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A framework for making citizen science inclusive with storytelling methods

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Citizen science is challenged by a participation inequality that is not compatible with a democratic approach to science. To include the voices of underrepresented groups, this article presents "STORCIT", a framework for making citizen science inclusive with storytelling methods. This framework was trialed in the project "Climate Stories" with two small-scale pilot studies in Hasselt and Brussels (Belgium). This project involved around 50 young people with a diverse background, since they are often overlooked as agents of change in the climate debate. During the project, they recorded their experiences related to the changing climate through citizen science and storytelling methods. The STORCIT-framework was designed through five consecutive phases: i) setting the scene, ii) generating knowledge and learning, iii) sharing personal narratives iv) developing stories, and v) exhibiting to the public. The results reflect on the implementation of this approach, together with the experienced challenges, limitations, and gains. Overall, the approach is highly participatory, multi-faceted and supports the democratization of knowledge generation. The gathered knowledge helps participants to reflect on their story, raise their voice and catalyze actions for social change. In the context of citizen science research, practitioners are encouraged to explore and further adapt this framework to other (justice) domains and involve other vulnerable target groups. In particular, it can be deployed by those who aim to include diverse audiences and stimulate inclusive dialogue between science, society and policy with actions for social change.

KEYWORDS

citizen science, participatory action research, storytelling, photovoice, dialogue, inclusion, youth, climate change

1 Introduction

Citizen science (CS) is referring to a diverse set of activities in which the public can participate to generate new knowledge or understanding. It is an approach for realizing public participation in science (Bonney et al., 2009), by which a two-way communication is favored to transmit science information (Rüfenacht et al., 2021). In different degrees of participation, researchers and citizens interact and collaborate to define the project design, the analysis and dissemination of findings (Shirk et al., 2012; Haklay, 2013). By making the scientific process participatory, CS holds the promise to democratize science (Strasser et al.,

2018; Herzog and Lepenies, 2022). One particular meaning of democratization refers to the inclusion of citizens, through a representative sample of the general population, in the decision-making processes (Strasser and Haklay, 2018). In this sense, something becomes more democratic when people, especially those who have a stake can take part (Strasser et al., 2018). However, from the available demographic analyses of CS projects, it seems there exists a clear participation inequality. People with less formal education, people of color, younger people and women seem to be underrepresented in CS projects (Raddick et al., 2013; Merenlender et al., 2016; National Academies of Sciences, 2018). This lack of broad participation is not consistent with a democratic approach to science and affects the quality of CS projects (Pandya, 2012). Furthermore, the under-participation of certain groups might result in their concerns, wishes, and needs not being considered in the research, or that they might not benefit from certain outcomes. This can reinforce existing inequities in society and, especially, when the research overlooks groups who are often disproportionately impacted by environmental hazards (Grineski et al., 2022).

To leave no one behind and to fully leverage the democratic potential of CS, more inclusive approaches are necessary. In this regard, various efforts in the field are being established to develop new frameworks for wider and deeper public engagement with science. For instance, the "DITOs escalator framework" of Skarlatidou and Haklay (2021) that helps people to decide which level of engagement is suitable for them, or the framework of Pandya (2012) with specific design recommendations to better align with community priorities. There are also various case studies and initiatives which are looking into establishing collaborations with other approaches, such as participatory action research (PAR), community-based research and transdisciplinary research (e.g., Paleco et al., 2021; Senabre Hidalgo et al., 2021).

Against this backdrop, this article proposes a new framework for making citizen science more inclusive with storytelling methods, called "Storytelling in Citizen Science" or short "STORCIT". This framework builds upon the synergetic potential of CS and PAR, with photovoice and digital storytelling as main methods. PAR is an umbrella term to cover diverse participatory approaches and action-oriented research studies which seek for socially and environmentally just outcomes (Kindon et al., 2007). In comparison to CS, a strong collaborative nature between researchers and participants is also present in PAR, whereby participants act as "co-investigators" (Freire and Ramos, 1970). However, the action-oriented approach is not always that prevailing in CS, especially when participants are involved as mere data gatherers in contributory projects (Chevalier and Buckles, 2019; Senabre Hidalgo et al., 2021). By drawing on these two streams of thought, photovoice and digital storytelling are being put forward as main means of engagement in the STORCIT-framework. Through photovoice and digital storytelling, participants gather visual materials to translate an experience into a narrative that has been often overlooked at. Under the right conditions, these narrative methods have demonstrated their effectiveness in raising the voices of underrepresented groups, and establishing social change (Liebenberg, 2018; Moutafidou and Bratitsis, 2018). The application of these narrative methods in CS is underexplored, although rapidly evolving in the field as a way to establish dialogue between science, society and policy (Richter et al., 2019).

The main aim of this article is to present and reflect on this framework for making citizen science more inclusive. To this end, the STORCIT-framework was pilot trialed in the "Climate Stories" project which aimed at empowering the voices of young people in the climate debate. Young people, specifically youngsters with a diverse background under 18 years old, are often under-engaged in the climate change dialogue and overlooked as agents of change (Trott, 2019). Through two small-scale studies in Hasselt (located in the Flanders Region, Belgium) and Brussels (Brussels-Capital Region, Belgium) around 50 young people with diverse backgrounds were involved and recorded their experiences about the changing climate.

The next section draws out inclusive approaches in CS research, and photovoice and (digital) storytelling which act as main means of engagement. This is followed by the method section which describes the study setting, the strategies for participant recruitment and the STORCIT-framework. Based upon the principles of CS and PAR, STORCIT is implemented through five phases: i) setting the scene, ii) generating knowledge and learning, iii) sharing personal narratives iv) developing stories, and v) exhibiting to the public. The results section presents the main experienced challenges, limitations, and gains of the framework. In the context of CS research, practitioners are encouraged to explore and further adapt this framework to other (justice) domains and involve other underrepresented groups. Therefore, specific recommendations are formulated in the discussion section, and which might be particularly interesting for CS practitioners who wish to stimulate inclusive dialogue and social change.

1.1 Towards inclusive citizen science

CS stands for public participation in scientific research, in which participants contribute to the research process across a wide range of fields (Bonney, 1996). With varying degrees of participation, the interaction in the research process can occur in multiple stages, from defining the research question to sharing evidence-based results (Shirk et al., 2012). Originally, Bonney's definition of CS emphasized the role of citizen scientists as data collectors, rather than as full participants in the research process. In this perspective, large-volume observations are gathered to serve the objectives of the scientific enterprise, rather than the co-creation of knowledge with society (Cooper and Lewenstein, 2016). A more democratic definition of CS was earlier introduced by Irwin to represent a multitude of ways in which the public can involve in science (Irwin, 1995). From this latter point of view, citizen scientists have a meaningful role in the project, and both researchers and participants benefit from taking part (cfr. ECSA, 2015).

While most CS projects today tend to be contributory in nature (Land-Zandstra et al., 2021), participatory CS projects following Irwin's vision are gaining interest. This is particularly the case for environmental-oriented CS projects that involve monitoring of environmental justice, whereby researchers and participants strive to change the power dynamics between science, society and policy (Cooper and Lewenstein, 2016). In participatory approaches, CS can be deployed with an action-oriented framework, e.g., with behavior

change frameworks, public interventions aimed at raising further awareness or policy change, hands-on stewardship actions at the local level, *etc.* (Jordan et al., 2019; Coulson et al., 2021). In these projects, opportunities for broad participation are often supported by everyday digital devices, such as smartphones, to gather and evaluate data (Burke, 2006). Citizens can also count on open, low-cost technologies and do-it-yourself (DIY) kits to measures issues that affect them (Gabrys, 2019). These data measurements are often gathered and made accessible via apps or web dashboards, e.g., for air quality through the sensor.community[1]. These advancements of information and communication technologies (ICTs) have certainly enabled a democratization of the knowledge production process, with data becoming more and more available (Bonn et al., 2018).

Although CS projects have taken a participatory turn, the degree to which projects are truly participatory or empowering remains under scrutiny (Strasser et al., 2018). CS projects often only reach participants who already hold an interest (and most often have experience) in science, and thus not a broad and varied audience (Segal et al., 2015; Obiorah et al., 2021; Paleco et al., 2021). Yet, if CS truly aims to contribute to the democratization of science, the research design process should be inclusive, flexible, and adaptive in all its stages (Bonney et al., 2016). CS projects may benefit from deploying inclusive approaches, such as overcoming unfamiliar concepts through understandable language and clarifying expectations (Paleco et al., 2021), articulating comprehensible timeframes (Senabre Hidalgo et al., 2021) and anchoring in local contexts (Devine-Wright, 2013). Such translating practices—whether textual or tacit—may ideally be performed in shared physical spaces, such as science shops or FabLabs, as these allow participants to have access to a tangible version of the translation (Senabre Hidalgo et al., 2021). Here, participants can also acquire the ability to configure their own measurements with DIY-technology. Such physical ways of engaging with CS can overcome the high entry point of online platforms (Spiers et al., 2019; Obiorah et al., 2021).

Another way is to deploy visual thinking strategies and art-based methods, such as storytelling, which can contribute to the alignment of participants' interests in CS (Ravetz and Ravetz, 2017). Telling stories can play an important role in bridging the discourses between science and society (Hecker et al., 2018). They can help to humanize science by communicating scientific facts in an engaging and entertaining way. Stories can thus yield various benefits, such as a greater interest and curiosity in science, raised awareness about science, a deeper connection between science and society, and so on Dahlstrom (2021). Storytelling is often used in the fields of science education (Abrahamson, 1998; Alterio and McDrury, 2003) and science communication (Green et al., 2018; Joubert et al., 2019), and also recently in the field of CS. To explore the role of stories in CS, Richter et al. (2019) identified a typology with three main applications. They found that stories can be non-exclusively applied as objectives (something to pursue), tools (something applied), and agents (something causing effects). For instance, Ottinger focusses on the hermeneutic source of stories for making sense of air quality data (Ottinger, 2017), Constant and Roberts (2017) describe how narratives can be used as a tool to perform research evaluation in and Wehn et al. (2021) detail how storytelling can be used to communicate and measure the impact of new environmental policies. To add meaning to CS data, storytelling techniques are also often being deployed in data representation, e.g., Liu, Cranshaw, and Roseway (2020) showcase how air pollution data can be enriched with subjective anecdotes, perceptions and experiences. Although these examples demonstrate that the field is developing, more systematic research is needed to investigate the multifunctional nature of storytelling in CS. In this regard, this article explores how storytelling can make CS projects inclusive.

1.2 Participatory storytelling for social change

Telling stories is an intrinsic human characteristic and evolutionary skill that has been refined over thousands of years (Gottschall, 2013). Throughout history, storytelling has evolved from visual to oral to written, and most recently from analogue to digital formats. Although formats have changed, telling and sharing a story is a universal way to make meaning and sense of life (Straub, 2005). People communicate by telling stories and these stories pass on through history to educate or entertain, or to preserve cultural identity. In narrative communication, storytelling is defined as "*the act of sharing information through a narrative*" (Dahlstrom, 2021, p.2), whereby a narrative tells someone's experience of something. Although various features determine a narrative (Bruner, 2009), a narrative will most often describe a sequence of events with a cause-and-effect relationship in a certain time frame with a set of characters (Dahlstrom, 2014).

By telling stories, people can also speak up and be heard. It provides them the opportunity to share their story and make their voice count. In PAR, storytelling is often used as an instrument to give voice to a certain group (de Jager et al., 2017). Typically, participatory approaches represent "*a counter-hegemonic approach to knowledge production*", whereby researchers recognize the plurality of knowledges and especially of those who have been systematically excluded (Kindon et al., 2007, p.9). Although PAR leaves room for interpretation, at its core, a minimum threshold of genuine participation, tangible action and scientific research should be present (Chevalier and Buckles, 2019). Combining these essential elements, through a cyclic process of action and reflection, can lead to social change and the construction of theory (Fisher and Ball, 2003). This societal change is a deep commitment of PAR, whereby the collected insights into real-life situations can help to address identified concerns and result in effective problem solving.

The most common methods in PAR focus on dialogue, storytelling and collective action (Kindon et al., 2007). In this regard, photovoice and digital storytelling have been employed in various settings to democratize the research process and drive social change, e.g., to examine men's care responsibilities and living conditions in low-income contexts (Tarrant and Hughes, 2020), with young people as agents of change in the climate debate (Trott,

1 https://sensor.community/en/

2019; Finnegan, 2022), with indigenous communities to map out decolonization (Sium and Ritskes, 2013), *etc.* More applied initiatives of these methods, linked to the specific theme of this article, are for instance Young Reporters for the Environment[2] and Voices of Youth[3] which engage young people in the climate debate by exchanging stories, blogs, poems, *etc.* These examples showcase that storytelling methods are highly appropriate to use with underrepresented groups. Participants can express themselves in their own (visual) language and share a story that has often been overlooked at or shared in traditional media (Costera Meijer, 2009). These stories can be positioned as "counter-narratives", *versus* the single or dominant narratives, that may challenge certain stereotypes (Delgado, 1989). Sharing stories can contribute to social change, both on individual, interpersonal and community levels of analysis, with diverse outcomes, e.g., building trust, cultivating norms, generating emotional connections, *etc.* (Winskell and Enger, 2014).

In the set-up of these research methods, three phases are often included, i.e., collection of narrative data, collective interpretation and dissemination of the results (Liebenberg, 2018). Specifically, with the photovoice method, participants are provided with (digital) cameras to capture narrative data of their lives in order to act as recorders and potential catalysts for change (Wang and Burris, 1997). Before they collect data individually or as a group, consensus is reached about the research topic among the participants and researchers. This is an important step in facilitating meaningful engagement and scoping of the research track. The participants are also informed about photography essentials and fieldwork ethics. In a next step, the collected (digital) photographs are used during group discussions to reflect about individual or collective strengths and concerns. A critical dialogue is promoted during these sessions for collecting insights about people's experiences that have been overlooked, rejected or silenced (Singhal et al., 2007). In a final step, the collected narratives are disseminated with the wider community to promote dialogue and eventual social change, e.g., through an exhibition or by translating the findings into policy recommendations (Wang et al., 2000). Photovoice is being used for various applications, often with adaptations to the method according to the specific settings (Naranjo-Bock, 2012). However, Sitter argues that when photovoice is being guided by PAR, certain core attributes should be inherent to the processes, i.e., the positionalities of researchers who intervene as insiders or outsiders, a high decision-making power of the participants, and sufficient time to develop trust (Sitter, 2017).

In the same logic as photovoice, digital storytelling has been used across a wide range of social and environmental issues, such as environmental justice, health services (Gray, 2009), *etc.* In the tradition of Joe Lambert, the founder of the StoryCenter, digital stories are powerful instruments "*to help building a just and healthy world*" (StoryCenter, 2023). In their practice, they define digital stories in a non-elusive way through several characteristics. In brief, it is a personal, experiential narrative on a particular (emotional) subject with a restrained length and design. The digital stories tend to use still images in combination with sound effects and the recorded voice of the storyteller (Lambert and Hessler, 2018). Like photovoice, digital stories are created through a set of workshops, which usually last for three full days and with a small number of participants (5–10) (Gladstone and Stasiulis, 2019). The workshop process includes the necessary time for writing and revising a script, selecting images, and getting acquainted with video-editing software. Story circles, or talking circles, are at the heart of these workshops (Lambert and Hessler, 2018). They provide a safe space for hearing and reflecting about each other's stories, whereby feedback can help to iterate the story. At the end of the process, a final event, such as an exhibition or video screening is organized whereby the stories are presented with some additional comments about the storyteller's experiences and efforts.

In the next section, a framework is presented for using storytelling methods in CS for including underrepresented groups.

2 Methods

This section presents "STORCIT", a new framework developed by the article's authors to make citizen science inclusive through storytelling methods. The main objective of this framework is to include the voices of underrepresented groups through stories in which CS data and knowledge are embedded. The STORCIT-framework exists of five implementation phases: i) setting the scene, ii) generating knowledge and learning, iii) sharing personal narratives iv) developing stories, and v) exhibiting to the public.

This framework was pilot trialed in the project "Climate Stories" with two small-scale studies in Hasselt and Brussels. This project was conducted from June 2021 till February 2022, with an average duration of 3 months per pilot, and focused on stories that reflected on the changing climate. Due to the COVID-19 health measures in force at that time, a pragmatic approach was taken to set up the study (e.g., shortening or postponing of activities, smaller group of participants, *etc.*). At the end of the project, a short questionnaire with five questions was distributed among the participants to evaluate the research process. This evaluated their knowledge gain, attitudes towards climate change, and their intention to develop a story in the near future.

The pilot studies, the strategies for participant recruitment and the STORCIT-framework are described in the following sections.

2.1 The pilot studies

The pilot studies took place in Hasselt and Brussels. These two regions were selected for their diversity in population figures, the context-specific challenges, and the local expertise of the partners.

The first pilot took place in the summer season of 2021 in Hasselt. Hasselt is the regional capital of the Province of Limburg and counts a population of approximately 80.000 inhabitants. Around 24% of the population has a foreign background (Hasselt, 2022) and 11.5% is at risk of poverty or social inclusion in the Province of Limburg (STATBEL, 2023). Certain areas in the province are highly industrialized, such as Hasselt and Genk, with scrap processing companies and steel factories. The project partners involved in this pilot study were a center of expertise on inclusion, participation, and diversity (UCLL), and a professional youth-

2 https://www.goodplanet.be/nl/yre-nl/

3 https://www.voicesofyouth.org/

service supporting vulnerable young people (Habbekrats vzw). The pilot also received operational support, i.e., facilitation and space, from the LUCA School of Arts, the City of Hasselt, and the University of Hasselt.

The second pilot took place in the winter season of 2021 in Brussels. Brussels, officially the Brussels-Capital-Region, counts a population of approximately 1,2 million inhabitants (STATBEL, 2022). Around 40% of the population has a foreign background and 38.8% is at risk of poverty or social exclusion (STATBEL, 2023). Overall, Brussels is not performing well in meeting the air quality standards of the World Health Organization and is ranked among the top ten cities with the worst health impact in Europe (Khomenko et al., 2021). The dispersion of socio-economical classes in Brussels shows that lower classes live in more densely populated areas and have less access to green space. As a consequence, socially vulnerable groups are increasingly exposed to environmental elements with a negative impact on health (Noel et al., 2020). The project partners involved in this pilot study were a research group in media, innovation, and technology with expertise on CS and PAR (Vrije Universiteit Brussel), a university college dedicated to art and design with expertise on storytelling and DIY-sensing techniques (LUCA School of Arts), and a non-profit organization specialized in digital skills development of vulnerable groups, including youth programmes on digital storytelling (Maks vzw).

2.2 The participants

The recruitment of participants occurred through a partner-led approach; Habbekrats vzw led the efforts in Hasselt and Maks vzw for Brussels. A promotional video was developed to engage participants and communicated through social media, newsletters, and mailing lists. Finally, a total of 10 participants in Hasselt and 42 participants in Brussels signed up.

In Hasselt, the pilot was organized as part of an informal learning program of Habbekrats vzw whereby youngsters are invited to go out and explore the city. The age deviated from 10 to 20 years old (with one group of 10–14 years old, and another of 16–20 years old) and all with a migrant background. In Brussels, a secondary school subscribed through Maks vzw for organizing the pilot during their STEM-courses. This secondary school implements a policy aimed at equal educational opportunities to overcome educational disadvantage of underprivileged native and immigrant pupils. 57% of the school population speaks a different native language at home than the language of instruction, and about 60% receives an educational allowance (Overheid, 2022). The average age of the participating group was 14–15 years old, 44% female, and most of them had a migrant background (around 90%).

Prior to the participation in the pilot studies, all minors were informed about the set-up of the study. In agreement with the General Data Protection Regulation, parental consent was attained through a privacy statement and consent form.

2.3 The STORCIT-framework

Based on the principles of CS and PAR, the STORCIT-framework involves five consecutive phases to include the voices of underrepresented groups (Figure 1). In all phases, participatory strategies are applied to engage participants in the research process. The first phases focus on research through data collection and analysis, while the latter phases work towards action for social change by developing and sharing stories. In the pilot studies, each phase consisted of one or multiple activities, which lasted on average 2 hours with the support of two or more moderators.

In the first phase, the research theme is identified, as well as an exploratory introduction to the theme. The objective is to collaboratively define the scope of the research, kick-start the project and spark interest and curiosity. In the pilot studies, the main applied activities consisted of thematic field visits, exploration of CS databases, and interactive presentations.

During the second phase, participants are generating knowledge and learning about the research theme. The objective is to collect observations and evidence, analyze the data, and stimulate reflection. In the pilot studies, the main activities for generating knowledge and learning were DIY-sensing, photovoice, and a participatory analysis of the collected photographs and sensor readings.

In the third phase, participants are invited to develop a personal narrative related to the insights that were gained on the research theme in phase one and two. This personal narrative is iteratively developed through the organization of story circles. During a story circle, one participant reads the personal narrative and others listen. In a second iteration, the participant progresses from reading to telling their narrative, which is richer in its performance.

During the fourth phase, participants are invited to collaboratively translate their narratives into a creative format. Stories can be developed with photos, images, video, art supplies, and so on. In the pilot studies, this resulted into the creation of digital stories, photography series and creative slogans.

In the final phase, the objective is to share the stories of the participants with the wider community. In the pilot studies, it was

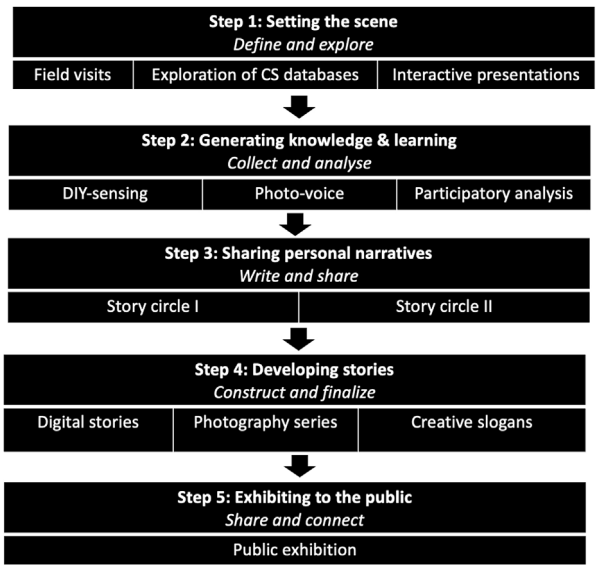

FIGURE 1
STORCIT–Framework for making citizen science inclusive with storytelling.

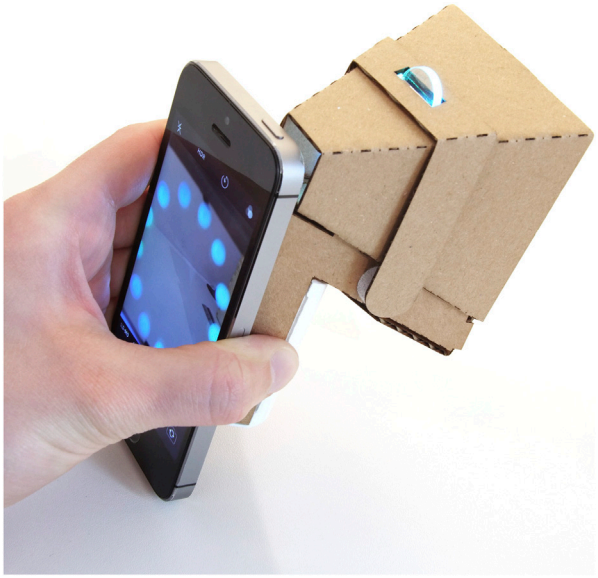

FIGURE 2
Air quality lens (De Greve et al., 2022).

FIGURE 3
Photograph with a green and blue filter applied by the air quality lens. The air quality is good (De Greve et al., 2022).

opted to organize an exhibition to display the stories. Exhibitions help to raise awareness about the issue, enable community members to rethink the issues from their perspective, and serve as a catalyst for broader social change.

2.3.1 Setting the scene

In the pilot study of Hasselt, a brainstorm session about climate change was organized with the participants to define the research theme in a collaborative way. The themes of water, air, heat stress, biodiversity, and circular waste streams were identified, and the participants picked the one that they felt the most enthusiastic about. During the kick-start of the project, three introductory field visits were organized to gain some real-world learning about a particular theme, i.e., a visit to a circular hub, a visit to a local stream to measure water quality together with a CS lab, and a photography workshop. This was complemented with informative presentations about air quality and a quiz about climate change. The participants also explored an online map with air quality measurements collected by citizens from their region. Due to time and financial constraints, it was not possible to explore every theme in depth.

Based on the practical experiences of the pilot in Hasselt, it was collaboratively decided to solely focus on the theme of air quality for the pilot of Brussels. The participants found this theme to be the most interesting, as they wanted to learn how to build the air quality lens. An interactive presentation was organized by the research partners to inform the participants about the sources of pollution, its potential health impacts, and the direct effects of the weather on air quality. Midway the presentation, the participants were invited to look for pollution hotspots in Europe through an online mapping tool. At the end of the presentation, the participants brainstormed about their contributions to good or bad air quality with the help of post-its. In preparation of the next phase, they also received some photography tips and ethical guidelines on paper on how to take good pictures.

2.3.2 Generating knowledge and learning

In the second phase, a workshop was organized in both pilots where the participants received a kit to assemble an air quality lens (De Greve et al., 2022). This air quality lens (Figure 2) can alter photographs based on real-time data from nearby air quality sensors of the network Sensor. community[4]. The lens can be placed in front of a smartphone or point-and-shoot camera and will apply a blue or green filter when the air quality is good (Figure 3), and a red or purple filter when the air quality is bad. After the assembly process by the participants, the photovoice method was explained and a walking tour in the city was organized with five short stops. During the walk, the participants photographed landscapes and sources related to air quality, sometimes with or without the lens. They also recorded their experiences through pen and paper. At every stop a short show-and-tell was organized to collaboratively analyze and discuss the photographs. Reflections were made about the sources of air pollution, the effects of the weather, and the link between the source and the color filter on the photographs. Besides the air quality lens, a temperature sensor was also used in the pilot of Hasselt. A dedicated walking tour was organized with these sensing devices to reflect about heat stress in the city.

2.3.3 Sharing personal narratives

In this phase, two story circles were organized with three moderators per session, each session lasting approximately 2 h. Maks vzw, specialized in digital storytelling, moderated these

4 https://sensor.community/en/

FIGURE 4
Story circle I - writing the narrative. (Photo by Carina Veeckman).

FIGURE 5
Developing a digital story on the tablet. (Photo by Carina Veeckman).

sessions and gave prior training to the other moderators. During these sessions, the collected photographs from the previous phase were printed or digitally archived. With the help of these photographs, the participants formulated a narrative and reflected about the main message they wanted to share. The moderators guided the participants by asking questions on why they took that photograph and what it meant to them: "What do you **S**ee?", "What was **H**appening here?", "Does this happen in **O**ur community?", "**W**hy is this a problem? and "What can we **D**o about it?". These questions are part of the SHOWeD technique of Shaffer (1983) and help to promote self-awareness, sensitivity and self-reliance in problem solving. After writing down their narratives on paper (Figure 4), they were presented within a small group with respectively four to six participants. These presentations helped the participants to finetune their storyline.

2.3.4 Developing stories

The stories were developed in different creative formats. The participants in Hasselt translated their narratives into creative slogans and artwork on big posters, while in Brussels a digital format was preferred. The choice of format was influenced by the participants' preferences for a simple or more elaborated format, the context (i.e., an informal *versus* formal learning environment) and the age difference between the participants; with younger participants opting for tangible artwork. For the digital format, the participants translated their narratives with the help of tablets and video editing software (Figure 5). Therefore, the participants could use their photographs from phase two or royalty-free images which they searched online. The participants also recorded their own voiceover with the help of a microphone and added it to their videos. Sound and video effects were added in the final editing stage. Each digital story lasted approximately between 30 and 90 s.

2.3.5 Exhibiting to the public

In Hasselt, due to COVID-19 regulatory measures at the time, it was not possible to organize an indoor exhibition for the public. Instead, the creative slogans, art works, and photography series were exhibited on the front windows of the town hall of the City of Hasselt for a 2-months period (Figure 6). In Brussels, an exhibition was organized in a gallery space, in collaboration with bachelor students of LUCA School of Arts. The students helped to set up the exhibition space and some of them also participated by sharing their own personal narrative about climate change through an interactive art installation. The digital stories, 23 in total, were exhibited through three old television screens and a headset to create an intimate atmosphere (Figure 7). The air quality lens was also displayed, as well as a selection of the photographs from phase two. This exhibition lasted for 3 days. A press release was sent out to promote the event and local policymakers in the domain of sustainable development received a personal invitation.

3 Results

In the following sections, the main experienced challenges, limitations, and gains of the framework are described. Based on core principles of CS and PAR, the findings are grouped into the themes of participation, research, and actions for social change.

3.1 Participation: youth as agents of change

In both pilot studies, the local partnership successfully resulted in a mixed group of young people with a diverse background. In Hasselt, the youngsters voluntarily signed up via the informal learning activities organised by Habbekrats vzw, while in Brussels the study was part of a formal learning setting. Although the intention was to organize both pilot studies in an informal learning setting, whereby participants could voluntarily sign up out of interest, this was not possible in Brussels. The restrictive COVID-19 health measures at that specific time resulted in a low sign-up rate. For this reason, Maks vzw reached out to a high school in a multicultural neighborhood in the capital. Although it was not

FIGURE 6
Exhibition of the photography series and creative slogans in Hasselt (Photo by Jessica Schoffelen).

FIGURE 7
Exhibition of the digital stories in Brussels (photo by *Petar Veljačić*).

investigated as such, it can be argued that participants had different motivations to participate in the research process.

During the pilot studies, the youngsters were deeply engaged in the research process, whereby they could define the research theme, collect and analyze the data, and share an outcome. The workshop moderators only intervened in the research process in case of financial and/or practical time constraints, or if support was needed. As such, based on the practical experience of the pilot study in Hasselt, it was collaboratively decided to focus on one theme instead of many in Brussels. In addition, moderators supported the participatory analysis by asking and rephrasing questions, and by providing exploratory information for the collected findings. The moderators also made the final selection of the photography series exhibited at the event in Brussels based on the top-three voting of "best pictures" by the participants. Overall, a high level of engagement was thus established in the research process, with participants having significant freedom to create their narratives.

The pilots' duration of 3 months, with five to six workshops in total, demonstrated to be effective for establishing trust between the moderators and the participants. On the other hand, this timeframe caused a loss of knowledge that was build up during phase one and three. During the narrative development, moderators noticed that the participants had to be reminded about, e.g., the main sources of air pollution, or its causes and effects.

3.2 Generating knowledge and learning about the changing climate

In both pilot studies, easy-to-use instruments were opted for data collection and analysis of the changing climate. The main instrument was an air quality lens that helps to visualize air quality data captured by low-cost particulate sensors of the sensor.community[5]. This lens supports narration of the data through a color overlay on photographs. The air quality lens was used during a walking tour with several stops, in combination with a digital camera or smartphone for taking photographs. The walks with the lens took place during winter, with mostly open skies and strong winds, and thus an overall good air quality. This resulted in mostly green overlays on the photographs. However, this contrasted with the experience of the participants when they wanted to photograph

5 https://sensor.community/en/

specific objects, e.g., traffic jams, busses, trucks, chimneys, *etc.* This caused a misperception among the participants that the air quality is always good, although they clearly identified sources that contribute to bad air quality. During the show-and-tell stops, the workshop moderators reminded the participants about the main takeaways from the training in phase one in order to avoid misinterpretation of the findings, i.e., the weather effects on air quality and the spatial distribution of the sensors. Although the air quality lens made the data more visually accessible, the interpretative processes still needed support and critical questioning from the workshop moderators.

When the participants wrote and shared their narratives, collaborative analysis was mixed with individual problem solving. It was up to the participants to choose whether to work independently or in pairs; 6 in 10 participants preferred to work in pairs. Working in pairs sparked creativity and created a safe space to share their narratives. For instance, this sparked the idea to compare the air quality between Belgium and their countries of origin. Those working individually were satisfied to work at their own time and level, and shared their narrative once they were finished.

During the analysis, the workshop moderators noticed that for most participants it was difficult to translate the findings into a personal narrative. Intuitively, participants tended to write a factual narrative in an educational manner, rather than from their personal experiences. The moderators provided support during the story circles by asking questions through the SHOWeD technique, e.g., about the ways they feel affected by the changing climate, the main message of their stories and its central emotions, *etc.* Through these discussions, the participants succeeded in finding a personal storyline with often a clear call-to-action at the end of their narrative, e.g., "*it is our city, our world, we have to act now*", "*everyone struggles with it, and we soon hope for a better air quality*", "*we need to protest against it, and let the government take measurements*".

3.3 Action for social change

Through the exhibitions organized in phase five, the participants were able to have informal conversations with community members about their stories in a setting outside of their familiar context. In Hasselt, the resulting stories were displayed in public space, without context. Through the deployment of street art strategies, these posters were oriented at any passer-by that opportunistically engaged with the information. In Brussels, the exhibition took place inside a public institution for the arts, in a semi-public space. The digital stories were surrounded by students' artworks on the topic of climate change, which provided additional context.

Through these exhibitions, the participants learnt how to communicate their voice and claim their equal participation in society. While some participants were a bit nervous about hearing their own voices in a public space, others found it neutral to positive. Half of the participants also acknowledged to have learnt something new: taking photographs, interpreting the findings, presenting a narrative for a group, editing a video, recording audio, and so on. A third of the participants in Brussels acknowledged that they would love to develop another story in the future.

A federal policy maker and an educational organization in sustainability for youngsters passed by the event in Brussels. Some of the participants were encouraged by these stakeholders to also share their story through their dissemination channels and enter a competition. The developed stories are also shared through the (social media) channels of the involved partners in the consortium, and through an online Vimeo channel[6] of Maks vzw. As such, these stories continue to exist and retain attention to young people as agents of change.

4 Discussion

This article presents a novel framework for including the voices of underrepresented groups in CS through storytelling methods. The framework was specifically designed for the "Climate Stories" project that aimed to empower vulnerable youth in the climate debate. The implemented framework, designed on the core principles of PAR and CS, helped to empower the youngsters in various ways. They were deeply involved in the research process and could define the research topic, collaborate in the data collection and analysis, and share their personal narratives. Secondly, capacities were built to raise their voice and speak for themselves through storytelling methods, and finally, a collective action was taken to disseminate the research results to a broader audience.

In the context of CS research, practitioners are encouraged to validate this framework in other (justice) domains (e.g., health, mobility, food, *etc.*) and with other vulnerable target groups (e.g., older people, migrants, *etc.*). Thereby, it is advised to fit the technology formats and activities with the (digital) profile of the target group. The choice of technology should be in line with the participants' demographics, affordability and access, and fitness for purpose (Mazumdar et al., 2018), and in turn, this might influence the level of engagement in the research study (Sanabria-Z et al., 2022). Furthermore, a set of potential activities is described in the framework, but these are not set in stone and can be modified to suit the research context. Other activities that might support the objectives in the phases are for instance the usage of mobile applications to collect narrative data (cfr. The "Our Voice" method in King et al. (2021)), or other types of action-oriented activities such as family or community action projects to support the sustainability in the area (cfr. Trott, 2019).

During the implementation of the framework, core attributes of PAR were duly considered, i.e., the positionality of the researcher, the decision-making power of the participants, and sufficient time for building trust (Sitter, 2017). Based on the experiences from the workshop moderators, some suggestions for improvement were found.

- First, although participants received training in phase one, several participants were experiencing difficulties for interpreting the data in phase three. Without the intervening of workshop moderators this could have led to the misconception that most of the time our air is clean.

6 https://vimeo.com/maksvzw, specific example: https://vimeo.com/721386265 (The story of Ruby & Lana).

Therefore, in agreement with Ottinger (2017), it is recommended that meaning-making of data should still be a collaborative process between participants and workshop moderators, or with thematic (data) experts. To enhance independent learning and critical thinking skills, it is recommended to build in extra training for the data collection activities in phase two. Another recommendation is to look into resources which can support argumentation skills in phase three, e.g., activities that invite participants to understand and practice scientifically valid ways of arguing, formulating arguments consisting of claims with either data or warrants (Osborne et al., 2001), fact-checking workshops, *etc.* These recommendations can help to overcome "narrative mismatches", i.e., stories not matching with the available data, and give due credibility to their stories.

- Second, workshop moderators found that participants were initially struggling to balance science-based facts with their personal views on climate change. Intuitively, they wrote a fact-based narrative on climate change, without including a first-person perspective. Martinez-Conde et al. (2019) investigated how the brain works when engaging with scientific storytelling and stress that a story should not only engage people's intellect, but also their feelings. If there is little interest in a story, there is probably a disconnect between the scientific content and its emotional impact. Therefore, a correct balance should be sought between deductive and inductive reasoning in the story circles in phase three, i.e., between generalizable facts and the expression of emotion and values. To support this, additional training on the photovoice methodology and expert help in making data meaningful is recommended in phase three of the framework.
- Last, it appeared that the total length of the research, i.e., five to six workshops spread over 3 months, caused a loss of knowledge between the first and last phases. Some research projects with storytelling methods continue over many months or years, with photovoice focusing on various aspects of participants' lives (cfr.Wilson et al., 2007). In this case, the research focused only one perspective related to climate change, namely, the capturing of data in a city context. Since the data insights gathered in the first phases are of importance for the latter phases, it is recommended to opt for a more regular interval of reflection and action when handling CS data.

A question for future research is whether this framework resulted in any longstanding impacts. The results showed that the participants acquired additional skills and knowledge related to the research topic, however, it is unclear if this knowledge and active engagement retained after the Climate Stories project. Investigating the long-term impacts of these projects is thus of crucial importance to understand the transformative potential towards building testimonial justice and inclusive dialogue between science, society, and policy.

Finally, in terms of further theory building and practice, the STORCIT-framework provides an additional approach for CS practitioners who wish to engage diverse audiences in multiple stages of their research. In this way, STORCIT demonstrated that combining CS and storytelling methods is showcasing potential for engaging underrepresented groups and establishing inclusive dialogue between science, society, and policy. Although not all CS projects are intended to democratize science or to lead to social justice outcomes (Bonney et al., 2016), a strong link between science, society and policy will only be reached when a genuine two-way collaboration is established between researchers and participants. To further advance the field, CS practitioners are thus encouraged to use and adapt this framework to build inclusive science for the benefit of all.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Materials, further inquiries can be directed to the corresponding author.

Ethics statement

Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

Author contributions

CV was responsible for the project administration and funding acquisition. CV and SC contributed to the conception and design of the study. CV conceptualized the method part and performed the analysis. CV wrote the draft of the manuscript. CV revised the manuscript. SC contributed to section 1.1. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The 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

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