frontiers | Frontiers in Environmental Science

TYPE Methods
PUBLISHED 09 May 2023
DOI 10.3389/fenvs.2023.1177413

OPEN ACCESS

EDITED BY
James Kevin Summers,
United States Environmental Protection Agency (EPA), United States

REVIEWED BY
Margaret Gold,
Leiden University, Netherlands
Kate Mulvaney,
United States Environmental Protection Agency, United States

*CORRESPONDENCE
David Kocman,
david.kocman@ijs.si

RECEIVED 01 March 2023
ACCEPTED 17 April 2023
PUBLISHED 09 May 2023

CITATION
Kocman D, Righi V, Errandonea L, Maccani G, Creus J, Froeling F, Hoek G, Andrusaityte S, Grazuleviciene R, Ficorilli A, De Marchi B, Biggeri A, Ftičar J, Gignac F, Toran R and Basagaña X (2023), Toolkit for conducting citizen science activities in environmental epidemiology. *Front. Environ. Sci.* 11:1177413. doi: 10.3389/fenvs.2023.1177413

Toolkit for conducting citizen science activities in environmental epidemiology

David Kocman[1]*, Valeria Righi[2], Lucia Errandonea[2], Giovanni Maccani[2], Javier Creus[2], Frederique Froeling[3], Gerard Hoek[3], Sandra Andrusaityte[4], Regina Grazuleviciene[4], Antonella Ficorilli[5], Bruna De Marchi[5,6], Annibale Biggeri[5,7], Jure Ftičar[1], Florence Gignac[8,9,10], Raul Toran[8] and Xavier Basagaña[8,9,10]

[1]Department of Environmental Sciences, Jožef Stefan Institute, Ljubljana, Slovenia, [2]Ideas for Change, Barcelona, Spain, [3]Universiteit Utrecht (UU), Institute for Risk Assessment Sciences, Utrecht, Netherlands, [4]Department of Environmental Science, Vytautas Magnus University, Kaunas, Lithuania, [5]Epidemiologia e Prevenzione "Giulio A. Maccacaro" Social Enterprise, Milan, Italy, [6]Centre for the Study of the Sciences and the Humanities (SVT), University of Bergen, Bergen, Norway, [7]Department of Statistics, Computer Science, Applications "G. Parenti" University of Florence, Florence, Italy, [8]Barcelona Institute for Global Health (ISGlobal), Barcelona, Spain, [9]Universitat Pompeu Fabra (UPF), Barcelona, Spain, [10]CIBER Epidemiología y Salud Pública (CIBERESP), Madrid, Spain

Scientists and practitioners implementing citizen science projects, in which the involvement of citizens is key, often need ideas and tools that help in reaching citizens, engaging them in the project and maximizing their contributions. In this paper, we describe the creation of an open toolkit, a web-based portal citizensciencetoolkit.eu[1] designed in the framework of the CitieS-Health project for the development and promotion of citizen science (CS) projects. The main focus is on projects linking urban environmental exposures and health, but it has applicability to other settings. The toolkit comprises the steps and phases during the implementation of CS activities in environmental epidemiology. A total of 28 tools are currently included, of which most were co-designed and tested within CitiesS-Health, as well as some resulting from external projects. For each tool, in addition to the details of its purpose and the specific challenges it poses, downloadable support content is available. To help facilitate inspiration and the adoption of tools provided, an illustrative step-by-step demonstration and description of its use in a CS project in a real-life setting is included, focusing on recommendations derived from the user experience. The portal is designed as a live inventory of tools, enabling interested CS practitioners not only to replicate, but also to continuously update and enrich it is content. To this end, the long-term objective of the portal is to act as a hub of resources that would enable the active inclusion of citizens in all the phases of the participatory research projects.

KEYWORDS

citizen science, toolkit, epidemiology, co-creation, urban pollution

1 https://citizensciencetoolkit.eu/

1 Introduction

Citizen Science (CS), broadly defined as the active engagement of the general public in scientific research tasks (Vohland et al., 2021) is on the rise. Regardless of the ongoing debate on different definitions and interpretations of CS (Haklay et al., 2021), all CS projects need to reach citizens, engage them in the project and try to maximize their participation and contributions. Researchers, especially those with less experience in citizen science activities, can benefit from existing tools designed to facilitate the inclusion and participation of citizens in scientific projects. This is especially the case for co-created CS projects, where citizens are involved in all project phases and activities. In a context where there is a growing interest in involving the general public, civic society organizations, patients, and end-users in research, supported by research funders in the context of Open Science, the availability of successful tools that facilitate the participation of citizens becomes more important.

Initially, tools for CS projects were related to the development of Web 2.0 technologies that facilitated the production of user-generated content mainly in crowdsourcing type of projects. More recently, as a result of the rapid development of various sensing technologies, supporting Information and Communication Technology (ICT) and digitalization in general, even more active participation of lay people in co-creation of research activities has been enabled, including in the co-design of tools developed based on the Do-It-Yourself (DIY) principles. To this end, a relatively large number of resources designed to support both researchers and citizen scientists in carrying out various activities in different project phases were generated. These can vary considerably in scope, from very specific and thematically oriented to more general methodological frameworks. They usually comprise indicative step-by-step recommendations and instructions that can be adapted to the user's own needs and the specificities of the matter of issue affecting the context, and the context itself. One such example is the UKEOF Guide to Citizen Science that aims to help people involved in CS to design and implement projects related to biodiversity or the environment (Tweddle et al., 2012). It covers the different steps, from the identification of research questions, the establishment of the project team, the practical aspects of study design, to the planning for analysis and interpretation of data. Similarly, Federal Crowdsourcing and Citizen Science Toolkit[2] provides a general framework for carrying out a crowdsourcing or citizen science project. It starts with guidance and recommendations for scoping of the research problem, continues with details on project design and data management, and concludes with different aspects of sustainability and evaluation of outcomes, with different external resources available for each step. More technology driven example is the Bristol approach, a six step framework aimed at helping lay communities and researchers run citizen sensing interventions to tackle local environmental issues (Balestrini et al., 2017). In its application within the Making Sense project, the Citizen Sensing toolkit was developed – a framework of eight stages designed to run a citizen sensing project, and providing detailed description of methods and tools alongside their examples in action (Woods et al., 2018). More focused is the ACTION Toolkit designed for pollution-focused citizen science projects of all kinds and that follows the participatory science lifecycle conducted through three stages: problem framing, research implementation, and legacy (Thuermer et al., 2022). On the other hand, tools like the Societal Readiness Thinking tool exist, designed as a guidance to scientists on the maturity of societal readiness of research projects (Bernstein et al., 2022). Such a tool is based on sets of reflective questions to help researchers align their project activities with citizens' needs and expectations at different stages of a project life. Platforms like eu-citizen.science[3] also exist, designed for sharing knowledge, tools, training and resources for CS.

The abovementioned resources have been designed with a specific goal in mind and do not necessarily allow for direct transferability and adaptation outside the prescribed structures. On the other hand, as emphasized by (Greenhalgh et al., 2019) in their systematic review of the frameworks for supporting patient and public involvement in research, "a single one-fits-all framework may be less useful than a range of resources that can be adapted and combined in a locally generated co-design activity". In this context, this paper discusses the development of the CS Toolkit, a web-based platform containing tools designed as support in the steps and phases during the implementation of CS activities in environmental epidemiology. The Toolkit was developed within the EU Horizon 2020 programme founded project Cities-Health (Citizen Science for Urban Environment and Health), and is aligned with its general methodological framework. In the context of this work, the Tool is defined as any type of activity designed to engage citizens in some stage of a research study. Specifically, the Toolkit aims to (i) support environmental epidemiologists in planning, designing and implementing CS studies that tackle citizens' concerns in various aspects of environmental pollution and health, (ii) inspire other citizen science practitioners with creative ideas on how to actively engage citizens in various phases of research, (iii) enable replication by providing useful resources and examples of applications of different tools in real-life situations of selected case-studies, and (iv) provide a platform where the interested scientific community can interactively contribute by sharing their own tools, resources and experience. Although the Toolkit was developed for environmental epidemiology projects, many of the tools are also useful in other settings.

2 Materials and methods

2.1 Toolkit in the context of CitieS-Health project

The Toolkit was developed within the H2020 project CitieS-Health, which engaged citizens in five European cities in co-designing citizen science studies that address their concerns related to environmental pollution and health (CitieS-Health, 2023). Building on the Bristol Approach (Balestrini et al., 2017),

2 https://www.citizenscience.gov/toolkit/

3 https://eu-citizen.science/

the project developed a methodological framework by taking specific characteristics and needs of participatory citizen science in the field of epidemiology, comprising four phases: identification, co-design, deployment and action (Toran et al., 2019; Froeling et al., 2021). In summary, in the identification phase concerns and interests of citizens are mapped and translated into research questions. In the co-design phase, data collection and data governance protocols are co-designed. In the deployment phase, overall data collection and analysis follows, including the reflection on the findings. The last action phase comprises civic actions to drive positive change, including dissemination of the results, and planning of the legacy of the project. This methodological framework then serves as a basis for the distribution of the individual tools within the Toolkit. The tools included in the Toolkit presented in this paper were mostly developed and used as part of the activities in the five pilot studies of the CitieS-Health project in Barcelona (Spain), Amsterdam (Netherlands), Lucca (Italy), Ljubljana (Slovenia), and Kaunas (Lithuania). This paper deals with the methodological description of the toolkit creation and described some use cases in real-life applications of the CitieS-Health project, while the specific activities carried out in the individual pilot studies, the results obtained and the lessons learned are given elsewhere (Grazuleviciene et al., 2020a; Grazuleviciene et al., 2020b; Kocman et al., 2020; Grazuleviciene et al., 2021a; Grazuleviciene et al., 2021b; Grazuleviciene et al., 2022; Gignac et al., 2022a; Gignac et al., 2022b; De Marchi et al., 2022). Substantial elements of this work have been reported in deliverables from the CitieS-Health project, and reused for the purpose of this paper, in particular D2.1 (Kocman et al., 2019), D5.2 (Balestrini et al., 2019) and D5.3 (Errandonea et al., 2022).

2.2 Evolution of the toolkit

The motivation behind the design and development of the toolkit was twofold: (1) to guide and inform local citizen science studies across the CitieS-Health pilots; and (2) to act as a legacy of the project so as to enable scaling of the CitieS-Health principles and outcomes beyond the CitieS-Health project context, and thus make them useful to other CS practitioners. The main challenge therefore referred to the need of providing a set of resources that had to be, on the one hand, detailed enough to effectively inform local studies and, on the other hand, flexible enough to acknowledge that each CitieS-Health pilot is very much situated in a specific socio-cultural-infrastructural context and addressing different environmental epidemiology related issues. More generally, the literature acknowledges that CS projects are typically heavily context dependent and the learning outcomes are more situated and specific than transferable (Craglia and Granell, 2014; Manzoni et al., 2019; Maccani et al., 2020), such as in the case of the CitieS-Health pilots. Each pilot tackles a specific matter of concern, from air and noise pollution, biomass burning, industrial pollution to general environmental quality in urban settings. This makes the idea of a single, strict, step-by-step methodology that fits all cases, not viable. The idea is to move away from "waterfall" and strict step-by-step processes towards a more open and flexible set of resources that can be adopted and adapted to diverse local contexts, the issues experienced, and the specificities of the communities involved. Waterfall models, a concept originated in the discipline of software engineering and now widely adopted, represent those situations whereby implementations follow strict stage-based approaches where a given phase does not start prior to the end of the previous. Rather, to cope with the exploratory nature of typical CS interventions, we argue that a more flexible and iterative approach should be taken, at the same time allowing for some level of generalization. In this way, the concept of toolkit acknowledges that although citizen scientists' work is heavily influenced by local experiences and cultural traits, there are methods and strategies deriving from best practices that can be transferred across settings, making it easier for practitioners to enact or know how to run certain processes. Consistently, citizen scientists across the CitieS-Health interventions are conceptualized as motivated craftspeople, as opposed to followers of rigid methods. Craftspeople are passionate about the job and skilled in using a range of tools, and adapting them to the specific challenges they are facing.

A fundamental decision to be taken during the design phase revolved around the scope of the solution. First, we considered the toolkit as an artifact (Hansen and Dalsgaard, 2012) covering citizen science interventions in environmental epidemiology. By *artefact* we refer to material objects, including software that are employed to support the implementation of an activity of inquiry during a CS project. However, it became clear that, given the need to achieve generalizability (see above), the effort of translating it to a wider audience was feasible and consistent. Indeed, at the core of citizen science activities in CitieS-Health reside basic actions that are relevant for all (or most) citizen science projects - e.g., participatory problem formulation, co-design data governance arrangements for the data collected and analysed in the action, co-design the pilot themselves in terms of place, time and commitment, *etc.* Therefore, the scope of the toolkit has been defined as to inform, inspire, and enable practitioners on how to involve citizens in research activities.

From understanding and establishing the breadth and scope of the toolkit, the next challenge faced revolved around its target audience. After experimenting with the design of dedicated tools for specific audiences (e.g., policymakers, community champions, academics, practitioners, *etc.*), the decision was taken for the toolkit to be designed as a set of structured resources aimed at encompassing all potential users, i.e., those actively driving citizen science studies. This experimentation followed the general development process of the overall toolkit whereby after their initial design, each tool was tested and improved accordingly in one or more of the CitieS-Health pilots. Consistent with the CS literature, CS interventions may differ based on the actual actor(s) driving it from different perspectives. Some appear to be more government-led, whereas others appear to be led by either the communities themselves, or academics, or from actors from the private sector. This diversity, also experienced across the pilots, led to the decision of developing the toolkit in a way for it to be adopted and used by everyone, independently from their vested interests, skills, or experiences. Accordingly, the choice was made to develop and concurrently test design and language styles that were as accessible and understandable as possible.

The third milestone revolved around user interface and usability. In this respect, the overall solution was continuously tested and improved in terms of its general design and user

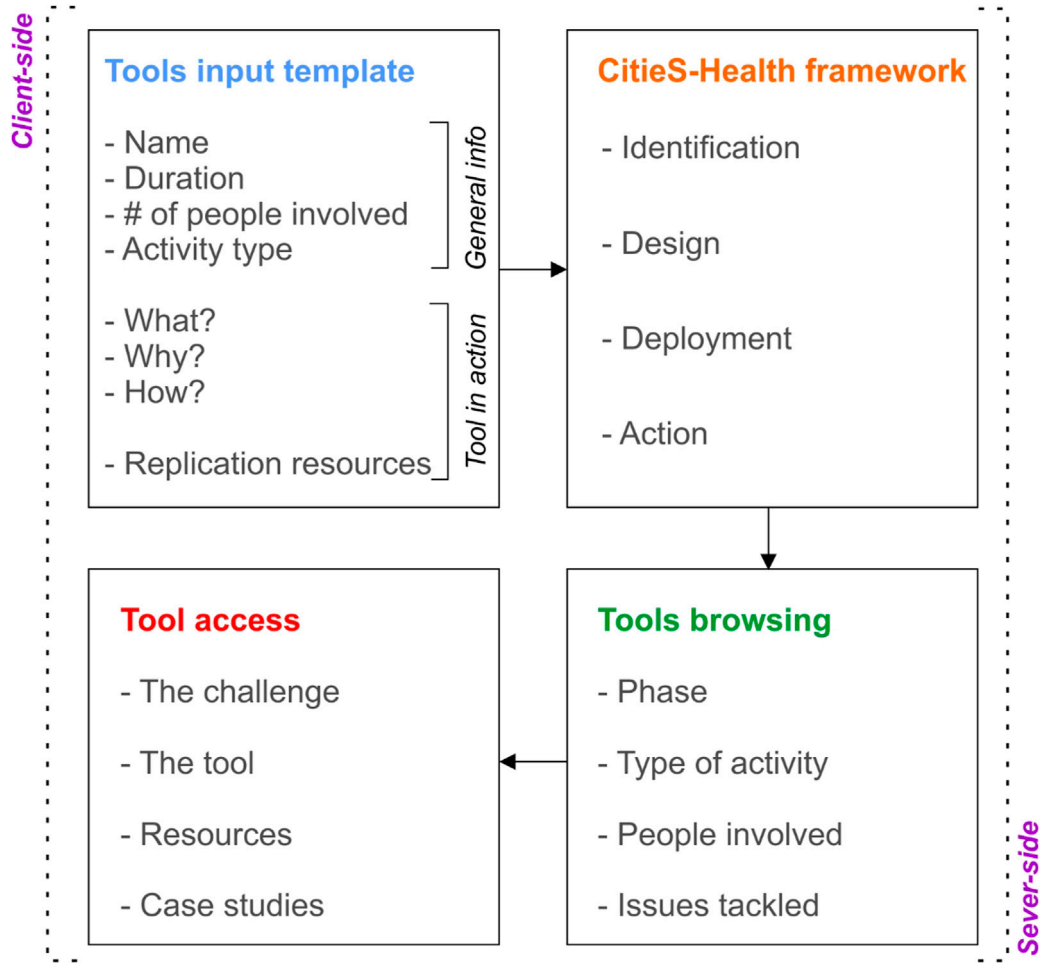

FIGURE 1
Schematic visualization of design and Toolkit structure.

interface. As an important element of this step, knowledge transfers sessions with practitioners outside of CitieS-Health were organized to gather additional feedback on the quality, utility and usability of the overall solution. This allowed gathering independent and neutral perspectives which further informed required changes in the design and user experience.

In summary, testing and evaluation happened in two main ways: (i) concurrently with its design through its continuous application across the CitieS-Health pilots; and (ii) ex post (CitieS-Health) with future potential adopters.

From there, an agile and iterative development process was adopted with respect to each tool whereby: (1) at a critical engagement activity within the pilots, tools were explored from the literature, existing resources and/or designed by a dedicated team considering the specific need in the specific step of the engagement methodology; (2) these were adapted to the specific need and situationally of the pilot; (3) these were instantiated and tested in real citizen science settings; (4) feedback and lessons learned were gathered and tools were improved subsequently; and (5) the nature of each tool was extracted and defined in a generalizable manner, so that others can be inspired for their own, situated and context specific, interventions. By doing so, each tool included in the toolkit embodies the experiences of its application in real contexts, thus providing tips and rich descriptions on how it can be operationalised across phases of engagement in citizen science.

2.3 Toolkit design and architecture

In Figure 1, a schematic representation of the Toolkit design and structure is outlined. The tools input template serves as an off-line means for the systematic collection of information regarding individual tools and is initially filled out by those contributing the tool. The following information is gathered: general information about the tool such as its name, duration, number of people involved and the type of activity (artifact, communication, event, online engagement, pop-up, research or workshop), and details regarding the implementation of tools in action. The latter gives examples of how the tool has been implemented in practice, including relevant replication resources where they exist, and answers questions about what the tool is for, how it is used and for what purpose. The content provided is then entered by the web

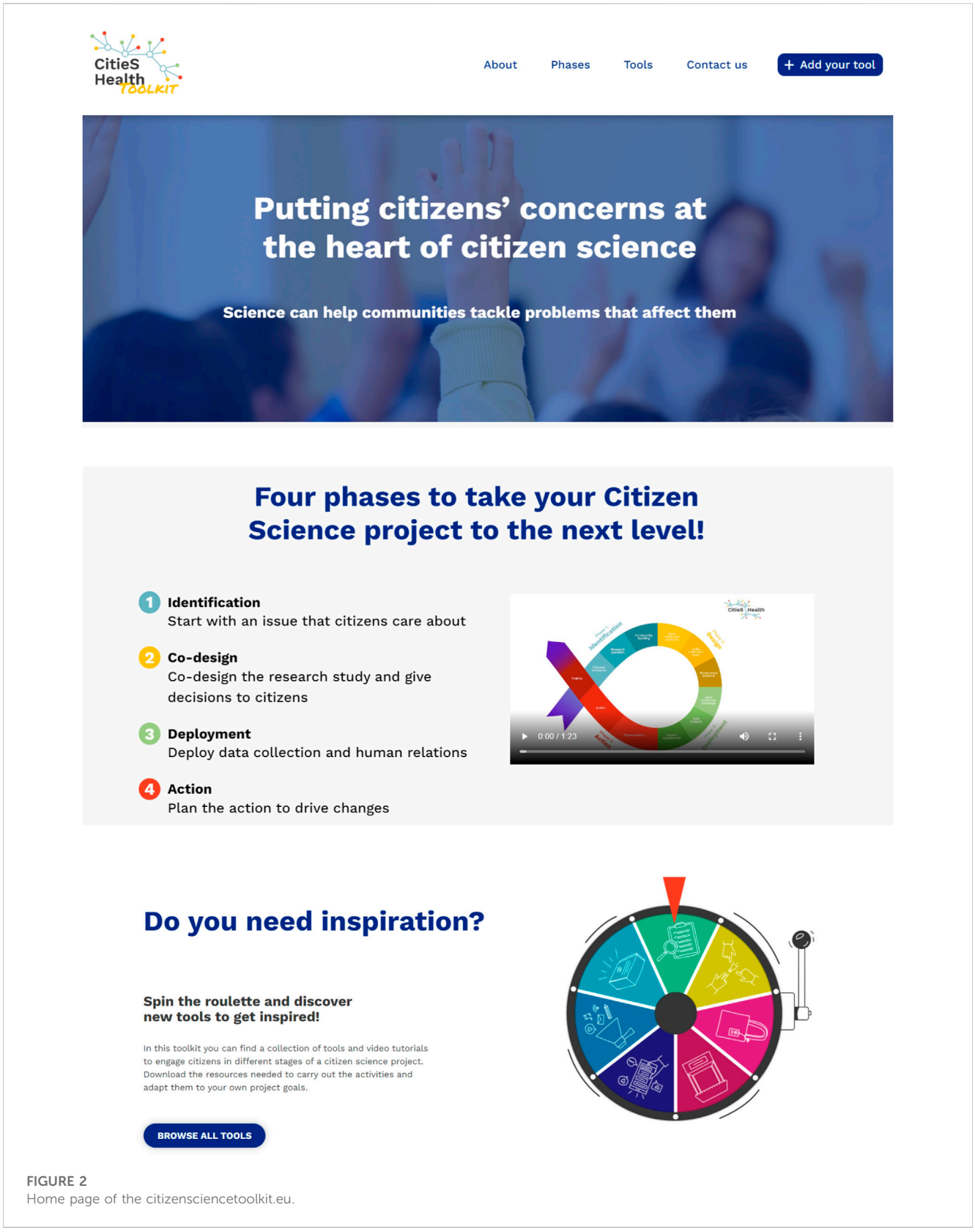

FIGURE 2
Home page of the citizensciencetoolkit.eu.

portal administrators into the online tools and, among others, re-categorised according to the general CitieS-Health methodological framework. The tools proposed within the Identification phase aim at exploring health and environmental citizens' concerns, translate these into a feasible research question and build a community of participants. The tools included in the Design phase are meant to

enable effective co-design of the data collection protocol, of the associated devices (e.g., sensors) employed, and of the project governance protocols. Tools categorized into the Deployment phase aim at assisting CS practitioners during the data collection and analysis phases, as well as during the assessment of the impact achieved through citizen science intervention. Tools categorized under the Action phase provide instruments to facilitate dissemination of the findings of the project and co-creation of related citizens' actions. In addition to the aforementioned phases, users can browse the tools also according to the type of the activity, number of people involved, and the thematic issues tackled (air pollution, food, green spaces, health, mobility, and noise). Once selected, the visualization of each tool is built around a description of the challenge the tool addresses, a general description of the tool, links to additional supporting (external) resources, and a detailed description of how the tool was used in practice.

2.4 Evaluation

The Toolkit was evaluated using a user feedback survey. For this purpose, a short five-question questionnaire (Supplementary Material S1) was developed where users can report on their expectations and user experience and suggest potential improvements. Moreover, another important way of external feedback on the user-experience across the toolkit materials are personalized consultancy sessions organized for those interested in any aspects of the Toolkit.

3 Results and discussion

3.1 General structure and graphical user interface of the toolkit

At the home page level of CitieS-Health Toolkit web portal (citizensciencetoolkit.eu), the four steps of the CitieS-Health engagement framework are presented together with an explanatory video that facilitates its understanding. In this way, the user can identify and select the specific phase to depart from. After this step, the front page incorporates the gamification approach: a spinnable roulette with a collection of tools and video tutorials to reach the user's attention in an attractive and inspirational way. This option serves as a method for the user to get started and have a first overview of the Toolkit. Also, a display of the six latest tools is shown and the option to browse all the tools. Finally, there are two calls to action for practitioners. The first one is to add their tools to the toolkit. The second one is invitation to one-on-one consultancy sessions with project partner on citizen engagement (Figure 2).

The About section provides a detailed outline of the Toolkit, describing the initiative, its main objectives, the community involved and how it works. It is a short box intended to provide more information about the project and its connection with the CitieS-Health project. Potential applications and benefits for various stakeholders as per the quadruple helix framework - citizens, the scientific community, public authorities and industry, are also indicated.

The Phases section details the structure of the CitieS-Health engagement framework according to the four main phases and their subphases. Step-by-step, in an interactive manner, each of the subphases is explained - its purpose and positioning within the overall framework, and various useful tips and recommendations in the light of drivers and barriers during implementation (Table 1). Upon selection of the subphase, the relevant tools are displayed on the website.

The Tools section is where the whole collection of tools can be found and browsed. On the page, users can filter the tools over (i) the project phase: identification, co-design, deployment or action; (ii) the type of activity: artifact, communication, event, online engagement, pop-up, research or workshop; (iii) people involved to implement the activity: +1,000, ~100, ~15–40 or project team and finally, (iv) the issues tackled: air pollution, food, green spaces, health, mobility and noise.

The Add your tool section offers the opportunity to CS practitioners to add examples of participatory activities they implemented in their projects.

3.2 Individual tool structure

Each of the tools included in the toolkit is described following a uniform structure. It starts with a brief description of the challenge addressed by the tool, together with the general question to which it provides an answer. This is followed by a brief overview description of the tool. In this way, the visitor of the portal can get an immediate sense of the tool's potential usefulness. Links to the toolbox are then provided, with various resources that allow the use of the specific tool and its associated activities. The Toolbox also provides a set of materials ready to download and useful to replicate the activity or to adapt. The main part of the tool presentation is an illustrative demonstration and description of how the tool can be used in a citizen science project in a real-life setting. The latter provides detailed answers to the What-Why-How questions. Specifically, what exactly was the context and purpose of using the tool, what was the expected outcome, and a detailed step-by-step description of how the activity was implemented, with an emphasis on recommendations derived from using the tool. In the following section four examples of the tools are detailed, one for each of the four CitieS-Health phases.

3.3 Tools examples

The four tools presented below are representative of how the term 'tool' is broadly defined in our toolkit. It encompasses both material resources that could be used in some stages of a research study, as well as a whole activity with a description of how to organize it and what is needed. By embracing a broad definition of 'tool' we seek to respond to the wide variety of contexts, needs, and approaches experienced in the CitieS-Health pilots, as well as in any CS study.

The first tool represents an activity to be organized on a public street to start conversations with the public about the project topics.

TABLE 1 Overview of the individual tools included in the toolbox according to the (sub)phases of the CitieS-Health project.

Phase	Subphase	Aim of the subphase	Outcomes and Recommendations	Example tools in the Toolkit
Identification	Citizens' concerns	To identify an issue that interests citizens	Citizens' interests and concerns must be at the heart of activities Citizens concerned are engaged and the sustainability of the project achieved Citizens mobilise new participants and contribute to build a community	Rapid appraisal mapping[a] Historical research Symptoms mapping Scientific (but fun!) surveys City safari[b] Popup intervention
	Research question	To translate citizens concerns into a research question	Researchers should provide the necessary knowledge and resources or suggest a set of possible research questions Questions co-created should be original and feasible (e.g., considering budget, time or other constraints)	Science shops[c] Online voting tool Question formulation canvas
	Community	To build a community of people keen to be actively involved and to collaborate toward a solution	Differences in participants should be embraced and considered Citizens will be motivated to participate if there is an alignment with their concerns Continuous dissemination of activities might trigger a snowball effect that contributes to increasing the base of participants	Community contribution canvas School techday event Treasure hunts
Co-design	Study protocol	To provide participants with the knowledge to design an experiment aligned with the research question	Study protocol that includes information on the experimental variables, the type of data to be collected and the methods and tools to be used	Research protocol Experiment design canvas Network of variables[d]
	Tools	To source and/or design the tools employed for collecting the relevant data	Tools selected should be user-friendly and fit for the purpose If tools need to be specifically developed, participants should be involved in their design and development	
	Governance	To establish a governance framework	Roles, decision rights and accountabilities of each individual/entity involved are defined and agreed	Citizen science information sheet 4 possible futures Decision-Making canvas Citizen committee
Deployment	Data collection	To collect data and information needed	Collecting data needs to be perceived as a meaningful and entertaining activity Engaging and motivating is of paramount importance, especially in the case of long-term studies It is crucial to further spread awareness and recruit more participants	Health data collection kit Sensory walks
	Data analyses	To analyse the data collected	The nature of the research question dictates the appropriate methods for analysis Citizens should be proactively engaged in data analysing, as they have valuable situated knowledge that can contribute to interpreting data and results	Data analysis platform Collaborative correlation data analysis
	Impact assessment	To measure and assess the impact of activity at different levels	Reflection on what goals have been achieved and to which extent, and any other expected or unexpected (positive and negative) outcomes Participants should be engaged in the assessment of targets and indicators, taking their expectations and goals into account	Impact assessment survey
Action	Dissemination	To disseminate the results	Dissemination through communication should be ongoing and should start from the very beginning of the project Dissemination should reach the four most relevant audiences: citizens, scientific community, public authorities and industry	Individual report results Coauthorship Citizen Scientific congress[d]

(Continued on following page)

TABLE 1 (*Continued*) Overview of the individual tools included in the toolbox according to the (sub)phases of the CitieS-Health project.

Phase	Subphase	Aim of the subphase	Outcomes and Recommendations	Example tools in the Toolkit
	Action	To co-create, plan and deliver actions that can generate recognition and make an impact	Participants should work together to propose courses of action toward the common goals	Data awareness action[e]
	Legacy	To codify and transfer knowledge gained and make a plan for sustainable impact	Reflection on the legacy should start from the beginning of the project in each of the actions developed in the previous phases	The plants of ideas

[a]Street Mobility Project: www.ucl.ac.uk/street-mobility/toolkit
[b]D-NOSES, project: dnoses.eu
[c]InSPIRES, project: inspiresproject.com
[d]Atenció project: isglobal.org/en/-/atenc-o
[e]WeCount project: www.we-count.net

The second tool is a canvas to be used to facilitate conversations during a co-creation workshop. The third tool is an artifact that takes the form of a software that enables participatory data analysis. The fourth tool is another artifact in the form of an artistic installation to be used in a pop-up intervention on a public street.

3.3.1 Pop-up intervention

This tool is designed to ease approaching citizens into the initial phases of the project, making them aware of the activities and start conversations about their interests and concerns. Pop-up interventions are temporary spaces within the cities' infrastructure that combine playful materials and audio-visuals to stimulate reflection, action, and interactions among the general public. A pop-up intervention could be organized around a variety of different activities, such as playing games on the street and using artistic installations.

Within the CitieS-Health project, the "Strawberry Campaign" was organized, aimed to distribute 1,000 strawberry plants to measure air pollution (Gignac et al., 2022a). Citizens living in different neighbourhoods of Barcelona hosted a strawberry plant on their balcony for 3 months and then sent a leaf of the plant to have it analysed in a lab, following an example of Van Dyck et al., (2019). This activity raised public and media attention about the project with a massive and entertaining activity, as well as strengthened the collaboration with local groups who helped develop the intervention. At the same time, insights into people's health concerns regarding air pollution were gathered, and the accompanying online survey was promoted. Launch of the campaign was aligned with an international Parking Day event that took place in Barcelona, which enabled easier access to interested communities, civic organizations and citizens. Besides distributing the plants in all districts of the city, the aim of this intervention was also to gather information about citizens' concerns on environmental issues and health. For this reason, a canvas that showed possible health issues and environmental issues was used, depicted in Figure 3, and participants were asked to vote which was the most concerning issue for them.

3.3.2 Decision-making canvas

In a research study, many decisions are made at different stages, ranging from the selection of the research topic, the type of data to be collected, how to collect the data, and what to do with the results, just to mention a few key decisions. Often these decisions remain in the hands of researchers who make decisions based on their prior knowledge and experience. However, in a citizen science project where the participatory component is at the center of the process, involving citizens in the decision-making process is vitally important also in this phase beyond the choice of the research question.

The Decision-Making Canvas is a tool that helps researchers to guide conversations with citizens around the decision-making processes in science. The tool allows one to identify (i) at what stages of a research study do citizens want to be consulted to make decisions, (ii) what decisions do they want to make, and (iii) how we can involve them to make these decisions. The tool is meant to be used during a co-creation workshop, which can be carried out in different stages of a research study, preferably starting at the onset of the project.

Within CitieS-Health, an online workshop was organized to start discussing with participating citizens about how they wanted to get engaged and what roles they wanted to take during the data collection campaign, the analysis phase and the dissemination of study results. The Decision-Making Canvas was used to guide the conversation (Figure 4), and participants were asked to mark the stages in which they would like to actively make decisions and write down which decisions they want to make. Based on the outcome of this activity, they decide on the decision-making process itself, how it should be organized, in what format, *etc.* The overall process increases transparency in the research process.

3.3.3 Data-analysis platform

In participatory epidemiological studies, after the environmental and health issues are identified and data was collected, a strategy for the active engagement of participants during data analysis is needed. Often, however, it is not straightforward to involve participants in this stage because of their lack of knowledge and various technical barriers (e.g., data formats and harmonization, software ...), respectively. A traditional report made by researchers might be too long and complex, and there is a risk of leaving out correlations and insights that each individual may be interested in. To this end, within the CitieS-Health project, a data analysis platform was built, an online tool in which individuals can access and analyse the data autonomously. Using this tool, after signing in, individual-level data would be loaded automatically, and chart templates created. The user can then select various types of charts, and any combination of variables. Moreover, users can review their own activity, inspect and

FIGURE 3
Canvas for driving conversations with citizens.

download their own raw data in the form of tables, and view their measurements on a map. In Figure 5 two examples of such functionalities are shown.

Within CitieS-Health, this tool was developed for the purposes of a study conducted in Ljubljana, Slovenia, where the participants gathered a lot of data from different sources: noise levels, location (GPS), mood, cognitive abilities, sleep quality, location characteristics, physical activity indicators, *etc.* (Ftičar et al., 2021). The tool was created based on initial feedback by participants on the type of information and visualizations they would like to receive. The beta version of the app was then tested with the help of a focus group and modified based on the feedback received. In addition to access, this tool enables lay people to analyse their own data themselves, even though they have different levels of computer and data analysing skills. At the same time, researchers get an insight into what data and outcomes interests participants the most.

3.3.4 Plants of ideas

Beyond producing new scientific knowledge, citizen science projects aim to foster evidence-based changes in our living environments. Affected citizens and communities are in the best position to propose possible actions that can lead to positive changes in the short and long term. The plant of ideas is an artifact that enables collecting ideas from passersby about how they would like to improve different aspects of the city they live in. The artifact has the shape of a human-sized cardboard plant. The leaves represent the proposed ideas. Different types of leaves or trees can be used to represent different categories of ideas. The plant of ideas could be placed in a community place such as a library or civic center, or could be used during a pop-up event.

Within CitieS-Health, this tool was used in Barcelona as part of the Parking Day event in which the results of the Barcelona pilot were presented to the general public (Figure 6). The artifact, which was placed on a through street, invited passers-by to reflect on what can be done to improve the problem identified by the results of the research study, that is how to reduce the effects of air pollution on people's attention levels and increase the access to green spaces together. Passersby were invited to think around three categories that were related to the topics covered during the study: green spaces, sustainable mobility, and healthy habits. Each of the categories was represented by a human-sized cardboard plant. Passersby were invited to propose three types of actions: (i) individual, actions that each person could implement by his own, (ii) community, actions that could be implemented by local groups and organizations, and (iii) public, those actions that should be

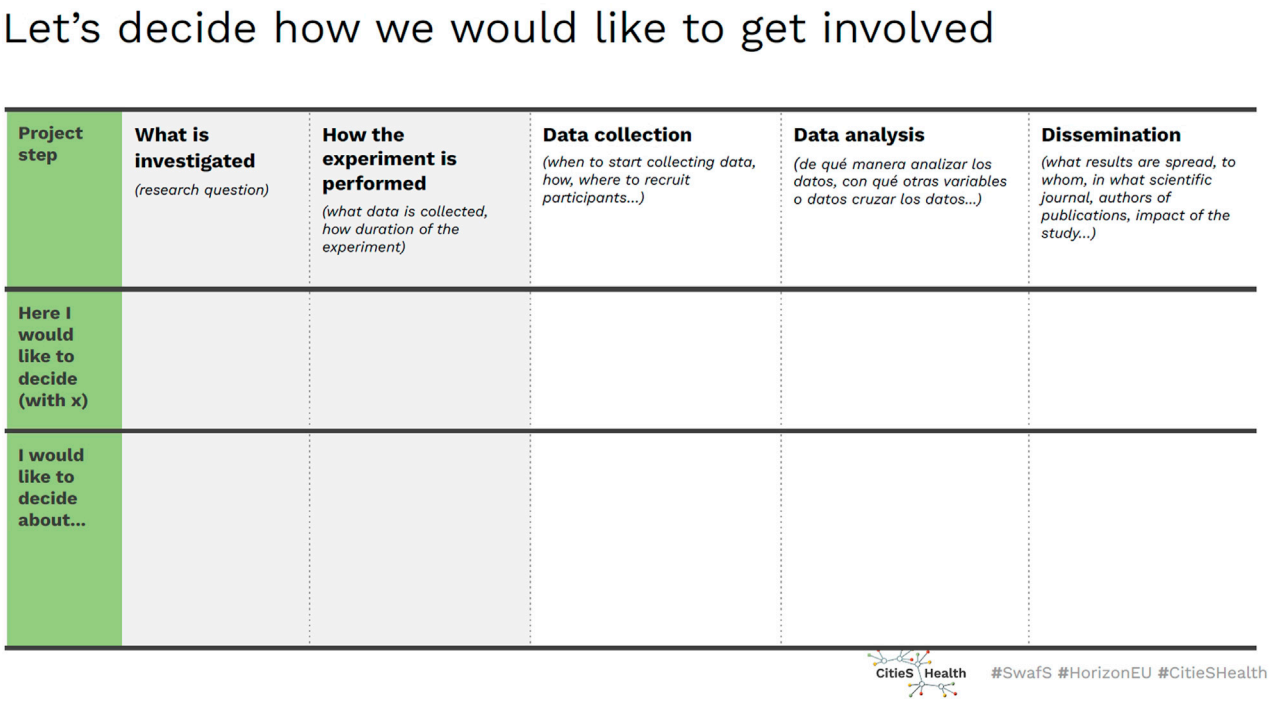

FIGURE 4
Decision making canvas. An editable version of the canvas is provided in the ToolBox section.

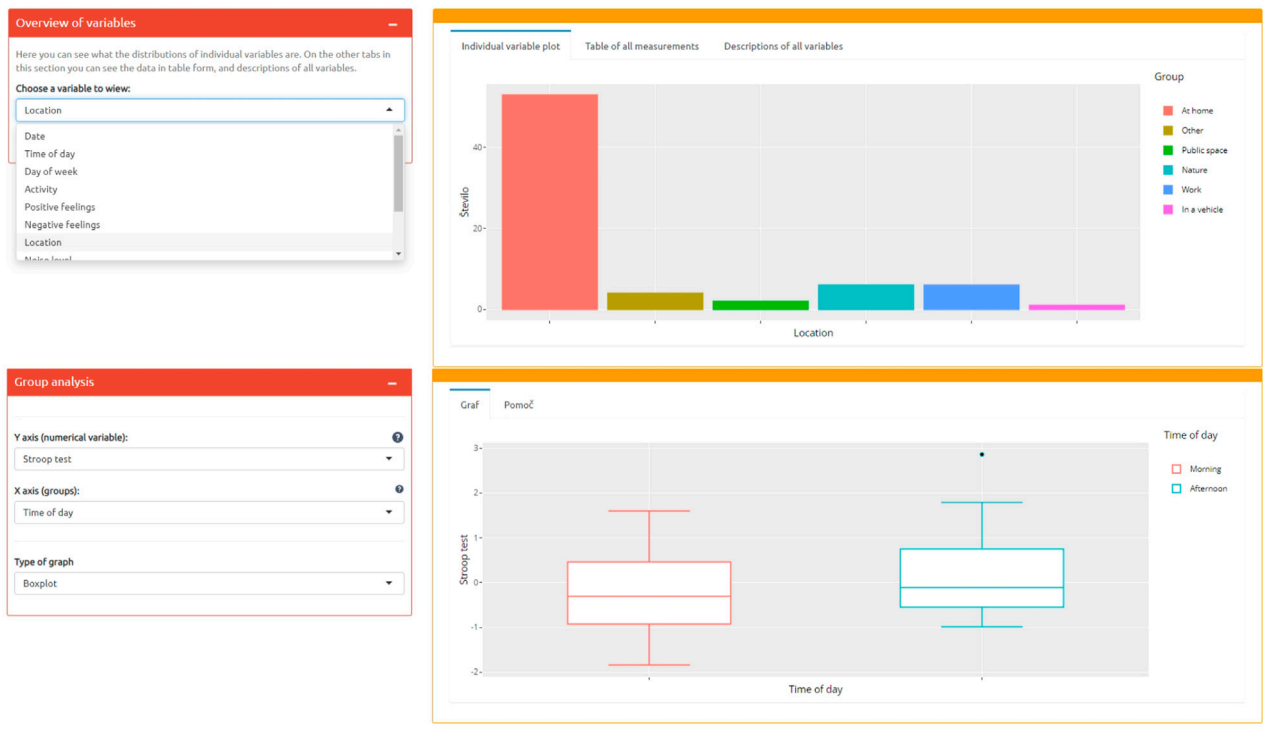

FIGURE 5
Examples of functionalities of the data analysing platform: an overview of data gathered on location (above) and a Box-plot comparing preselected outcomes of the Stroop cognitive test according to the time of a day (below).

FIGURE 6
Plants of ideas created in Barcelona in the framework of the Parking Day event in Barcelona.

implemented by public authorities. They were also invited to think of three different time frames: actions that could be implemented today, in 1 month and 3 months. Participants placed the proposed idea in the corresponding plant.

3.4 Consultancy session and assessment of the value of the toolkit

In order to promote the Citizen Science Toolkit, and to engage relevant actors and stakeholders within the citizen science ecosystem, free consultancy sessions are provided within the platform. Consultancy sessions are a distinctive feature of the Citizen Science Toolkit that differentiates it from other toolkits. Through them, we intended to interact with the user of the platform in an original way seeking to generate inspiring conversations and acknowledging that CS practitioners need additional support that goes beyond reading previous experience through the texts of tools description. So far 15 consultancy sessions were offered to researchers from different fields: sea conservation, health and clinical services, environmental pollution, mobility, and education, among others. Moreover, the consultancy sessions acted as a good dissemination strategy for the toolkit, as the number visitors of the webpage increased considerably during the promotion campaign of the consultancy sessions.

As part of the assessment strategy, a user feedback survey was distributed among practitioners that had some experience with the Toolkit. A total of 15 answers were collected, most of them identified during the consultancy session. The results obtained revealed that in terms of initial expectations of the Toolkit, the perceptions about it can be divided into three groups. Some visitors of the web portal wanted to learn about the potential of Citizen Science approaches in research, others were looking for ideas and inspiration, and some were looking for concrete solutions and user-friendly tools. With the exception of the three users who have already used individual tools in the Toolkit for their work, most of them plan to do so in the future and intend to adapt the tools to their specific needs. In this sense, the tools provided in the Citizen Science toolkit act as inspiration for their future work. Users further recognized the added value of the Toolkit and suggested that it should be made sustainable through further promotion, and constant provision of new tools and assets, in collaboration with established relevant partnerships and initiatives.

4 Conclusion

This paper discusses the development of a web-based CS toolkit originally designed for addressing specific needs related to the conduct of CS in the field of environmental health epidemiology. However, as it was recognized from the outset that the main purpose of successful and useful Toolkits is not that they should be strictly adhered to, but that they should allow for adaptation according to the context of the specific project. The CitieS-Health Toolkit platform was designed in a way that fosters adaptation, knowledge sharing and flexibility. To this end, the toolkit is aimed to enable not only easy replication of CS actions by both citizens and researchers facing similar needs (e.g., by using downloadable materials and adjusting these to the local context and goals of their study), but even more importantly - to inspire others practitioners who are looking for ideas on how to engage citizens in different phases of a research study. It presents a customized and interactive collection of adaptable instruments to empower practitioners to engage communities in their research projects.

Tools contained in the Toolkit are organized according to the interrelated phases of the CitieS-Health methodological framework that is fostering active inclusion of participants in all phases of the project. To this end, they comprise of various tools designed to (i) initially identify concerns of citizens, translate them into research questions and build interested communities around them; (ii) co-design study protocols, including tools for study design and data governance frameworks; (iii) collect and analyse data, including self-reflection on the impacts of CS activities, and (iv) disseminate the outcomes, co-create, plan and deliver actions, including a plan for the legacy of the

project. Moreover, the CitieS-Health Toolkit offers the opportunity to everyone interested in participatory approaches in research projects to add their own experience to the website. The idea is to foster sustainability and continuous collaborative development. This will furthermore enable a widening of the scope of respective solutions and the collective continuous development of the toolkit beyond the project partners.

Data availability statement

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

Author contributions

DK, VR, and LE conceptualised the manuscript. VR, LE, GM, and JC designed and developed the architecture of the toolkit. DK, FF, GH, JF, SA, RG, AF, BD, AB, FG, RT, and XB contributed to individual tools description. DK, LE, VR, GM, and XB drafted the manuscript. All authors reviewed and edited the manuscript, and approved the submitted version.

Funding

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 824484, and the P1-0143 program "Cycling of substances in the environment, mass balances, modelling of environmental processes and risk assessment", funded by the Slovenian Research Agency. This publication reflects only the authors' view, and the European Commission is not responsible for any use that may be made of the information it contains.

Conflict of interest

Authors VR, LE, GM and JC were employed by the Ideas for Change.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2023.1177413/full#supplementary-material

References

Balestrini, M., Errandonea, L., Maccani, G., Creus, J., Basagna, X., Gražulevičienė, R., et al. (2019). *D5.2 first version of toolkit*. CitieS-Health project.

Balestrini, M., Rogers, Y., Hassan, C., Creus, J., King, M., and Marshall, H. (2017). "A city in common: A framework to orchestrate large-scale citizen engagement around urban issues," in *Proceedings of the 2017 CHI conference on human factors in computing systems* (ACM, New York, USA), 2282–2294. doi:10.1145/3025453.3025915

Bernstein, M. J., Nielsen, M. W., Alnor, E., Brasil, A., Birkving, A., Chan, T. T., et al. (2022). The societal readiness thinking tool: A practical resource for maturing the societal readiness of research projects. *Sci. Eng. Ethics* 28 (1), 6. doi:10.1007/s11948-021-00360-3

CitieS-Health (2023). Citizen science for urban environment and health. Avaliable At: https://www.citieshealth.eu/(Accessed January 25, 2023).

Craglia, M., and Granell, C. (2014). *Citizen science and smart cities Report of summit Ispra*. Publications Office of the European Union, Luxembourg.

De Marchi, B., Ficorilli, A., and Biggeri, A. (2022). Research is in the air in Valle del Serchio. *Futures* 137, 102906. doi:10.1016/j.futures.2022.102906

Errandonea, L., Boloix, E., and Creus, J. (2022). *D5.3 final version of the toolkit*. CitieS-Health project.

Froeling, F., Gignac, F., Hoek, G., Vermeulen, R., Nieuwenhuijsen, M., Ficorilli, A., et al. (2021). Narrative review of citizen science in environmental epidemiology: Setting the stage for co-created research projects in environmental epidemiology. *Environ. Int.* 152, 106470. doi:10.1016/j.envint.2021.106470

Ftičar, J., Pratneker, M., and Kocman, D. (2021). "Knowledge generation in citizen science project using on -line tools 14th International Technology Transfer Conference," in *Proceedings of the 24th international multiconference INFORMATION SOCIETY* (Jožef Stefan Institute, Ljubljana, Slovenia), 45–48.

Gignac, F., Righi, V., Toran, R., Errandonea, L. P., Ortiz, R., Nieuwenhuijsen, M., et al. (2022a). Co-creating a local environmental epidemiology study: The case of citizen science for investigating air pollution and related health risks in Barcelona, Spain. *Environ. Health* 21 (1), 11. doi:10.1186/s12940-021-00826-8

Gignac, F., Righi, V., Toran, R., Paz Errandonea, L., Ortiz, R., Mijling, B., et al. (2022b). Short-term NO2 exposure and cognitive and mental health: A panel study based on a citizen science project in Barcelona, Spain. *Environ. Int.* 164, 107284. doi:10.1016/j.envint.2022.107284

Grazuleviciene, R., Andrusaityte, S., Dėdelė, A., Grazulevicius, T., Valius, L., Kapustinskiene, V., et al. (2020a). Environmental quality perceptions and health: A cross-sectional study of citizens of Kaunas, Lithuania. *Int. J. Environ. Res. Public Health* 17 (12), 4420. doi:10.3390/ijerph17124420

Grazuleviciene, R., Andrusaityte, S., Dėdelė, A., Grazulevicius, T., Valius, L., Rapalavicius, A., et al. (2021a). Urban environment and health: A cross-sectional study of the influence of environmental quality and physical activity on blood pressure. *Int. J. Environ. Res. Public Health* 18 (11), 6126. doi:10.3390/ijerph18116126

Grazuleviciene, R., Andrusaityte, S., Gražulevičius, T., and Dėdelė, A. (2020b). Neighborhood social and built environment and disparities in the risk of hypertension: A cross-sectional study. *Int. J. Environ. Res. Public Health* 17 (20), 7696. doi:10.3390/ijerph17207696

Grazuleviciene, R., Andrusaityte, S., Rapalavicius, A., and Dėdelė, A. (2022). Environmentally related gender health risks: Findings from citizen science cross-sectional study. *BMC Public Health* 22 (1), 1426. doi:10.1186/s12889-022-13824-3

Grazuleviciene, R., Andrusaityte, S., and Rapalavicius, A. (2021b). Measuring the outcomes of a participatory research study: Findings from an environmental epidemiological study in Kaunas city. *Sustainability* 13 (16), 9368. doi:10.3390/su13169368

Greenhalgh, T., Hinton, L., Finlay, T., Macfarlane, A., Fahy, N., Clyde, B., et al. (2019). Frameworks for supporting patient and public involvement in research: Systematic review and co-design pilot. *Health Expect.* 22 (4), 785–801. doi:10.1111/hex.12888

Haklay, M., Dörler, D., Heigl, F., Manzoni, M., Hecker, S., and Vohland, K. (2021). "What is citizen science? The challenges of definition," in *The science of citizen science*. Editors K. Vohland, A. Land-Zandstra, L. Ceccaroni, R. Lemmens, J. Perelló, M. Ponti, et al. (Springer International Publishing, Chem, Switzerland), 13–33. doi:10.1007/978-3-030-58278-4_2

Hansen, N. B., and Dalsgaard, P. (2012). "The productive role of material design artefacts in participatory design events," in *Proceedings of the 7th nordic conference on human-computer interaction: Making sense through design* (Association for Computing Machinery, New York, USA), 665–674.

Kocman, D., Novak, R., Ficorilli, A., de Marchi, B., Biggeri, A., Gignac, F., et al. (2019). "D2.1 Compilation of good practices in governance models," in *Research protocols, in bottom-up impact assessment, and in informing policy making and local governments* (Cities-Health project).

Kocman, D., Števanec, T., Novak, R., and Kranjec, N. (2020). Citizen science as part of the primary school curriculum: A case study of a technical day on the topic of noise and health. *Sustainability* 12 (23), 10213. doi:10.3390/su122310213

Maccani, G., Goossensen, M., Righi, V., Creus, J., and Balestrini, M. (2020). *Scaling up Citizen Science - what are the factors associated with increased reach and how to lever them to achieve impact*. Luxembourg: Publication Office of the European Union. doi:10.2760/00926

Manzoni, M., Vohland, K., Schade, S. C. T., and Dusart, J. (2019). *Citizens science and environmental monitoring: Benefits and challenges*. Luxemburg: Publications Office of the European Union.

Thuermer, G., Reeves, N., Baroni, I., Scandolari, D., Scrocca, M., van Grunsven, R., et al. (2022). Participatory science toolkit against pollution. Available at: https://actionproject.eu/wp-content/uploads/2022/04/TOOLKIT-9_.pdf (Accessed February 01, 2023).

Toran, R., Ortiz, R., Gignac, F., Daher, C., Nieuwenhuijsen, M., Basagana, X., et al. (2019). Documentation on activities and outcomes in CS actions (first report). Available at: http://citieshealth.eu/download/435/?v=440 (Accessed February 01, 2023).

Tweddle, J. C., Robinson, L., Pocock, M., and Roy, H. (2012). *Guide to citizen science: Developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK*. NERC/Centre for Ecology and Hydrology, Wallingford, UK. Available at: https://www.ceh.ac.uk/sites/default/files/citizenscienceguide.pdf (Accessed February 01, 2023).

Van Dyck, L., Bentouhami, H., Koch, K., Samson, R., and Weyler, J. (2019). Exposure to indoor ferromagnetic particulate matter monitored by strawberry plants and the occurrence of acute respiratory events in adults. *Int. J. Environ. Res. Public Health* 16 (23), 4823. doi:10.3390/ijerph16234823

Vohland, K., Land-Zandstra, A., Ceccaroni, L., Lemmens, R., Perelló, J., Ponti, M., et al. (2021). *The science of citizen science*. Springer International Publishing, Cham, Switzerland. doi:10.1007/978-3-030-58278-4

Woods, M., Balestrini, M., Bejtullahu, S., Bocconi, S., Boerwinkel, G., Boonstra, M., et al. (2018). *Citizen sensing: A toolkit*. Making Sense, Dundee, Scotland. doi:10.20933/100001112