CITIZEN SCIENCE:
THEORY AND PRACTICE

Keep the Flow: Citizen Science as Agonistic Learning

RESEARCH PAPER

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ABSTRACT

This paper addresses the transformative and emancipatory potential of citizen science not only concerning its role in groundwater management, but also regarding its contribution to enhanced and sustainable well-being. Our work is in the Hout Catchment region of the Limpopo province in South Africa where living conditions vary greatly, but all share a vulnerable dependency on the dwindling availability of water. We propose that the interaction between human water systems and its contextual social dimensions with regard to diversity and historically shaped structures of power has had serious impacts on the ability to tackle challenges of sustainable water management. In our project, citizen scientists markedly expanded data collection and analysis at a fraction of the cost of traditional scientific endeavours. Keep the Flow is not simply about effectively using measurement instruments, but also about practices of authentic learning through innovative methodologies that were used to communicate with citizens about science and with scientists about social transformation and well-being. In our workshops, we used art as a bridge. Citizen science takes place in agonistic learning spaces in which historical and geopolitical circumstances that have resulted in an uneven playing field for its participants were acknowledged. We begin by introducing the project, then we discuss plural understandings of citizen science and present our stakeholders. We subsequently examine our own citizen science approach as agonistic learning, which brings us to ideas of entanglement and meshwork. We then present our participatory action research methodology and the go-to tools we use in in agonistic learning spaces, followed by our conclusions.

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KEYWORDS:
Citizen science; agonistic learning; groundwater; art and science; entanglement; transformative methodologies; participatory action research; Limpopo

TO CITE THIS ARTICLE:
Goldin, J, Suransky, C and Kanyerere, T. 2023. Keep the Flow: Citizen Science as Agonistic Learning. *Citizen Science: Theory and Practice,* 8(1): 5, pp. 1–11. DOI: https://doi.org/10.5334/cstp.515

INTRODUCING THE PROJECT

Our project, Keep the Flow, is situated in the Hout Catchment area, set in a very remote rural region in the province of Limpopo in South Africa. It comprises around 2,845 square kilometers. It is an arid to semi-arid region, subjected to serious climate and socioeconomic challenges. Its inhabitants are diverse and marked by great inequalities that flow from South Africa's colonial and apartheid history. There are commercial farmers (generally white landowners with large properties), farmers on small holdings, and residents of small and often isolated villages. While their backgrounds and living conditions may vary greatly, they all share a vulnerable dependency on the dwindling availability of water.

In this context, we started a project funded by the Water Research Commission (WRC)[1] of South Africa, with the primary aim to promote sustainable groundwater management. The current project draws on experiences from an earlier project entitled Enhanced Sustainable Use of Ground Water in South Africa (ESGUSA).[2] ESGUSA was the first citizen science project of its kind in the country. Its objective was to assess and propose a citizen science approach that would enhance the understanding of catchment hydrogeology in the region and equip local stakeholders to better participate in water resources management (WRM). The ESGUSA experience yielded four main insights about groundwater management that we addressed in follow-up initiatives.

The first insight relates to mismanagement of water resources (such as pollution of water sources and vandalism of boreholes), which adversely impacts the ecosystem, water access, human health, and food production. The second insight revolves around the hydrological data void in municipal and governmental databases on groundwater. As a result of this void, farmers in remote areas lack knowledge about the water in their wells, which makes them feel that they have no part in the protection, conservation, use and control of water, which is the third insight. The fourth insight concerns the need to better understand the transformative and emancipatory potential of citizen science not only in terms of its contribution to groundwater management but its contribution to enhanced and sustainable well-being. This paper particularly focusses on our follow-up research regarding the fourth insight, and discusses our experiences with citizen science in Limpopo.

Despite an increasing awareness of the complexity of water-related problems, the pursuit of knowledge related to water remains a major challenge (Klenk and Meehan 2015; Mechlem 2016). Particularly lacking is knowledge about the interaction between human water systems and its contextual social dimensions, for instance with regard to diversity and historically shaped structures of power, which may have serious impact on the potential to effectively tackle challenges of sustainable water management. Conscious of this knowledge gap, we will discuss the Hout Catchment region not only as a geographical site, but also as a canvas on which complex living threads between water and people manifest, unravel, come together, and draw apart. Consequently, our project Keep the Flow is not simply about effectively using dip meters, rain gauges, smart phones, etc., but it is also about practices to promote authentic learning through innovative methodologies and visual cues, used to communicate with citizens about science and with scientists about notions of social transformation and emotional well-being.

Given these ambitions, we put together a diverse project team of hydrogeologists, and social scientists, and we identified local stakeholders who were interested in groundwater monitoring. With the help of the Department of Water and Sanitation (DWS) and the tribal authorities in the area, a first list of possible participants was drawn up. This list included Catchment Management Agencies (CMAs) such as the Sand River CMA, municipalities, the Agricultural Farmer's Union, NGOs, consulting companies, the Department of Agriculture, Forestry and Fisheries, local communities, farmers, the private sector, and research organisations.

For logistical reasons, and based on the specific farming activities of stakeholders, we began by dividing the stakeholders in the catchment area into three distinctive groups, namely (1) commercial farmers, (2) smallholder farmers, and (3) people in smaller rural communities clustered in parts of the region that were extremely deprived under apartheid policies and still suffering because of it. However, as our work progressed, we became more aware of the complexities within this socio-political environment, and began to see many more entanglements than first appeared. Our initial list was too simplistic and by no means complete, and many new stakeholders became enmeshed in our work as the project progressed. In this respect, we became keenly appreciative of the work of Ingold (2015, 2017) on knotting and entanglements and the meshwork metaphor of Klenk (2018). Ingold (2015) claims lived lives are interwoven as meshwork where individual entities interact and pull apart only to meet up in the future (Ingold 2015). The meshwork idea offered us a helpful alternative to traditional descriptions of social relations that emphasise more rigid social structures and/or default to supposed universal normative rules and practices. These ideas, which we will discuss in more detail further on, helped us to develop our own citizen science approach in the Keep the Flow project.

PLURAL UNDERSTANDINGS OF CITIZEN SCIENCE

Before we discuss our own project, we briefly explore how others have conceptualized citizen science. As is obvious from its name, citizen science brings two realms together. These two realms are generally detached, which can be problematic because as Ballard (2021) reminds us, scientists do not necessarily understand the needs, interests, and knowledge of people and communities, nor have they typically been educated or encouraged to support community engagement as part of their scientific efforts. The British sociologist Alan Irwin (1995) defined citizen science in the mid-1990s as both a science that assists the needs and concerns of citizens and a form of science developed and enacted by the citizens themselves. Irwin's definition foregrounds the necessity of opening up science and science policy processes to the public (Balazs et al. 2021: p. 145). Citizen science has been predominantly pursued within the domains of the natural sciences (Crain, Cooper, and Dickinson 2014; Goldin et al. 2021). Activities and projects following social sciences and humanities topics and approaches are less easily discernible.

In their article, "Contours of citizen science: a vignette study," Haklay et al. (2021) draw attention to the proliferation of definitions and typologies of citizen science.[3] The authors also discuss challenges in terms of reaching consensus about a definition of the concept and conclude that plural understandings are far more realistic given the diverse disciplinary lenses that are applied in citizen science. Wehn et al. (2021) also reflect on the many forms, definitions, and meanings of citizen science, and remind us that while some definitions focus more on citizen science as a tool for collection and analysis of data (e.g., Oxford English Dictionary 2014), "others define it as a multi-stakeholder process that aims at increasing democratization of science and policy, scientific citizenship, public engagement, transparency, equity, inclusiveness and justice" (Wehn et al. 2021: p. 1). Ernst (2019, in Jadallah and Ballard 2021) recognises the scarcity of profound analytical concepts that can help to guide empirical analysis of citizen science. To some extent the work of Jadallah and Ballard (2021) aims to address this gap. However, despite the vast body of knowledge on citizen science, we have not yet seen a coherent theoretical frame that discusses its transformative potential in terms of community change. Our work attempts to fill this gap.

KEEP THE FLOW STAKEHOLDERS

Based on our initial stakeholder identification, we started by conducting three stakeholder workshops between March and November 2019, prior to the COVID-19 lockdown. Each of the three workshops was attended by between 30 and 40 participants, including farmers, residents from villages, officials from the Department of Agriculture, Forestry and Fisheries and the Department of Water and Sanitation, ward councillors, and the motley group of stakeholders we have mentioned above.

Commercial farmers own huge tracts of land that belong to families who have been farming in the Hout for more than 50 years. These commercial farmers used their advanced understanding of surface and groundwater and shared their data on the aquifers, in particular for the purpose of drilling successful and continuously functioning boreholes for irrigation. They are embedded in an institutional reality that has legitimized their position over many years and has united them as a group. The Agricultural Farmer's Union represents them as a collective "other" that gives gravitas to what often seems to be considered as a powerful unified voice of male, white, commercial farmers. At the first workshop, for instance, members of this Agricultural Farmer's Union were able to debate and engage head on with technical groundwater issues in the Hout. Some of them had experienced land dispossession, water scarcity, or/and water stress, and focused on that, whilst others foregrounded their besieged identity of being white and Afrikaans. Technical presentations by scientists from the University of the Western Cape and government officials from the Department of Water and Sanitation, or from farmers who were in Section 2, visibly alienated and silenced the small-scale, poor, white, female and male farmers.[4] The latter group did not speak even when invited to. We were in the same room, but only some were vocal and the others remained silent. Yet, in these spaces silence was as powerful as words. Their struggle was muted but palpable. The dichotomy in the room clearly challenged us as workshop facilitators to create dialogical spaces.

We noticed that it made sense to approach both the small-scale and commercial farmers with some caution. We became aware that farmers on smaller tracts of land (around 3 to 10 hectares) often feel ignored and believe they are judged as lacking in scientific knowledge. The wealthier commercial large-scale farmer community was challenging for different reasons. They seemed apprehensive and, at least initially, rather unwilling to engage with us as outsiders, perhaps because they were already quite well informed about their water sources (primarily groundwater) and considered us a hassle that interrupted their busy farming schedules. They also feared that their borehole usage may become visible and that they might be held liable for licensing and additional billing for water consumption.

Nonetheless, both small-scale and commercial farmers felt a squeeze on their livelihoods because of intensifying climate variability and increasing unreliability of their groundwater resources. As we see from the narrative

extracts we present below, this common problem helped to open doors and to bridge the divides between them.

After the first two workshops, we set up a pilot study and selected 15 volunteers who came from Sections 1 and 3 of the catchment where farming activities are small scale. This group became our first generation of volunteers. Commercial farmers from Section 2 attended the third workshop for the first time. Prior to that, over a period of 9 months, the volunteers had been asked to capture weekly data on rainfall, daily data on groundwater levels, and river flow on a by-event basis, and they sent the data through a mycitizenscience app using their smart phones (see Goldin et al. 2021). The volunteers received feedback in the form of graphs with a simple narrative explanation on a bi-weekly basis from an experienced hydrologist, a post doc from the University of the Western Cape who was working in the catchment. This data was shared with commercial farmers and other stakeholders at the third workshop. The groundwater and rainfall graphs assisted both commercial and small-scale farmers in understanding the relationship between rainfall in their area and the groundwater response/recharge in their specific boreholes or farms. The project team anticipated initial hesitance from volunteers regarding collecting data as they might not have sufficient incentives to do so, but this was not the case. The volunteers felt engaged and readily participated. We believe that this was not only because the instruments to monitor water were cost effective and technologically appropriate but because there were instruments, tools, and techniques that were developed in the workshops, designed to build trust and to empower. Because the volunteers had become co-creators, they were invested in the research process and the knowledge-chain that they had become part of.

CITIZEN SCIENCE AS AGONISTIC LEARNING SPACES

As can be deduced from above, our project brought together a wide range of people and institutions, all with different knowledge and interests as well as different and unequal stakes. Water scarcity caused tensions among the diverse inhabitants of the Hout Catchment area. Discussing the dwindling water availability due to climate change made them more conscious of their own and each other's struggle for the same water. It was not only the local stakeholders who were a diverse group of people but also the academics involved, who came with different backgrounds and baggage, entangled in what we call subjective water hegemonies. Engineers, hydrologists, and geology experts in groundwater with positivist interpretations of the water world encountered anthropologists who came with quite different academic lenses and responses to the same water world. Participation in our citizen science project became a platform, a learning space to encounter and rethink interdependencies and possibilities for cooperation for a wide range of people.

It is at this point that the ideas of Schellhammer (2018), Suransky and Alma (2018), and Mouffe (2013) became helpful in shaping our citizen science project. In their work on agonistic learning, Suransky and Alma (2018) build on Schellhammer's ideas about "learning in tension" (Schellhammer, 2018). Schellhammer argues that learning happens in contexts of difference and diversity. According to Schellhammer "dialogue in tension of differences is pivotal to learning and transformation, both internally and externally" (p.23). Rather than aiming to assimilate or harmonize differences, people should be enabled to engage in dialogue in which there is room to explore their differences, while also being challenged to rethink their perspectives. As such, learning together involves ongoing critical engagement with oneself and the world. Learning is thus construed as an active, dialogical process of developing contextual knowledge. Agonistic learning contexts acknowledge that dialogues do not take place in social vacuums. Rather, these dialogues take place under particular historical and geopolitical circumstances that seldom encompass a level playing field for all who participate. According to Suransky and Alma (2018),

> xPeople who engage in dialogue bring along their own baggage of personal and systemic privileges and hindrances. People enter dialogues in social contexts that are imbued with inequalities and injustices. These kinds of differences may deeply affect them and cannot be addressed by simply proclaiming that "we are all equal" in a dialogical setting. Those who engage in dialogue are not only individuals, but also members of larger social groups in which meanings and solidarities are created collectively. [...] Broader social inequalities and social injustices, which people inevitably carry with them, need to be explored and acknowledged because they will find their way into the dialogue (p. 32).

In order to facilitate dialogues that make room for such complexities in our project, we turned to Chantal Mouffe's concept of agonistics (Mouffe 2013). Mouffe proposes to develop democratic practices in plural societies that go beyond an aggregative model in which people are assumed to be in permanent pursuit of their own interests, and also go beyond a "deliberative model which stresses the role of reason and moral considerations" (Mouffe 2013: p. 6). Her idea is that in agonistic struggles, conflict does

not "take the form of an 'antagonism' (struggle between enemies,) but the form of an 'agonism' (struggle between adversaries)" (Mouffe 2013: p. 7). Other than what happens between enemies, adversaries become opponents with whom "one shares a common allegiance to the democratic principles of 'liberty and equality for all', while disagreeing about their interpretation. [...] Adversaries may both strive for their interpretation to become hegemonic, but they do not put into question the legitimacy of their opponent's right to fight for the victory of their position" (Mouffe 2013: p. 7). According to Mouffe, the agonistic struggle that then emerges can be considered the "very condition of a vibrant democracy."

ENTANGLEMENT AND MESHWORK

We conducted our workshops and follow-up activities in the spirit of agonistic learning by making room for shared as well as divisive concerns, and positioned the project as a space to practice vibrant local democracy. We searched for ways to understand and deal with difference within social relationships as what Ingold (2015, 2017) calls knotting and entanglements and Klenk (2018) sees as meshwork. Ingold (2015) claims lived lives are interwoven as meshwork where individual entities interact and pull apart only to meet up in the future (Ingold 2015). Meshwork explains the entanglement of individuals, full of loose ends and always on the move (Klenk 2018). Or as Ingold (2015) claims, in a world of life, it is knotting that is the fundamental principle of coherence and that is generative of new forms.

As discussed in more detail elsewhere (Goldin et al. 2021), we also found it helpful to look through a feminist lens. Feminist thought, as presented in previous work,[5] helps us to keep focussed on an ethics of care and the pursuit of social justice. We find the feminist emphasis on diversity and difference particularly helpful. At the same time, we question the actual claim that these writers make to level the playing field for all in real-life situations. Given our emphasis on agonistic struggle and learning-in-tension in learning environments, we chose to engage with difference. Dialogue in tension must always be power sensitive and attuned to historical relationships of enfranchisement and disenfranchisement, acquisition and misappropriations, authorisation and de-authorization. In our project, it meant, for instance, that privileged commercial farmers as well as deprived local villagers and small-scale farmers were included rather than excluded, and we needed to be conscious of the fact that their processes of inclusion requires different strategies. Subjectivities of a farmer, an engineer, a government official, a local chief, and an anthropologist or engineer, are enmeshed with cultural differences and modus operandi, making for confusing (dis)connects between players trying to solve, together—or in their separate ways—what is often a wicked problem, the problem of sustainable water resources management.

The meshwork idea offered an alternative to more traditional descriptions of social relations that continue to emphasise rigid social structures and/or default to universal normative rules and practices. All involved in the project came together and apart in tension, influenced by particular historical prejudices, different disciplinary stances, gender, economics, and multiple centres of power or control—or lack of power and control, as the case might be.

ART AS MESHWORK

In order to strengthen our agonistic learning spaces and the potential of the meshwork metaphor, we turned to art. According to Zaelzer (2020), the democratisation of knowledge and the transformative aspects of citizen science through visual art-based designs enhances the social narratives with science as a dynamic, knowledge-building process. Zaelzer argues that because of the direct relationship between art and emotion, using art and design in science communication assists the public to situate themselves in the complexities of scientific inquiry. Art in popular culture has a strong influence in shaping people's perception of science and scientists. Films, novels, comics, and illustrations are usually more appealing, eye catching, and memorable than formal scientific lectures (Van Riper 2003 in Zaelzer 2020). The rigorous objective nature of the natural scientific method provokes the avoidance of emotions so foundational to human nature. Proponents and practitioners of the arts have criticized this scientific method and warned of the moral implications of an emotionless practice of science (Ruttkay 2020 in Zaelzer 2020). Oxman (2016) sought to narrow the divide between academic disciplines and particularly the binary between science and art. She claims that at the dawn of the new millennium, the meme "anti-disciplinary" appeared, which yanked us out of Aristotle's shadow and into a new age of entanglement. For Oxman, perhaps the artist's mindset is not really that different from a scientist's—they are simply two ways of operating in the world that are complementary and intertwined. There are elements of surprise and puzzling forms and shapes that emerge as art and science collide. In such collision moments, agony and learning-in-tension were not just permitted but strongly encouraged in our project.

PARTICIPATORY ACTION RESEARCH AND THE "GO TO" FOR KEEPING THE FLOW

In the design of our workshops, we turned to participatory action research (PAR), which is variously termed as a dynamic educational process, an approach to social investigation, and an approach to take action to address a problem or to engage in socio-political action (Gillis and Jackson 2002; Koch, Selim and Kralik 2002). PAR is considered a mode of systematic inquiry and an action research methodology that focuses on social change and empowerment (Gillis and Jackson 2002; Reason and Bradbury 2006). We developed a toolkit with several instruments (see Goldin et al. 2021) including participatory mapping, the River of Life (RoL), storytelling, story boards and participatory monitoring and evaluation. In order to indicate how we translated our ideas about agonistic learning and meshwork into concrete PAR workshop instruments, we will discuss each of these instruments below.

Our first "go to" was participatory mapping. This is a tool that provides a sense of belonging and ownership. In our project, it meant that catchment boundaries and new features such as wells, streams, contamination points, etc., were plotted through conversation, consent, and dissent. This method resonates with Veiga et al.'s (2017, in Balazs et al. 2021) convincing argument in favour of prioritising data quality needs from the data user's perspectives. In our project, the local water features (e.g., boreholes, rivers, dams, and ponds) were identified by workshop participants during the first stakeholder workshop, so that areas of fragility in the catchment (contamination, dried riverbeds, etc.) could be marked. The process of adding new features on the map became iterative and required intermittent negotiation as the catchment was re-visited, recognized, and re-defined by volunteers and as new evidence of forgotten or invisible features were made visible.

The second instrument (see Figure 1) is called the River of Life (RoL), which is often used by indigenous groups as a

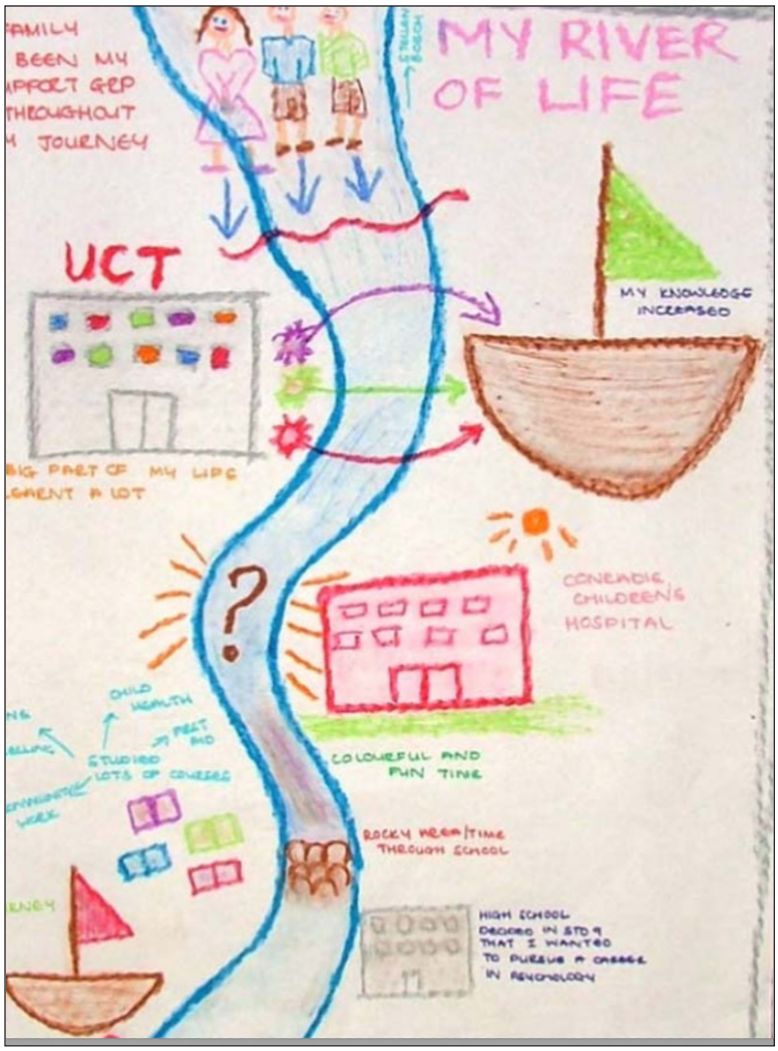

Figure 1 A typical river of life.

tool to counter dynamics of power and control as discussed by Hall and Sullivan in the early 1990s. The RoL is a powerful visual storytelling method in which people are invited to tell stories about their past and to introduce life experiences that might previously have been hidden or unshared. We found the RoL tool conducive for building trust and for engaging with emotional and intangible goods as well as identifying the more tangible events that brought participants to where they are today. In this way, the metaphor of the river was used to tap into experiences and personal life histories. Participants were invited to identify trials and tribulations that were marked on the RoL, seeing these as tributaries of the greater river of life that eventually leads to the sea. As such, this exercise worked on the idea of storytelling or yarning—weaving and knotting together life experiences. Each participant's RoL shows different paths, different experiences, and the common thread is water. In the workshops people were able to share their own RoL, which brought new questions and insights to light and enhanced mutual understanding of current diverse positionalities and opinions.

The third tool we introduced was the storyboard (see Figure 2). According to Wikstrom (2013 in Ayob and Omidire 2021), the storyboard dates back to the 20th century when it served as a pre-visualisation tool for the film industry in a graphic storytelling and visual narrative form. Storyboarding is a technique used in the visual arts that has been adapted for use in indigenous research regarding community development (Simeon et al. 2010 in Ayob and Omidire 2021) and in participatory research (Pittaway and Bartolomei 2012 in Ayob and Omidire 2021). This method proved to be powerful in making sense of the water world and giving meaning to experiences both within the workshop settings and beyond. Figure 2 presents an example of a storyboard. Participants told us what was meaningful to them and what words or images could best capture the lively discussions held in the workshop. A storyboard captures tensions and can reflect agonistic learning (see, for example, words such as fraught, fragile, fleeting, anger, hope, and pride, and the phrase water is fluid, so are your emotions).

Figure 2 Storyboard entitled Life as a River.

The storyboard technique, as a creative qualitative method, helps to tap into emotional meanings from the perspectives of participants' encounters (Ayob and Omidire 2021) and to bring the materiality or tangible goods aspects to the fore as well. For Ayob and Omidire (2021), the decision to use a storyboard tool was to elicit authentic and raw information in its original form from the learners in a non-threatening and fun way. The emphasis here was on learning in tension while participants visually shared their experiences, which enabled them to relate with more immediacy through the storyboard. Storyboards are accessible in a way that narrative reports are often not and as such address concerns of equity and justice (Ballard 2021). Creative methods are increasingly used in qualitative research to generate richer data and to promote more meaningful participation. We also experienced the power of storyboarding as a manifestation of agonistic learning through storytelling or yarning.

The fourth instrument we used was the participatory monitoring and evaluation chart (see Figure 3). This is an interactive citizen science monitoring and evaluation tool that was designed by and for the volunteers. The subjective experiences of each volunteer were evaluated by using twelve indicators that the volunteers themselves had identified. Their responses were captured through smileys and emoticons, as well as through a simple narrative text. Some typical responses are on the chart below.[6]

The PAR instruments we chose are all art forms that fit well with the project as they enable people to communicate personal preferences and experiences and also offer innovative ways to communicate science. As such, these tools are instrumental in making emotional connections alongside creating and gaining new knowledge about people, about water, and how these connect. The narratives below are examples of water narratives and keeping the flow despite (or because of) difference and inequality:

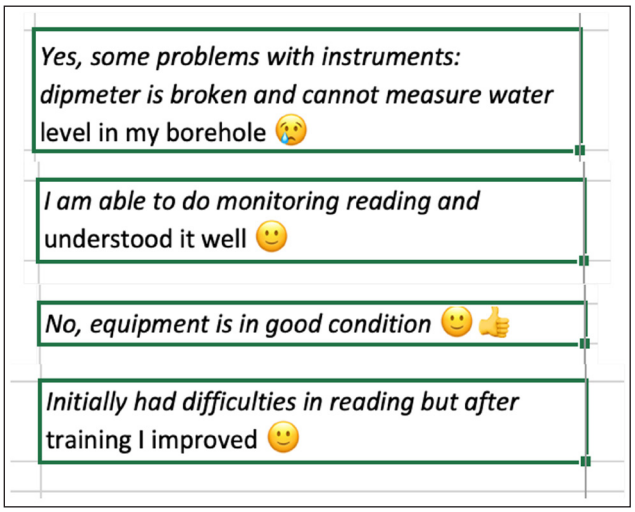

Figure 3 Participatory monitoring and evaluation responses.

> *I joined the project because of agriculture and I love water. Water is my passion. I never thought water was so important but here, on the farm, I actually realise how important water can really be for agricultural reasons… planting and ja ….. You can go without electricity but you cannot go without water* (Catherine Basson, small-scale farmer Buysdorp)[7]

and

> *I joined citizen science through volunteering. I was called to a workshop then I volunteered. I didn't understand what I was doing at first cos I just thought I was just measuring water with a water gauge–which I didn't even know the difference between a water gauge and a water meter. So now I do. I go to other boreholes to measure them. I understand what is going on. I understand a little about groundwater–not much. I would like to know more because (laughs) you have professors here who will help us do that. So I am very grateful to be part of the team* (Dorah Mashela, citizen scientist)

and

> *You see, if all the farmers can measure their water and use that data then we know we will still farm for many years. Otherwise if they don't look after their water it will only be a few years then we are all gone* (Klas Grobbler, commercial farmer)

Their stories show how people are differently and unequally situated in the broader water world. Our workshops created opportunities to become more aware of such differences—differences that matter in the realization that through water we are all connected and interdependent. Agonistic learning in such contexts is by no means an easy endeavor: sympathetic though we may be to emphatically taking the perspective of others, it becomes challenging when one is truly asked to critically examine one's own beliefs and the often-taken-for-granted realities in one's own familiar contexts and lines of reasoning. For a white commercial farmer who has been immersed in deep-seated feelings of separateness and apart-ness to come together with the other, dialogue is one of agonism. This is the case for small-scale farmers and residents living in very poor villages as well because they have rarely had an opportunity to be in the same room as commercial farmers, owing to a fragmented history that has them living very much apart. What emerges is dialogue in agony held together by water, a common vision of water keeping citizen scientists together and apart.

CONCLUSION

If we are going to address the wicked problem of sustainable water resources management, the social dimensions of human water systems are essential. When considering the idea of planetary health and consequentially human health, we need a successful politics of representation that is attentive to ideals of participation and democracy. Keep the Flow brought stakeholders with different knowledge and interests together, although they have unequal stakes. Water scarcity has caused tensions among the diverse inhabitants of the Hout Catchment area. Dwindling water availability due to climate change has made residents of the catchment more conscious of their own and each other's struggle for the same water. The question of how to democratise knowledge around sustainable water management reinforces the idea of citizen science as educational spaces for all involved. This is even more so in the case of groundwater, which—as an invisible asset—runs under the ground, and people often have little knowledge about how much there is, where it is, how clean it is, and how to conserve or use it. Alienation from water as a vital resource is felt not only by ordinary users. It is also experienced by government officials who, by having insufficient data and access to information, feel that they are all too often removed from the resource. Our Keep the Flow experience shows that citizen science can markedly expand data collection and analysis at a fraction of the cost of traditional scientific endeavours. But much more than that, participation in our citizen science project became a platform, a learning space to encounter and rethink interdependencies and possibilities for cooperation for a wide range of people. Rather than aiming to assimilate or harmonize differences, we prefer to see that people are enabled to engage in dialogue in which there is room to explore their differences, while also being challenged to rethink their perspectives. As such, learning together involves ongoing critical engagement with oneself and the world. In our work, learning is thus construed as an active, dialogical process of developing contextual knowledge. Agonistic learning contexts acknowledge that dialogues do not take place in social vacuums. Rather, they take place under very particular historical and geopolitical circumstances, which, given our fragmented past, seldom provides a level playing field for all who participate. As such, we conducted our workshops and follow-up activities in the spirit of agonistic learning by making room for shared as well as divisive concerns, and positioned the project as a space to practice vibrant local democracy.

In order to strengthen our agonistic learning spaces and the potential of the meshwork metaphor, we turned to art, which helped us to learn about people and what they carry in their hearts and heads, and about groundwater. It is here that the direct relationship between art and emotion, using art and design in science communication, can assist the public to situate themselves in the complexities of scientific inquiry. Keep the Flow is not simply about dip meters, rain gauges, smart phones, etc. It is about instruments that promote authentic learning through innovative methodologies and visual cues used to communicate science to citizens and the emotions and notions of transformation to scientists. Our work advocates for a bridge between art and science. Our project can thus contribute to the body of knowledge on citizen science by proposing a new lens—one that brings together ideas of entanglement and agonistic learning, thus adding value to understanding the transformative and emancipatory potential of citizen science.

NOTES

1 Entitled polycentricity, pluralism and citizen science (C2020/2023–000413) builds on a WRC Project (C2020/2021–0085). CISMOL: Citizen Science: groundwater monitoring in the Limpopo Province.

2 DANIDA-funded project. This project, and CISMOL that followed it (note above), were implemented through the Department of Earth Sciences at the Faculty of Natural Sciences, University of the Western Cape, the standard procedure of acquiring ethical clearance from the University was followed.

3 See also the work of Eitzel et al. (2017) on citizen science terminology matters.

4 Valentina Vadi's (2008) idea of *Sapere Aude*! which is the Latin phrase meaning 'dare to know!' proposes knowledge as the fundamental human aspiration and a form of individual and collective empowerment. It is pertinent that silencing implies also a denial of access to particular kinds of knowledge.

5 See Goldin et al.'s (2021) feminist philosopher's lens. Of relevance is the work of Nancy Fraser (2009) on the scales of justice, Iris Marion-Young (1990) on justice and the politics of difference, Joan Tronto (1993, 2012) on an ethic of care, and Vivienne Bozelek et al. (2013) on the use of emerging technologies for authentic learning. Also the work of Michalinos Zemblyas (2015) on a pedagogy of discomfort and its ethical implications.

6 Other indicators included whether they were able to access the mycitizenscience app, whether they were happy with the process, if they were active on the app (chatting, sharing pics), if they have their own borehole or use a public borehole, if they take photos of the river bed, if they measure rainfall regularly, and if they transmit rainfall data.

7 Citizen scientists were asked whether they prefer anonymity or the use of their own names and they preferred the latter.

COMPETING INTERESTS

The authors have no competing interests to declare.

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TO CITE THIS ARTICLE:
Goldin, J, Suransky, C and Kanyerere, T. 2023. Keep the Flow: Citizen Science as Agonistic Learning. *Citizen Science: Theory and Practice*, 8(1): 5, pp. 1–11. DOI: https://doi.org/10.5334/cstp.515

Submitted: 09 May 2022 **Accepted:** 25 October 2022 **Published:** 07 February 2023

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