From Data Literacy to Co-design Environmental Monitoring Innovations and Civic Action

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Abstract. SENSEI is an environmental monitoring initiative run by Lappeenranta University of Technology (LUT University) and the municipality of Lappeenranta in south-east Finland. The aim was to collaboratively innovate and co-design, develop and deploy civic technologies with local civics to monitor positive and negative issues. These are planned to improve local's participation to social governance issues in hand. These issues can be e.g. waste related matters like illegal dumping of waste, small vandalism into city properties, alien plant species, but on the other hand nice places to visits too. This publication presents initiatives data literacy facet overview, which is aimed at creating equitable access to information from open data, which in turn is hoped for to increase participants motivation and entrepreneurship like attitude to work with the municipals and the system. This is done by curating environmental datasets to allow participatory sensemaking via exploration, games and reflection, allowing citizens to combine their collective knowledge about the town with the often-complex data. The ultimate aim of this data literacy process is to enhance collective civic actions for the good of the environment, to reduce the resource burden in the municipality level and help citizens to be part of sustainability and environmental monitoring innovation activities. For further research, we suggest follow up studies to consider on similar activities e.g. in specific age groups and to do comparisons on working with different stage holders to pin point most appropriate methods for any specific focus group towards collaborative innovation and co-design of civic technologies deployment.

Keywords: Environmental monitoring · Collaboratively innovate · Co-design innovation · Data literacy · Civic technologies · Open data

1 Introduction

In the last decade, civic technologies such as citizen sensing (also known as ICT enabled citizen science or crowdsensing) have been a popular means for empowering citizen participation and citizen engagement [1]. Specially the civic technologies have popular

in context of management and governance of cities, by augmenting both formal and informal aspects of civic life, government and public services [2]. The up shift in popularity has definitely drawn part of it suggest from global digitalization and sustainability trends [3, 4], the new level of awareness in general population against unnecessary waste and improvement in waste processing capabilities of municipalities [5], growth in public – private sector collaboration [6], and miniaturization and quality improvement in IT and sensor technologies [7].

This article summarizes an environmental monitoring initiative named as SENSEI [8]. Core of the summary is the role of data literacy within the project for mobilizing people to take civic action. SENSEI aimed to co-design, develop and deploy environmental sensing technologies in collaboration with citizens. Sensei shows how hardware, software and participatory practices can be combined to create civic technologies for local communities to monitor their environment, make sense of datasets and solve problems collectively. SENSEI technologies are being designed to monitor relevant positive and negative environmental issues (e.g. alien plant species, abandoned items and places citizens appreciate) for both citizens and decision makers. Lot of other examples are available from different cultural, social and physical environments [9–13]. We selected those monitoring areas, which are natural for our experiments local living environment as the goal was for the local community to collect, share and act upon available data [14]. Also, citizens will be able to monitor issue of their own interest as private monitoring targets they control and share when considered relevant. The aim of SENSEI is to prompt civic actions to enhance public participation and the environmental management of the town and try to generate long term effects [15] from the citizen sensing project.

This initiative followed the "a city in common" framework by [14]. We started with a collective identification of potential issues in town, using a series of ideation and co-design workshops with local citizens. Goal was to deploy an environmental monitoring of issues of common and individual interest during June-September 2018. Next, citizens were supported to enhance their ability to understand, make sense and solve collective issues with resources created during the initiative such as data, prototypes and social networks. Also, a data exhibition in a public space was organized. The exhibition supports participatory sensemaking by curating the data collected during the monitoring, allowing local citizens (including the ones who were not actively monitoring) to explore and make sense of the data, which was collected to enhance civic actions. This paper describes our approach, addressing the challenges attached to the design and orchestration of activities to support people to informally acquire or use existing data literacy skills. In case one would be arranging similar activities for data collection, and assuming possible data quality issues, we suggest on referring "data quality issue to solution mechanism table", by Vaddepalli et al. [16].

2   The SENSEI Data Exhibition

To get the participants in speed with the formerly unknown data, SENSEI data exhibition was used to welcome visitors with different data literacy skills and ability to interpret the data. During the exhibition, visitors were invited to frame questions related to relevant issues and opportunities in the town, from their own point of view. This was done through

exploration and ideation around curated datasets. People who did not collect data themselves or have not had previous data collection experiences, could face challenges during this stage [17]. Therefore, the exhibition goal was to create an enjoyable and equitable sense-making event in terms of access to information and ability to participate. In general, it is critical that the event design supports informal learning of data literacy skills for whoever needs them. Finally, the event design should naturally support collaboration and participatory sense-making to enhance civic action and to reduce ending up having non-wanted challenges and to be able to focus on solutions and new opportunities [18].

Whilst several definitions of data literacy can be found (e.g. [19, 20]), in this article data literacy is defined as follows: "the ability to ask and answer real-world questions from large and small data sets through an inquiry process, with consideration of ethical use of data. It is based on core practical and creative skills, with the ability to extend knowledge of specialist data handling skills according to goals. These include the abilities to select, clean, analyze, visualize, critique and interpret data, as well as to communicate stories from data and to use data as part of a design process." [20]. See Fig. 1.

Fig. 1. Data literacy pool (taken from [20])

The research questions related to the design and development of this data literacy process are:

1. Are participants who have actively monitored issues more likely to be engaged with the data? Does this participation lead to better sensemaking?
2. Can urban data games help visitors, especially non-data collectors, get up to speed and become engaged with the data?
3. How does the design of the space and activities support participatory sensemaking?
4. Can an initiative such as Sensei, including both the participatory sensing and sensemaking, lead to mobilization of citizens around important topics?

As participation is based on semi structured activities, evaluation cannot happen in a controlled experiment as controlling might generate unwanted behavior such as the Hawthorne effect [21]. Instead we provide an experience which is both playful to explore and informative in relation to issues that citizens are truly interested in. Attending and all engagement actions are entirely voluntary. Since intervening with questions or questionnaires could distract the attention from participation, the data capturing was designed to be unobtrusive and integrated to the event themes.

2.1 Capturing the Visitor Experience

Behavior data collection starts with a visitor number linked to a badge, onto which visitor can add self-selected ribbons. These ribbons were visitor descriptors / participant classificators as data-expert, data-collector, volunteer or citizen. Badge number and the ribbon choices will be noted with information whether they participated in data collected or not. Visitors can also pick up ribbons as they leave, which will be noted. Visitors receive an event related activity game (linked to badge number) which encourages them to visit each activity station and use a stamp there and a pen to mark some additional data to the card. Stamping captures the participation order in the stations. When visitors write questions, or create artefacts, they will also use their visitor ID (and name, if they choose). This will help with additional data capturing. Visitors handing the card are rewarded with a small prize related to number of stamps and a lottery participation with the chance to win a bigger prize. If possible, other metrics are collected too, to identify visitor hotspots/participation time details, either with facilitators help or with technology solutions. In addition, interacting with data exhibits leaves traces of participants actions, which can be captured. For example, time spent exploring data, quantity and quality of questions asked and stories told from data. The data collected should help to answer to the set questions.

3 Designing the SENSEI Data Exhibition Experience

The event is curated as an interactive exhibition, with a number of activities related to the Lappeenranta environmental monitoring designed to encourage and support visitors to engage and collaborate in data sensemaking actions. Additionally, general information related to monitoring themes and some additional craft activities aimed mainly at younger visitors are also included. These are e.g. arts table to draw pictures inspired by displayed material. Results were photographed and uploaded to a Sensei online exhibition (with approvals from the participants).

Free exploration is allowed, but knowledge of museum curation strategies will be used in designing the space to prompt visitors to follow a path that takes them through several distinct phases of interaction with data, with increasingly less constrained data exploration. We hope that this will also help us in follow up stages with the collected data and digital curation of it [22]. Stages are shown in Fig. 2.

Designing the space, where it is easy for people to collaborate, is important for participatory sense-making support. This leads to the communal property of civic intelligence, as defined by Schuler et al. [23]. Each stage builds on work conducted within a
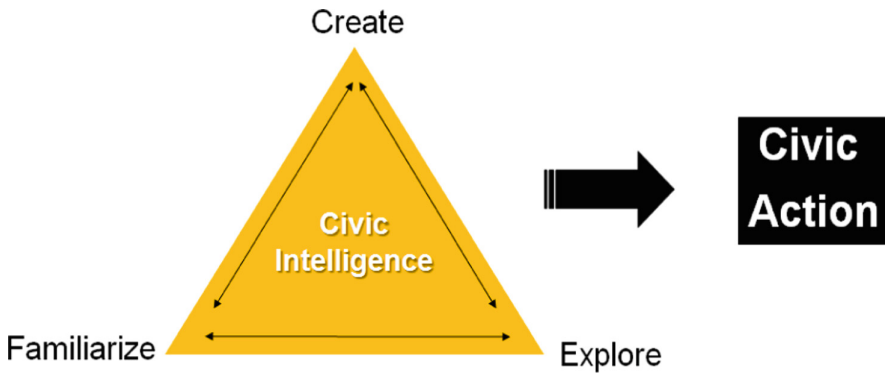
Fig. 2. Staged data exploration to build civic intelligence and enhance civic action.

UK data literacy initiative, that developed a number of Urban Data Games [24, 25] and founded a set of principles to support building data literacy from complex data sets in formal (e.g. classrooms) and informal (e.g. museum) settings. The principles were:

- Guide a data inquiry,
- Expand out from a representative part of dataset,
- Work collaboratively (STEAM approach) on creative activities and
- Balance screen activities with tangible ones [26].

3.1   Familiarize

The familiarization stage can consists of a number of interactive games; speed data-ing (Fig. 3), shark-bytes (Fig. 4) and top data-trumps (Fig. 5), for visitors to play. These would help visitors to know what types of data they can explore and what they might find. This is specially designed for non-data collecting visitors.

Speed data-ing is designed to help visitors get to know the different collected datasets. Visitors have only 30 s getting to know the open data types from the environmental dataset (decided by the city or by the citizen's, during the monitoring period). A short time period is used, as positive time-based stress helps people to focus on most important aspects and as such helps productivity too [27]. Key information will be a) the name and icon used to consistently identify the dataset in SENSEI platform and in the exhibition b) the types of places to look for instances of the data c) the most likely time periods containing data.

Shark-bytes is a play on the US television show Card Sharks (Play your cards right in the UK). The play starts with a random playing card. Contestant must guess if the following subsequent card (facing downwards) would be higher or lower. In this case, key datasets are the line of cards, in timeline order. Players predict whether the value for that datatype went up, or down (in total) in each following week. A player 'wins' by getting to the end of the line of cards without error. It is anticipated that players in general will discuss how they base their prediction, using their knowledge both of the town and also knowledge of human behavior e.g. by knowing popular holidays, player

Fig. 3. Speed data-in.

might predict lower values when those monitoring may not collect data. The aim is to support visitors in thinking about the importance of finding and analyzing data trends and to cause reflection on how data is collected, what sort of cultural, societal, human behavior and so on matters can affect the results and may also lead to 'errors' in data.
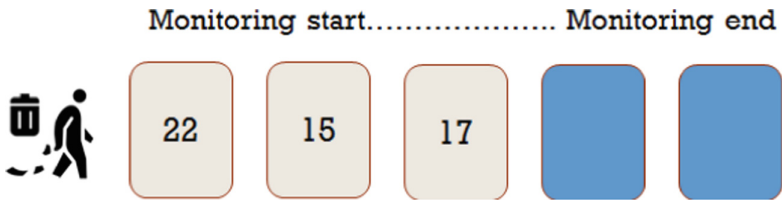

Fig. 4. Shark-bytes. 3 cards shown, the visitor predicting the next 2 values.

Top data-trumps is based on the original Top Trumps card game. Data-trump cards relate to places in Lappeenranta. Values relate to the data types and the total value for that data type in each place within the monitoring period. This game teaches data comparison skills. In general, utilization of different activation and idea generations support means and methods are all designed to make exploration of the complete datasets easier and more meaningful / understandable task.

Fig. 5. Top data-trumps.

3.2 Exploring Stage

The exploration stage gives citizens access to the data, via a map-based interface (presented on iPads and also a large interactive wall, used for collaboration activities). The data can be freely explored by selecting:

1. which specific part of data or datasets to look at
2. a region in Lappeenranta (with panning and zooming)
3. the time period (selected by a slider)

Instances of the selected data, based on the made choices, will appear on the map. This is supported by prompts that encourage visitors to focus in to just a small part of a data set, to make meaning from that, and then to do wider explorations. One of the ideas is, to help people find patterns in the data. This ideology is based on principles derived from and tested within the Urban Data School initiative and also expectations of interfaces by users in a study on participatory sensemaking by Filonik et al. [28], who studied this via a dashboard from which users could collaboratively visualize and share meaning from data, finding that visualizations should be 1) dynamic to support playful interactions 2) flexible to allow exploration of relevant data 3) educational and guide the initial inquiries 4) collaborative, allowing visitors to exchange ideas with one another. Therefore, visitors are encouraged to write down questions and predictions and display them, so visitors who will join later on, in different time and/or session, can build upon earlier findings. Visitors can work alone or discuss with others, whichever they prefer. However, collaboration is encouraged, with large interactive map interface.

3.3 Stage to Create

The creation stage provides visitors with artwork creation space to reflect a story they want to tell. Craft materials are provided, inspired by the data sculptures approach of [19]. After representation, they write a story card explaining what they have made and why it is interesting (like in museum exhibition), which visitors can add to museum by leaving their sculptures, or by taking a polaroid picture instead, if visitors prefer to keep the sculpture.

4 Discussion on Action Taking

The question is, does exhibition bring people together around certain topics. Such activities were encouraged and supported in monitoring stage, but not all of the participants were compelled to take action. It was not exactly clear, would additional gamification elements [29] had made people more active, but the general expectation among organizers and active supporters from the city was in this direction. Still in sensei initiative, over 240 participants, aged 7 to 85 years, were involved over a period of 10 months. Ten events and workshops generated over 100 ideas about issues of shared interest, 28 civic tech prototypes and dozens of sense-making artifacts, including data interactions, analysis of datasets and data sculptures [8].

To facilitate volunteering and participation, existing groups (whether pre-existing initiatives or created through earlier Sensei activities) were invited to attend in person and talk about their activities, or at least to leave flyers. Visitors will be able to sign up to participate in the groups or join through social media. New groups forming were able to leave something in the space to attract other people to join, through stigmergic action. E.g. a jar to drop participants contact details into (in anonymous way). This visualizes the traction gaining campaigns.

5 Conclusion

The study described an event to engage citizens of a town with their environmental data (collected during participatory sensing initiative). In any social governance matter, where collective responsibility is considered as a key for success, sensei like methodology to get citizens to participate into technology and data collection activities, makes them more invested to the process and how matters are handled in general in the governance case. In this particular example, the event was staged as an interactive data exhibition, designed to informally build data literacy, to encourage collective sensemaking and, in some cases, to lead to civic action. We suggest future research to look up into opportunities on developing new sustainability innovations on top of civic engagement-based data collection activities as the data is quite unique in nature and could offer seeds for developing e.g. new and novel environmental monitoring services [30–32]. Our research outlines a number of solution for typical challenges for engaging visitors, when playing with the data and in capturing feedback to assess the validity of the design decisions to support the intended outcomes. We recommended on learning from experiences between engineers and representatives of other society groups like artists [33], young students experiences from citizen participation activity [34] and realities of time pressure in innovation processes [27]. Additionally, especially because of the challenges the global covid-19 pandemic has given, e.g. requiring us to endure long term social distancing matters, we would like to suggest researching and experimenting hybrid / almost fully online co-design activities for environmental monitoring innovations, as these will definitely be different from physical events and brainstorming sessions [35].

Competing Interests.   Authors have declared that no competing interests exist.

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