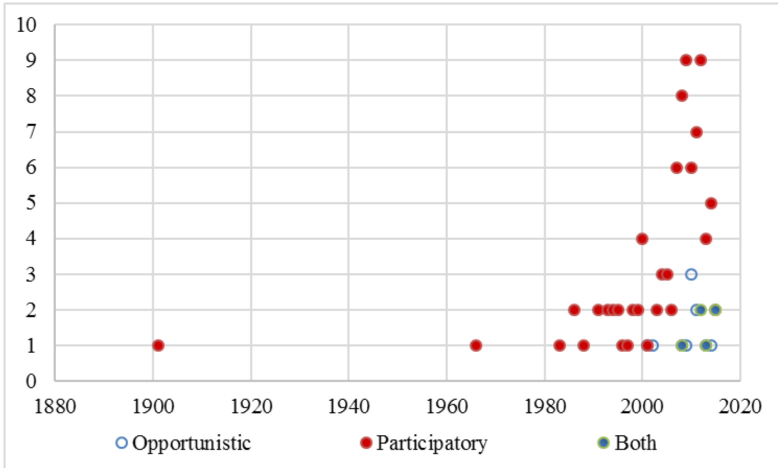

Figure 2: Data collection methods over the decades

3.3 Practices

Seventeen practices (Table 3) were identified from the studied projects. These practices are either (i) **Technology-intensive practices**, created to facilitate the collection, analysis, and dissemination of data or (ii) **Engagement-driven practices** aimed to combine strategies to locate and motivate observers. The top two practices among the projects are: (1) co-creation practices that involve co-creative solutions with citizens through direct and constant contact and (2) feedback from observations (observers can visualize the results of their contribution). Top two, less common practices are: (1) data aggregation (different data sets, often from different sources, are integrated) and (2) interest-based projects (allow people to set up monitoring projects based on their own interests).

Technology Intensive Practices	Engagement Driven Practices
• Real Time Visualization • Observatory Component Based • Opportunistic data collection • Provide training material • Provide Technology • Data Aggregation	• Co-Creation • Feedback from observations • Gamification • Identify stakeholders and their motivations • Participatory data collection • Environmental Campaign in Public Spaces • Interest based Observatories • Involve Decision Makers • Open Data for Engagement • Measure Motivation • Set common protocols for observers

Table 3: Practices among projects

3.4 Stakeholders

Five categories of stakeholders were identified in the studied projects. Along these categories, four types of activities that stakeholders performed were recorded. Table 4, summarizes the stakeholder groups according to their main activities and which type of domain involved them.

ICT enabled citizen science projects are being used in multiple fields and involve several types of stakeholders, but they are also run by various types of organizations. These organizations range from universities, charities, companies, consortiums, government institutions, initiatives (initiative is understood as an umbrella term for projects, companies, and their products), NGOs, to research institutes. Furthermore, these type of projects have been recognized for their potential for considerable improvements in terms of social innovations and democratization [1].

Stakeholder	Main activities	Domains of application
Citizen	Provide raw data; Install sensors or apps that collect background data; Deploy their own monitoring campaigns.	All domains
Academy and government	Provide data; Install sensors or apps that collect data; Deploy their own monitoring projects , Use resulting information for decisionmaking Research and development.	City management Tools for creating monitoring projects Species monitoring Air and spectrum monitoring
Nature enthusiasts	Provide data; Install sensors and apps to collect background data; Use the data for decisionmaking.	Biodiversity monitoring Species monitoring Water, streams, snow, and sea monitoring City management
Households	Provide data (4%); Install sensors and apps that collect background data (4%); Use the information for personal decisionmaking (4%)	City management Biodiversity monitoring Air and spectrum monitoring
Developers	Research and development (2%)	Air and spectrum monitoring

Table 4: Stakeholders' activities and domains of application

Figure 3, presents a socio-technical vision of ICT enabled citizen science projects. In this socio-technical system, the data providers are the volunteers that provide the contextual data and sensors that collect or measure specific contexts. The ICT infrastructure includes interfaces, storage and the processing capabilities for data collection and analysis. The outcomes represent some of the dissemination channels for the information and patterns found in the collected data. The ultimate beneficiaries are stakeholders and institutions that use the monitoring outcomes for their concerns, for example, improving lifestyle, decision-making, or research and development.

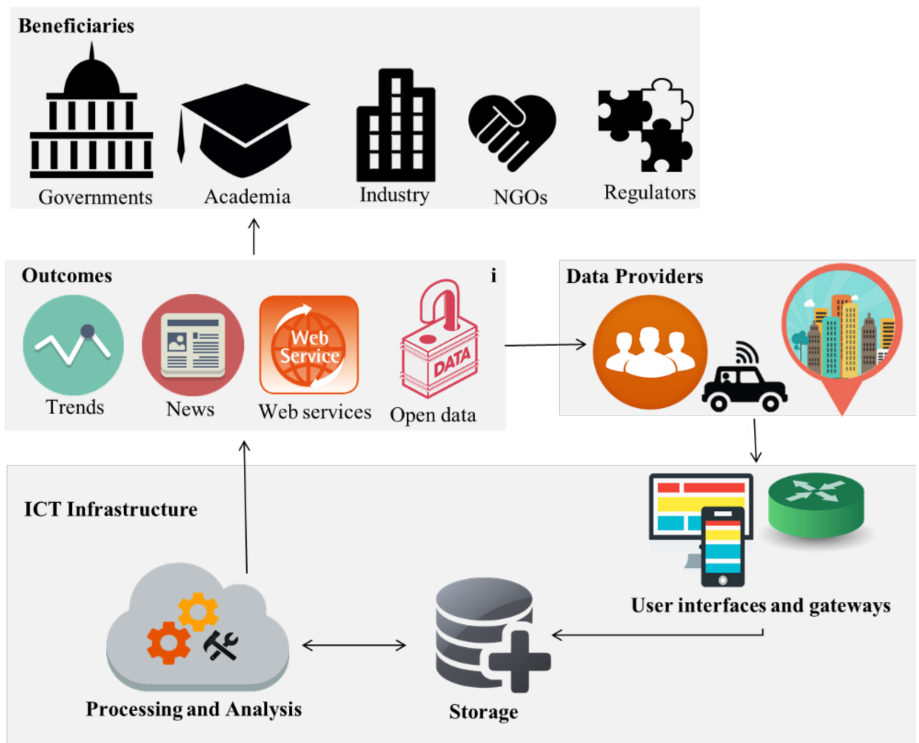

Figure 3: Socio-technical vision of an ICT enabled citizen science project

3.5 Volunteers' Motives to Participate

Engaging volunteers is a major issue for ICT enabled citizen science projects. Because, volunteers tend to abandon the initiatives early or do not commit with them continuously. The studied projects reported five major reasons that drive their volunteers to join and stay in a monitoring project. These have been mapped against the volunteer functions inventory from social sciences [31], [32] and are presented in table 5. This inventory is aimed at assessing volunteers' motivations. It highlights six motivations for volunteering: values (altruistic concerns for others), understanding (acquiring skills), enhancement (self-development), career (obtaining career benefits), social (interactions according to social standards) and protective (ensuring own wellbeing).

Volunteers motives according to the analyzed projects	Volunteer functions inventory
Drive to change, e.g. monitoring a lake due to activism.	Values
Understand data benefits, e.g. monitoring air quality due to an allergy is good for society and, in particular, for oneself.	Understanding Protective
Need for challenges, e.g. Increase the performance during a recreational activity by adding an observation challenge or get immersed into games.	Enhancement Social
Self-interest gains, e.g. carrying monitoring activities to gain free movie tickets or money.	Enhancement Career
Social recognition, e.g. carrying monitoring activities to receive a local recognition by the city hall.	Social

Table 5: Volunteers' Motives to Participate in ICT Enabled Citizen Science

Understanding what drives volunteers to join and stay in a monitoring initiatives has been focus of some studies [7], [22], [31]–[36]. In addition to the volunteer functions inventory, other study in social sciences identified four motives for community involvement [33]: egoism, altruism, collectivism, and principlism. In crowdsourcing, an integrated definition by [34] highlights four benefits that volunteers obtain by participating: self-esteem, economic, social recognition and skills development. In citizen science, based on experts' experience, volunteers join monitoring initiatives because they want to keep individual listings, compete/win something or care about the data [37]. In practice, the iSPEX project reported two core motivators among their volunteers [35]: contributing to science and interest on the monitoring topic. The Zooniverse project, reported three motives among their volunteers: helping, interaction with the website and social engagement. Finally, a review of 100 sites of crowdsourced geographic information [7], identified two generic incentives for participation among their volunteers: being part of a good cause and gaining something tangible. In participatory sensing, a common categorization of motivation is extrinsic and intrinsic [36]. Also, incentive mechanisms such as resource-awareness, privacy awareness, incentive driven design, QoI (quality of information) by recruitment, QoI by gamification, micropayment and reputation, auction and non-auction based mechanisms, are frequently proposed as a means to motivate volunteers [38], [39].

In overall, there are two streams of research focused on civic engagement [13]: 1) smart city initiatives aimed at using urban sensing to monitor and manage the cities as complex systems and 2) civic engagement tools and mechanisms aimed at enhancing citizens role in the management and maintenance of their city. However, it is still unclear what are the changes in volunteers motives and engagement behavior during a monitoring initiative [38], [40], [41]. Human motivation is inherently dynamic; what motivates us to start an action might change while we are performing that action. However, most of current literature in the field, reports motives as a static continuum among volunteers.

3.6 Challenges

ICT enabled citizen science projects face numerous challenges. We identified nine common challenges from the point of view of the studied projects (in order of importance):

- **Sustained participation**: The target stakeholders are not always ready for start contributing and often abandon the initiatives soon after their start.
- **Data Aggregation Issues**: Information is obtained only when multiple sources of information are combined. Hence, aggregating data from monitoring applications is important yet challenging due to the multiple data formats, metadata ontologies and data structures.
- **Technology**: This challenge refers to issues with devices' size, weight and reliability, power consumption limitations, calibration and configuration constraints, lack of systematic methods to reject false and spam observations.
- **Standardization**: There is a current the lack of reusable methods or frameworks for creating new observatories, the lack of standards for inter–communication among monitoring platforms, semantic discrepancies, and lack of systematic evaluations.
- **Limited Knowledge**: Several projects faced issues because of the lack of knowledge about how to build technically a monitoring application.
- **Limited Resources**: The development of an ICT enabled citizen science project tends to have limited resources that are mostly spent during the initial phases, creating a debt for the monitoring and maintenance phases.
- **Privacy Issues**: Understanding the concerns of stakeholder's regarding the ownership and use of their data is fundamental from the start of a monitoring project. Adequate technologies should be used to capture the volunteers' concerns and preferences regarding their data.
- **Recognition of Contribution**: There is a need for more social fairness when it comes to ICT enabled citizen science projects, which need to properly acknowledge the contributions and support of observers.
- **Data Accessibility**: Publishing raw data is not sufficient, stakeholders should be able to access, explore and analyze relevant information (extracted from raw data) in a simple and transparent fashion.

In the context of these challenges, it becomes imperative to improve the understanding of volunteers' motives and engagement behavior to be able to identify opportunities for building tools that enhance motivation and engagement. Some approaches researchers are exploring are auction based incentive mechanisms [38], social media and gamification [42]. However, there is an acknowledged need to start also studying the changes in motivation among volunteers, and answer questions like why they stay in the projects? [43] Why they dropout? What is the link between the monitoring domain and the motives? [40].

It is argued that limitations in knowledge or resources in a citizen science project could boost the civic action and innovation [44]. It is important to highlight that new frameworks are continuously emerging to tackle this challenge. For example, the city in common framework [45], the citizen sensing toolkit [46], the biodiversity guide to citizen science [47], the European citizen science association collection of guidelines and principles for citizen science [48]. Also, tools such as Ushahidi, the citizen field engineer [44], Alltagsspuren [49], Citizense [50] support the process of initiating a citizen science initiative in an effective manner with limited resources. Yet, there is still a need to develop standards that are widely known for ensuring that in a future we can explore and integrate data from different data sources and projects.

In addition, other studies have reported similar challenges to the ones we reported in here. Which range from: privacy and security concerns [29], [51], [52]; gaps in data protection laws between countries where the data is collected vs where it is stored [30]; data quality and interoperability issues [29], [53]–[57]; need to improve the reach of reusable development methods and frameworks [58]–[61] and a need to develop approaches and tools to enhance sustained citizen engagement and participation [7], [39], [53], [62]–[65].

4 Civic Participation Palette

ICT enabled citizen science initiatives are based on public participation but also serve the public in solving problems in people's daily lives. Public participation is the right of citizens to become engaged in their governance process because they are directly affected by decision makers' resolutions [4], [66]. As such public participation can take different forms, from merely informing to allowing citizens to take control of power. A "hierarchy of involvement," defined in Arnstein's ladder of participation [66], presents a view of participation as a balance of power that enables public inclusion in governance. This ladder remains the most cited approach in the field of public participation. However, the ladder model has been criticized, because it represents a hierarchy of roles where the top one is the most important (whereas in society, every role is important). This ladder has been subsequently adapted, improved, and debated in multiple studies [67]–[70]. In citizen science, this ladder inspired the levels of participation and engagement by Harklay M. [71].

ICT enabled citizen science are often seen as mean for public participation and social innovation [72]. In recent years numerous grassroots movements led by 'lay" people have started emerging around the world e.g. Ushahidi and Safecast. We observed that there was a gap in the literature reporting this participation spectrum. Hence, we developed a participation palette based on the studied 108 ICT enabled citizen science projects, additional 20 projects that were not reported in our literature review and existing frameworks. These frameworks include the Arnstein's ladder of participation, the democracy cube [69] and classifications of types of participation in citizen science [71], [73].

The participation palette (figure 4) can be described as a framework that portrays the current levels of participation when it comes to monitoring initiatives. Each of the five tones in the palette represents a deliberative act of civic participation. Some of the most important features in this palette are summarized below:

- ***180 degrees:*** In this palette, every level of participation is equally important thus, there is no hierarchy.
- ***Spillover effect:*** More than one tone of participation can be activated at the same time. As one tone of participation can enhance other tones.
- ***Temporality:*** The levels of participation are temporal and they can change over time based due to different contexts.
- ***The participation tones are not user types:*** Each participation tone represents a deliberative act of civic participation, which may be mediated by ICTSs or by other types of resources.

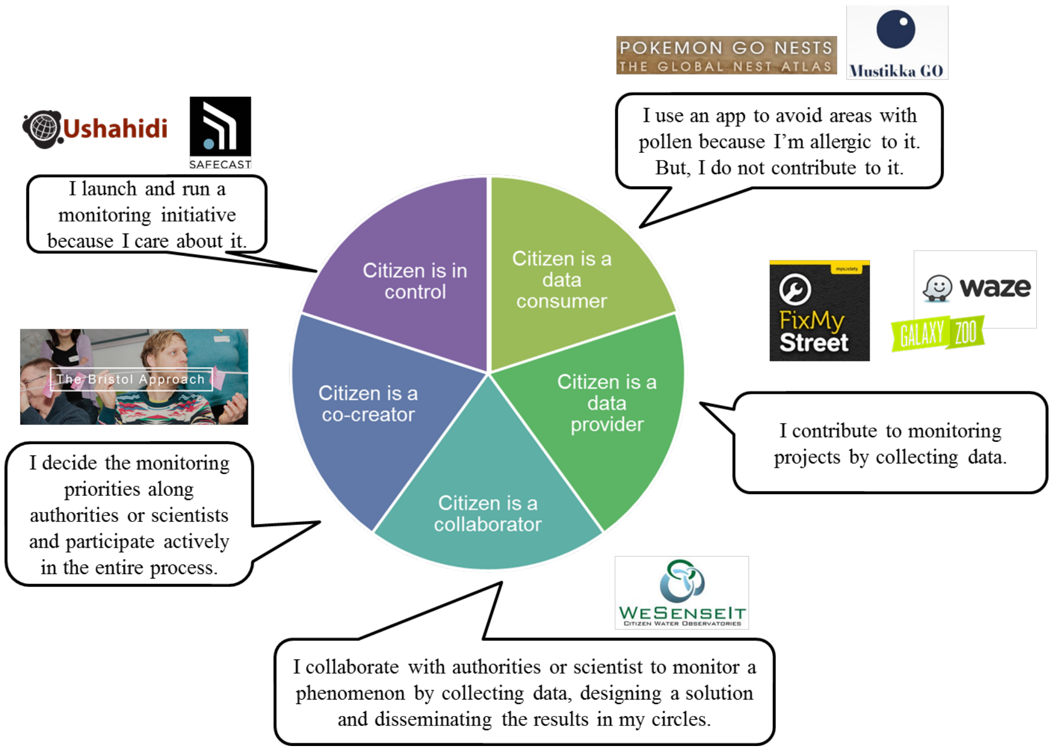

Figure 4: Palette of Participation

The **citizen as a data consumer** depict a citizen who does not contribute with data collection. Rather uses the data available through services. For example, a data consumer would use the application Mustikka Go to find blueberry locations in the forest. Hence, at this level, the participation is limited to self-enhancement and the engagement is minimal. This type of participation is a clear example of the 1% rule in the internet culture, the rule states that only 1% of the users actively contribute with content on the web and the rest 99% just use the content [74].

The **citizen as data provider** represents a citizen who provides data via data collection or classification using his own devices or borrowed devices from experts. Examples: Fix my street let people report city bugs. Galaxy zoo let people classify universe images telescopes using their computer. iBat borrows ultrasonic time expansion detectors to volunteers to record bats activity while driving in the nights. Waze finds you the best route while monitors your own velocity and location in background.

A **citizen as collaborator** is a person who helps through the entire process of setting up a monitoring initiative led by experts. The participation involves facilitating or collaborating in the design, improvement, and dissemination of a project. Experts define the monitoring priorities and ask citizens to collaborate. Most citizen science projects fall under this category.

A **citizen as co-creator** participates in the entire process of planning, designing, and implementing a monitoring initiative. Citizens decide along authorities what should be monitored based on what they feel it is important for their town. Example: The Bristol approach, the city is doing that and designing smart services based on citizens' perspectives.

A **citizen in control** is a person who wants to start a monitoring initiative due to his own interests and due to lack of monitoring initiatives led by experts or authorities. Some examples include: Ushahidi (let people report violence acts via text messages, web or calls) and Safecast (people build their own Geiger devices and measures radiation).

4.1 Potential Uses for the Palette of Participation

The first potential use for this palette is to improving the engineering of ICT citizen science platforms to better fit the needs of volunteers and build opportunities for active engagement. This can be a tool to explore and understand what motivates them volunteers to participate at various levels of engagement. Secondly, this palette can improve the design and development of ICT enabled citizen science projects. As it can be a basis for user research, for example, in figure 5, we show a way to integrate the palette of participation into a journey map. Thirdly, this palette can help understanding the human-data interactions for engagement, by supporting the development of customizable systems and approaches that allow citizens to explore and understand their data in relation to their living spaces.

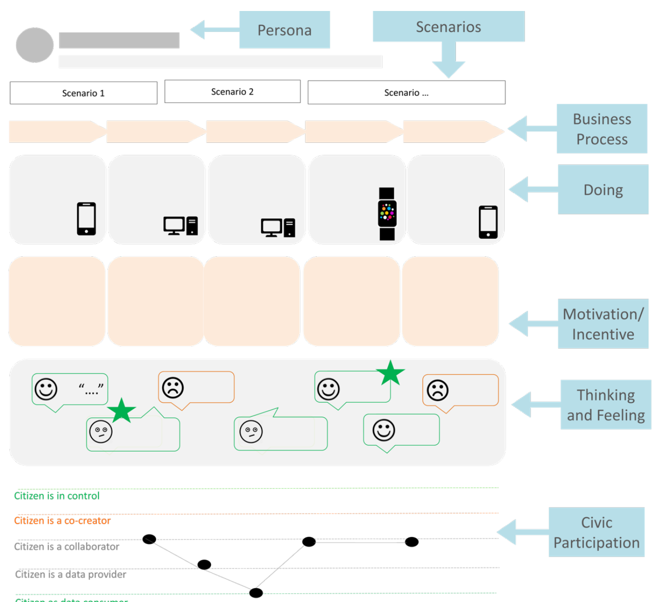

Figure 5: Integrating the Palette of Participation into a Journey Map

5 Conclusion

In this paper, we disseminate the results of a state-of-the-art study carried by Lappeenranta University of Technology and the Finnish Environmental Institute during 2015-2016 [22], which systematically reviewed practices, trends, and challenges of 108 ICT-enabled citizen projects that have been reported in academic literature. As such, these key highlights give a good basis for conceptualizing the reach of ICT enabled citizen science as data intensive socio-technical systems. In addition, we presented a palette for participation in ICT enabled citizen science that depicts the shapes civic participation is currently taking in different contexts. We also discussed the potential uses of this palette for improving the engineering of ICT citizen science platforms to better fit the needs of volunteers and build opportunities for active engagement and meaningful human-data interactions.

Even when the underlying technology is still evolving, ICT enabled citizen science has already shown its great potential, not only as a tool for citizens collecting data but also as a vehicle for engaging a large public community in solving social and environmental challenges. These systems have the potential to close the gaps among researchers, environmental experts, decisionmakers, and the people, while collecting data and building a whole new level of services (from the people, for the people). However, the success of ICT enabled citizen science initiatives relies heavily on continuous citizen participation and the computational capacity to extract patterns from the data being collected. Which translates into a need for tighter interdisciplinary collaboration between diverse communities of civics, researchers and decisionmakers. In order to be able to tackle the privacy and security concerns, gaps in data protection laws, data quality and interoperability issues, improve the reach of reusable development methods and frameworks, and develop approaches and tools to build sustained citizen engagement and participation.

Although, several studies have focused on studying the motives and incentives to improve and enhance sustained participation, it is still unclear what drives different volunteers to join, stay and abandon monitoring initiatives in specific domains. Hence, there is an opportunity to study the temporal and dynamic changes in user motivation and engagement in ICT enabled citizen science initiatives. This has been reinforced by recent calls for further studies to be performed to better understand the motivations of participants and the effectiveness of incentive mechanisms across different domains [38], [39], [53].

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