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Progressing from Science Communication to Engagement: Community Voices on Water Quality and Access in Makhanda

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Abstract: The EU's Responsible Research and Innovation framework advocates for engagement between communities and scientists, creating opportunities for scientific research and processes to be informed and shaped by community voices. To date, few examples in the literature explore this in practice. Hence, key questions remain as to the role that communities play in this framework and the nature of and extent to which community voices and localised perspectives inform research and innovation. This paper explores how a collaborative community engagement process, facilitated at the outset, could meaningfully inform the establishment of a water quality testing facility. In Makhanda, a water-scarce region of South Africa, focus group discussions as well as site visits/observations integrated community and researcher knowledges to shape the community-engaged water testing facility. This study details how the daily assessment of water by the community provided valuable insights to the researchers on the nature and extent of factors affecting water quality and informed the sites and timing of water testing in subsequent scientific measurements of the same. Furthermore, it opened pathways to sustained, longer-term engagement between scientists and communities around water quality, highlighting the need for a multi-stakeholder focus to support community agency around access to safe water.

Keywords: science engagement; responsible research and innovation; community; knowledge integration; biotechnology; water quality

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1. Introduction

Science engagement (initiatives supporting communities' engagements with science)—as a tool for bridging and facilitating exchanges and understanding between scientists and the public—represents a crucial step in creating awareness and shared frames of thinking towards attaining sustainable development goals. This extends to scientific research and innovation (R&I) outcomes, where advocates for more engagement between scientists and communities in R&I note the beneficial role that community engagement plays in enhancing the successful outcome of scientific research and innovation. Several challenges exist in the evolution of science engagement between scientists and communities.

Han et al. [1] provide a succinct definition of community engagement (CE) that draws on Brett et al. and is valuable in the study's framing. CE is defined as: "the process of meaningfully involving communities affected by research findings in the research process" [2] (p. 22). They further describe CE as an ongoing process that emerges dynamically through partnerships and relationships between researchers and communities. Similarly, CE can be defined as: "the process of working collaboratively with groups of people who are affiliated by geographic proximity, special interests, or similar situations with respect to issues affecting their well-being" [3] (p. 9).

Generally, the impact of engagement (i.e., changes in community practices as a result of engagement) and the continuity of the desired results tend to increase when engagement processes emphasise more collaborative and community-led interactions [4,5]. Engagement processes can encompass a continuum between the researchers having most/all authority during the engagement, an equal amount of authority being shared between researchers and community members, and the community possessing all/most authority [4,5].

The majority of engagements in meta-analyses have been evaluated as being researcher-centric [4,6] as opposed to being collaborative or community-led, even when engagements have been initially designed to be more collaborative [5,6]. Furthermore, central to calls for engaged research is the concern that engagement with the public generally occurs during the final to end phases of developing initiatives [7]. This top-down engagement is often expressed in deficit models, at which point much of the research and innovation direction has been finalised and only a limited amount of influence can be exerted by the participants.

Incorporating the voices of communities right from the design stage of research resonates with Responsible Research and Innovation (RRI) frameworks advocating for researchers to engage impacted communities by providing opportunities for local perspectives and knowledge to help shape scientific research and innovation [8]. Currently, few examples exist in the literature detailing engagement processes between communities and scientists that lead to new innovations.

Three approaches to engagement between science students and communities within the field of Biotechnology have been explored within the research team [9,10]. Biotechnology is an applied field of study focused on developing products and processes spanning water, energy, health, agriculture, and biodiversity. These studies explored a different model in which engagement with communities formed a core focus of postgraduate research. Communities were engaged at different stages of the research and innovation process: (i) from the outset of research (in a study of the beneficial properties of traditional medicinal plants); (ii) midway through research (developing tools for bioelectricity generation); and (iii) towards the end of fundamental research, i.e., at the onset of prototype development (for a new water treatment device). These studies, albeit at different stages of the R&I process, demonstrated the benefits of science engagement for student learning and also showed the potential for communities to shape research outcomes. However, the engagement phases of the studied projects were of short duration (from 1–4 weeks up to 3 months), limiting the scope for sustained community engagement and impact. Arguably, sustained, longer-term engagement approaches that emphasise community participation at the outset may offer the opportunity to explore the impact of participation on both the research direction and its impact on communities [11]. Key questions thus exist as to the models and approaches that may support the greater influence of communities in the shaping of research and innovation when participating at its outset.

It is widely acknowledged that researchers and practitioners need to do more to address emerging sustainability challenges. Safe water represents one of the most enduring sustainability challenges, profoundly impacting the daily lived experience of many communities across the globe. Van Eeden et al. [12] and Olsson and Folke [13] argue that-to address environmental challenges in context-there is a need to integrate local stakeholder perspectives.

Thus, engagement between researchers and communities may provide enabling spaces for advocacy and agency in supporting sustainable development outcomes as well as producing beneficial outcomes for R&I.

This paper explores how a collaborative community engagement process can be facilitated at the early stages of R&I (problem identification/design stages) and how communities can be included in scientific research and innovation processes, advancing theory into practice. We draw on experiences from an ongoing science engagement programme, headed by the BioSENs group of Rhodes University's Biotechnology Innovation Centre (RUBIC), in Makhanda, South Africa. This programme aims to put into practice different models for embedding science engagement into Biotechnology research curricula and innovation processes [9,10]. In this specific project, communities were engaged in conceptualising and informing the establishment and operation of a water testing facility set up at RUBIC to address water quality challenges in Makhanda (with an ongoing emphasis as to the nature of the water quality tests conducted). The water testing facility is termed a community-engaged water testing facility (CEWTF).

By engaging communities on the critical issue of water quality and access, the research further provides a valuable case study for connecting science with communities. This study presents an opportunity to explore the needs and concerns of the community surrounding this crucial resource and informs researchers on how to integrate and co-create knowledge with communities as a critical process for addressing development challenges in context. This paper highlights the value of bridging the gap between scientists and communities, of particular importance in the South African context and more so within a community like Makhanda's, in which deep inequalities and poor service delivery overlap and persist.

This study adopts community engagement as a collaborative process, legitimising the voices of the community in the research process and reporting results.

Aims and research questions

This paper explores community voices on water access and quality as it relates to household usage in Makhanda, South Africa. Focus group discussions (FGDs) were conducted with communities in order to develop a deeper understanding of the water challenges faced by Makhanda communities and as a means of gauging community interest and values/needs for a water testing service.

In this study, we explored an approach in which the design of an innovation (the CEWTF) is informed by communities' local knowledges during the initial stages of the innovation's establishment. This model serves as a case study of emerging collaborative approaches to science engagement seeking to explore and demonstrate these collaborative principles in practice: local community knowledge being integrated with scientific knowledge, each acknowledged as equally-valuable and mutually-reinforcing contributions. Few examples exist in the literature exploring the extent to which communities participating in engaged research frameworks inform, or otherwise shape, scientific research and innovation. This study seeks to explore how community voices informed the innovation process throughout, rather than towards the end of the research.

Theoretical framework

This research is framed within the EU's Responsible Research and Innovation framework (RRI) [8,14]. The RRI initiative advocates for direct engagement between scientists and targeted communities. At its core is the creation of opportunities for science engagements that recognise the value, knowledge, and impact that communities bring to scientific research and innovation processes, ultimately supporting the democratisation of scientific research [8].

Paradigms such as the EU's Responsible Research and Innovation Framework and Community-Based Participatory Research have grown in recent prominence [15]. Similar models are being actively pursued in South Africa through the National Research Foundation's Science Engagement Strategy [16], which places "the development of a critical public that actively engages and participates in the national discourse of science and technology to the benefit of society" as a key strategic aim. Within this aim, it is emphasised that the government has a duty "[to] empower [. . .] its citizenry to engage with substantive questions relating to the national science and technology enterprise, and to help shape its agenda directly in terms of what sort of science is undertaken and to what end, and whose interests are served". The value of communities as co-creators of research and innovation is increasingly acknowledged by both researchers, e.g., [9,10], and policymakers [16]. Consequently, the active participation of communities in scientific research projects is increasingly embraced by researchers and practitioners alike.

Raymond et al. (2010) [17] provide a productive approach to engaging with this topic as it closely links knowing and doing and explores the integration of knowledges both as a process (during the research) and a product (after the research), focusing on the value created for communities.

Even though there is no single way to integrate scientific and local knowledge, value lies in being attentive to the process of knowledge integration, i.e., the process of how knowledges are identified and how we engage with these knowledges. While inviting multiple approaches and methods, the framework emphasises key components and steps in realising the value of knowledge integration for both researchers and the community.

The theoretical framework developed by Raymond et al. in 2010 [17] outlines knowledge integration as an integral process within sustainable CE projects that needs to be conducted iteratively from the problem identification stage to the application of co-created knowledge in a manner that is systematic, reflexive, and cyclical. In this framework, the integration of local and scientific knowledge becomes an ongoing process of reflection and joint learning for all parties involved. As noted by Raymond et al. [17], there is: "a need to reverse trends of external experts coming in to tell communities what to do and to increase confidence in the ability of local people to think about and work through their own problems using their own knowledge (as there was little else available)" (p. 1773).

The framework of Raymond et al. (2010) [17] consists of four steps: (1) identifying existing knowledges that participants use in order to understand and address the matter of concern; (2) engaging with different ways of knowing through the use of knowledge integration methods; (3) evaluating knowledges and the knowledge integration process in terms of co-learning and knowledge creation; and (4) applying the results of knowledge integration in a way that is valuable, beneficial, and meaningful to both researchers and local stakeholders in the project.

Figure 1 illustrates an adaptation of Raymond et al. (2010) [17] encompassing these four steps. Study-specific questions have been added to each step to specify the topics of analysis reported here. The framework is outlined here:

Step one: identifying different (existing) knowledges that participants draw on to understand and address the matter of concern. This was divided into two separate phases: 1a. problem identification, addressing the question: is there a need for a Water Testing Facility for communities in Makhanda? and 1b. identifying existing knowledges, addressing the question: how have communities been assessing water quality and treating water outside of the WTF?

Step two: engaging with different knowledges held amongst the researchers and the communities through the use of knowledge integration methods. For this study, this phase focused on investigating community solutions to address the identified water challenges in step 1b.

Step three: evaluating different knowledges in terms of co-learning and knowledge creation. In this study, this phase was framed as engaging with the value of the integrated knowledges in the CEWTF.

Step four: applying the results of knowledge integration in a way that is valuable, beneficial, and meaningful to both researchers and local stakeholders as part of the project. These are framed as two final, interlinked steps: 4a. applying integrated knowledges during the project, focusing on adapting the water testing facility; and 4b. applying integrated knowledges after project completion, examining how future CE practice can become more sustainable.

Step three has been conducted here in an initial analysis. Step four is not directly included in the analysis of the findings in this study but is included here as it points forward to future research on the sustainability of CE efforts, framing further opportunities for study and analysis.

The above model was valuable in positioning and contextualising our efforts at knowledge integration and is interlinked with the empirical findings in this report.

The application of the framework to this study

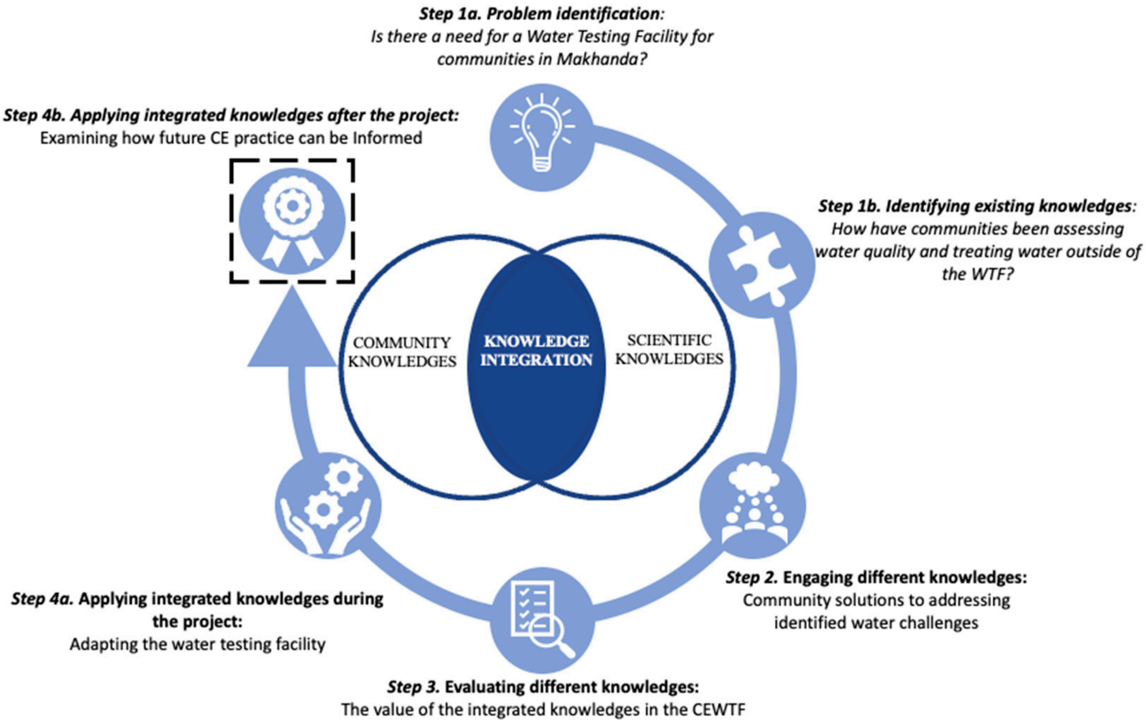

Figure 1. Application of the theoretical framework from Raymond et al. (2010) [17], detailing four steps pertaining to knowledge integration as an integral part of sustainable engagement with communities.

2. Materials and Methods

2.1. Background to This Study

Makhanda is in a water-scarce region of the Eastern Cape of South Africa. Arguably, water access has been further compounded by infrastructural failings. So-called water shedding (where water access is rationed) by the local municipality, either alternating between providing access to different parts of the town over different days or rationing to periods where water is shut off across the town, sometimes in cycles of one day off ("water off" days) and one day on ("water on" days), is common, as is the concern about the water quality itself. Additionally, shortly before the reported research occurred, concerns regarding microbial contamination of the municipal water supply were raised in local, e.g., [18], and national news services, e.g., [19].

Given the above, the concept for the establishment of a water testing service formed part of the research goals of the Rhodes University Biotechnology Innovation Centre's Research Chair in Biotechnology Innovation and Engagement. However, the community's expectations with respect to water quality analysis, which would inform the local needs for the facility (and the shape and scope of that), remained unclear. Therefore, in developing the CEWTF, we conducted a needs assessment during the planning stages of the innovation to empirically establish the existence of the need for a water testing facility and identify the specific community needs thereof in order to prioritise these.

We focused on engaging communities from the planning stage of the research, as CE at this stage is argued to be critical in setting the direction of the research practice, as well as building relationships and trust between researchers and communities around a shared understanding of the concern to be addressed [20]. For this paper, we highlight the findings emerging from the needs assessment, which was primarily informed by three focus group discussions. Three site visits/observations also involved preliminary water testing.

From its conception, CE in this study was founded on a transdisciplinary approach, drawing on the expertise of the natural and social sciences to collectively gather and analyse data that would form the basis, shape, and scope of a water testing facility and to address the potential for knowledge co-creation with communities.

A key characteristic of this community engagement was that the researchers themselves formed part of the community that had a need for water testing and had to establish what this need looked like. As such, the paper provides an example in which the recurring split between researcher and community is navigated in a novel way, with the researchers being part of the community and experiencing the same water access and quality challenges as other community members.

2.2. Focus Group Discussions

Focus group discussions (FGDs) were conducted to acknowledge the community's voices regarding concerns about the water used in their day-to-day lives [21]. The FGDs sought to create a space for voicing experiences of water access and quality and reflecting on joint experiences around the water in Makhanda.

The research relied on purposive sampling by recruiting participants for the FGDs through an ongoing collaboration with the Public Service Accountability Monitor (PSAM), hosted at Rhodes University's School of Journalism and Media Studies in Makhanda, South Africa. PSAM hosts the Action for Accountability (A4A) programme in Makhanda that enables community agency and advocacy around public services' accountability in South Africa. Access to clean water as a public service is a key focus of the A4A community members. As a valuable partner, PSAM has been key in reaching different communities with their established relationships with diverse communities in Makhanda. Community members from the A4A group were invited to participate in focus group discussions.

Three FGDs, involving an average of 8 community members, were held. Discussions were conducted in both English and isiXhosa to enable open engagement and to allow communities to freely express themselves. FGDs were facilitated by five researchers from transdisciplinary fields in the natural and social sciences, guided by a semi-structured interview guide (Supplementary Document S1).

Throughout the FGDs, we used note-taking as a selective endeavour of interpretation, highlighting what parts of the engagements emerged as more prominent [22,23]. Through purposive sampling and working with a key community partner, we were thus able to engage participants with interest, knowledge, and experience of using communal water sources and of the water challenges in Makhanda [24]. Voice recordings of each of the focus group discussions were also taken. Excerpts of these voice recording transcripts are presented in the results section. Since English was not the first language of most of the community participants, the text of the transcripts has been edited only where necessary to enhance clarity (denoted by square brackets where applicable).

2.3. Onsite Visits and Observations

In the initial phase of this study, prior to the FGDs, we conducted contextual profiling of community water practices to inform piloted water testing based on a few samples. The researchers thus had prior interactions with communities about their water concerns and needs for water testing. As such, the initial profiling phase came to inform the FGD.

The three onsite visits, each covering multiple sites around Makhanda, provided an opportunity to evaluate the everyday lived practices and experiences of communities, focusing on identifying how these practices and experiences emerge and are sustained [25]. Community profiling helped in determining where and when to conduct water tests. The approach also provided a means of identifying practices that might be unreported within the FGDs or by other methods that rely on participants' recollections from memory [21].

2.4. Microbiological Water Testing

The RUBIC water testing facility is the innovation that this paper draws from. The community-engaged water testing facility (CEWTF) was officially launched in March 2023 as a community service as part of efforts to address the longstanding challenges of water quality and access in Makhanda.

The CEWTF, still operating as of this report, conducts standard microbiological water tests for the presence of: (i) *Escherichia coli* (*E. coli*) bacteria, as an indicator of faecal contamination; and (ii) total coliform bacterial counts, as an indicator of the site's water treatment and distribution systems' integrity [26], in addition to other chemical tests. Water samples are collected from different water sources in Makhanda and taken to the laboratory for testing.

2.5. Ethical Procedures

This research project obtained ethical approval from the Rhodes University Human Research Ethics Committee (RU-HREC), approval number 2023-5974-7398. All ethical procedures were adhered to. The researchers explained the research to participants and ensured that communities understood the purpose of the research and that the information they provided would be treated with confidentiality and used solely for the purposes of understanding water quality issues in Makhanda. Moreover, where the materials collected are used for publications such as this, it was communicated that no personal names or details of the participants' identities would be revealed. Written consent forms were provided and signed by all participants prior to commencing any of the research procedures. Participants were also asked for permission to record the FGDs and were informed that none of the audio recordings would be shared.

3. Results

This section presents empirical data from the interactive FGDs held with Makhanda community members to establish their water needs (the local knowledges expressed by communities). The section presents empirical evidence applying the themes of integrating knowledges in community engagement approaches as detailed by Raymond et al. (2010) [17].

First, we discuss the results emerging from the problem identification, i.e., whether communities felt that there was a need for the water testing facility and the nature of those needs. Second, in the identification of existing knowledges, we outline how communities have been assessing water quality and treating it prior to engaging with researchers on the establishment of the CEWTF. Third, the section: engaging different knowledges discusses community solutions to the identified water challenges. Fourth, the section on evaluating different knowledges examines (i) how the researchers assess the reliability and validity of the integrated knowledges and (ii) the application of integrated knowledges and how these informed the adaptation of the CEWTF.

3.1. Problem Identification: Is There a Need for a Water Testing Facility for Communities in Makhanda?

To provide direction and purpose for knowledge integration, the process needs to be focused on a matter of concern shared by both the community and the researchers, as was the case here. We explore how local knowledge is acknowledged within the research paradigm such that it guides the shared understanding of the identified problem(s), thereby empowering communities to address matters of concern.

Even though access to clean water is a basic human right and a recognised constitutional right in South Africa, the research team could not assume the specific water needs of communities, the value of having their water tested, or which sources needed testing. It was therefore important for the research to establish the water-related challenges and needs of the community and to explore what considerations the CEWTF needs to be informed by in order to ensure that the service is effective in meeting the needs of the community.

The findings confirmed an urgent need for a community water testing facility. Needs expressed frequently included addressing the lack of transparency around which water sources are safe for the different household uses they are put to and health concerns revealed by community members who believed that the water that they consumed resulted in them becoming ill. Especially, many community members elucidated health concerns emanating from the current water used, which they believed caused waterborne illnesses. This highlighted the value of access to a water testing facility as a platform to enable communities to make more informed decisions on water practices based on the results of tests. Some of these expressed health concerns were as follows:

> *It can benefit [us]. We wouldn't have clinics full of sick children, and people [having] emergencies, and not overworking [the] nurses.* (Focus Group 2)

> *Because at the end of the day, people in the community are getting sick.* (Focus Group 3)

> *Drinking at the house, my stomach gives me problem[s] and I have to run to the toilet.* (Focus Group 3)

> *You can tell when you drink tap water; you get a runn[y]... tummy, seriously! You don't just drink from the tap.* (Focus Group 2)

A special concern was further expressed by communities regarding health concerns for children and the elderly:

> *You will hear that a lot of children hav[e]... stomach aches; they [get] diarrhoea because of this water.* (Focus Group 3)

> *I mean, there are old people that are supposed to have clean, purified, drinkable water for their [hydration needs]. They can't buy all of that water-it's expensive. We need to give respect to the elderly. We can at least give them honesty..* (Focus Group 3)

Communities expressed that the CEWTF was needed to ensure transparency regarding water quality. It is important for the community to know exactly what is currently in the water supplied to them to enable them to adopt safer water practices for their health and well-being. For example, being more informed on the status of the water would help some communities determine the causes of health-related concerns linked to poor water quality, such as diarrhoea in children and skin problems, as participants articulated:

> *In the situation where small children get diarrhoea ... at the clinic they can assume x, y, z but if samples are tested to identify the real cause (like what's the water condition), that would help.* (Focus Group 2)

> *I think one example is: since I'm having a skin problem, I would go, say, to the clinic and they give me [medication]. Maybe you don't know the actual cause, but when we know that it's the water [that is the cause], then we will know what we are treating.* (Focus Group 2)

While communities expressed knowing that the water available in Makhanda is not safe for drinking from their self-evaluation of the water quality (e.g., taste and sight), they saw value in scientific evidence supporting this by specifically identifying what is wrong with the water and-based on that-how best to treat it. As some participants expressed:

> *We would like to know, for example, what [...] it mean[s] when [the water is] brown, when it smells, when it has those snail-like things [...].* (Focus Group 1)

> *People want to be at peace because the water issue[s] causes a lot of worry.* (Focus Group 3)

> *Whether it is clean or not, [the] taste [of the tap water] is not right. The taste matters [as] to the opinion of the water. The taste contributes a lot to influencing [us to decide] whether it's safe or not.* (Focus Group 2)

> *We use buckets [to collect and store municipal water]. You will go to the tap when the water is coming but eventually, after a day, [...] you will find out that it's brown; it stinks. [You then know that] there's something wrong with [the water] without [it] being tested by the scientific test.* (Focus Group 3)

As the above indicates, the use of senses such as taste, sight, and smell has been used as an indicative measure of the consideration of water safety by the community. The scientific knowledge to be obtained from laboratory-based testing was viewed by the community as supporting and furthering their knowledge of water. Financial constraints limited access to what is considered clean water in the community, i.e., bottled water and spring water from a natural spring located outside Makhanda. Therefore, the knowledge of water quality would assist the community to gain an understanding of what water is safe for different purposes and how to treat it, e.g., for drinking usage, considering that not everyone can buy bottled water or can access the spring, as was expressed:

> *It would be very useful to the community, especially for the elderly and especially for those who can't afford to buy pure water, so it would benefit them. So basically, [scientific] knowledge of the water they use would be important to the community.* (Focus Group 1)

> *Now that in most instances, water isn't drinkable [. . .], I think the tests every now and then would actually help us to know if it's now safe to drink. Because not everyone can afford to buy water every now and then, [because] each household is different.* (Focus Group 2)

> *The spring is too far, so some don't have access to it and [. . .] it's always packed there, because people prefer that water. It's very far, so you would have to have transport* (Focus Group 1)

Further, managing rainwater storage becomes a challenge for those members of the community who cannot afford rainwater tanks and who, therefore, rely on limited storage containers such as buckets.

Overall, the community voices point to the need for the CEWTF to be contextually aligned, noting the already existing knowledges that communities possess of assessing their water and ensuring that the innovation supports these. Moreover, the research team learned to be cognizant of the socioeconomic differences in communities that affected the water they were able to access and how they could store it. These findings illustrate the valuable opportunity of the CEWTF to facilitate a shared understanding of water quality in Makhanda, combining scientific results with communities' own assessments of water quality. Herein, participants appreciated the value of science and innovation to support their existing understanding and everyday experiences of water quality and access.

3.2. Identifying Existing Knowledges: How Have Communities Been Assessing Water Quality and Treating Water Outside of the WTF?

The focus group discussions were aimed at engaging communities in the design of a CEWTF with the ability to provide communities with a comprehensive assessment of water quality that is relevant to their needs. What emerged during the discussions was the ways in which communities have-and continue to-evaluate the water quality themselves. Bodily senses of sight, smell, touch, and taste characterised the communities' assessment of water prior to use.

Through the discussions, community members expressed how they used their senses of sight and smell as the first steps in assessing the quality of water from their municipal taps or rainwater tanks. In addition to noting that the water smells bad, communities noted how the water coming out of their taps was often brown, which they interpreted as an indicator of poor water quality. Participants noted that the tap water could also be green or white in colour. Furthermore, poor-quality water was also described as cloudy and having particles suspended in it, further emphasising the importance of other visual cues beyond just colour for communities' initial assessment of the water.

> *. . .the water is brown* (Focus Group 3)

> *. . .sometimes the water is brown* (Focus Group 2)

> *it smells. . .* (Focus Group 3)

> *Sometimes the water has these greenish things, like flowers, or it can be white [. . . and] acidic.* (Focus Group 2)

Community members also noted that the colour of the tap water was variable and dependent on the cycle of 'water on' and 'water off' days during the water shedding rota. Respondents noted that when water supply resumed after a cut in distribution, it often changed colour. Longer disruptions in water delivery were correlated with an increased frequency of muddy and dirty water being supplied, resulting in communities avoiding using tap water for a few hours after supply was resumed.

> *When the water goes and comes back, it has [a] change of colour.* (Focus Group 2)

> *Sometimes, the water is on and [sometimes it is] off. So it depends on when it came [back on], [whether] it's brown or if it's clean. The tap water changes quite a lot: it's dirtier when we have no water for like four days, then [when] it comes [. . .] it's muddy. Sometimes, you have to wait at least 2 h to clear off the brown and residues.* (Focus Group 1)

Even though the look and smell of the water were important in initial assessments of water quality, community members spoke about how taste was a key determining factor in their assessment of water for drinking. As such, there were certain norms about how the water should taste depending on the supply, which also came to include the water delivered in municipal trucks to the communities. This water was considered salty and, therefore, of poor quality. This is illustrative of how taste emerges as the key sense; while initial water assessments are made based on the look and smell of the water, communities indicate that they ultimately decide whether to use water for drinking based on taste.

> *. . ..It's taste, the acidity, when the water comes back, the cloudiness* (Focus Group 3)

> *the water must be drinkable: even if it looks clean, the taste must be right. The taste contributes [. . ..] a lot, [. . .] [influencing] [. . .] people to say whether water is safe or not. Even if we don't know [the quality of the water], the drinkability of water contributes [to this assessment of safety].* (Focus Group 2)

> *Truck water is salty and it's not reliable, because [access to] it depends on knowing someone from the municipality. . .* (Focus Group 1)

Community members used their sense of taste to assess water quality and compare the water sources in Makhanda to water from other sources and places. Water provided by the non-governmental organisation (NGO), Gift of the Givers, and that from municipal water delivery trucks were noted to taste different; the NGO-operated water supply was considered to be of better quality and thought to differ from the municipal water obtained from taps in Makhanda.

> *I also assume that the Gift of Givers truck water is okay: that water has a different taste from the one we drink from the tap.* (Focus Group 2)

> *If you go to a different town outside Makhanda and drink the water there and then drink water here, it doesn't taste the same* (Focus Group 2)

3.3. Engaging Different Knowledges: Community Solutions to Addressing Identified Water Challenges

Not limited to assessing the water quality, the knowledge expressed by the communities in the focus group discussions extended to solutions to address the identified challenges in water quality and access. Specifically, communities were operationalising knowledge to treat the water in various ways. One such treatment was the use of chemicals, such as bleach.

> *We are trying now to improvise [methods] to clean the water by putting a bit of bleach, because our white things have to be washed and it doesn't look clean anymore with this water they are giving us.* (Focus Group 3)

Along with the use of bleach, boiling was perceived as central to the community's treatment practices.

If I don't have money to buy water, I boil my water for drinking and then I keep the [boiled] water, because when you boil water all the insects die. (Focus Group 3)

While both chlorine/bleach and boiling were recurring treatment solutions, many community members expressed how they used patience and time as a treatment solution. This was conducted by letting brown and discoloured tap water (when water supplies resumed) run out of the tap until it cleared.

We just wait until the dirt settles, until it clears up. (Focus Group 1)

We wait at least three hours, for the water to settle and then fetch/collect the water. (Focus Group 1)

[If] [t]he water is dirty, the dirt just goes down. (Focus Group 3)

However, a number of challenges with household treatment solutions were identified by the community members. The first was whether waiting for the sediment in the obtained water to settle was merely intermittently effective, as it sometimes did not address the look of the water.

Sometimes the water does clear itself up, sometimes it doesn't. (Focus Group 1)

A similar challenge was also expressed around treatment through the boiling of water. Sometimes, this common solution available to the communities was not enough to effectively treat the poor-quality tap water, especially after a long period of water shedding.

. . .it depends on when the water comes back, because you can't even boil the water when it's brown. It makes no difference. Unless you wait for, like, 2–3 h after the water is on. It also depends on how long the water has been gone for/has been off for. The longer it's been off, the [dirtier it is when] it comes back [. . .]. (Focus Group 1)

As such, treatment could necessitate the combination of multiple solutions of both waiting to let sediments settle, followed by boiling the cleared-up tap water. As a related challenge, communities noted that treatment solutions cost both money and time by having to boil water through the use of gas or electric cookers/stoves or letting the tap water run first for a significant time to remove some of the accumulated sediment. In addition to wasting money and time, treatment solutions were also seen by communities to waste water itself.

Now we are wasting water, because the taps must run first then we can see there's something happening, clearing up, so it's doubling our bill. (Focus Group 3)

The thing is: people don't have resources to treat water because it's expensive, because like myself I put it on my gas [stove]. It's expensive, because I have to wait until that water is boiled. So people don't have time and money to treat water. (Focus Group 3)

While having these water treatment solutions available, the communities acknowledged how they had limitations, especially in cases when the water quality was too dirty, brown and/or had an unpleasant smell. Treatment thus circled back to water quality assessment through the senses of sight and smell.

[comparing tap water to] other [sources of] water: we can't treat it. Even the boiling system, like when it's dirty and brown and we boil it. . . the truth is, it doesn't [make] much difference, that's why most people stopped drinking tap water. (Focus Group 2)

Even that boiling of the water doesn't really do anything. (Focus Group 3)

Even if you treat it, sometimes it still smells. One day we were in a lounge, suddenly I smelled the water in the tap; that water doesn't smell good. (Focus Group 3)

In addition to knowing that the water is unsafe and applying treatment options, community members expressed in the quotes above their awareness that their treatment practices are insufficient to address the challenge they are facing. This demonstrates an evaluation of existing knowledge and knowledge-informed practices: communities critiqued their own practices as inadequate to address the lack of clean and clear water. Hence, the community participants expressed that there was value in integrating the communities' expressed knowledges with scientific knowledges to address these challenges.

3.4. Evaluating Different Knowledges

The evaluation in this study was two-fold: the evaluation of the different knowledges to understand the contextual challenges of water access and quality, and the evaluation of the integration of knowledges to create contextually relevant practices.

A key aspect of CE is that researchers integrate contributions from those affected by the research and other matters of concern on an egalitarian basis [1]. In this study, the researchers themselves were affected by the matter of concern around water in Makhanda and worked with the community to explore and co-create understandings of water with the aim of integrating knowledges as a catalyst for transformative practices. For example, water trucks and stored water facilities (such as rainwater tanks) were identified through the evaluation as key sites of testing, as they are commonly used water sources in the community. Further, the evaluation filtered community-identified hotspots, such as clinics and schools, for targeted water testing.

On the other hand, evaluating the integration of knowledges regarding who is to be engaged and who is responsible for addressing the water crisis, such as how to get the municipality engaged in the CEWTF, was more complex, demanding more time and practical considerations even though these questions were central to ensuring change. While there was convergence in the community and the scientific knowledge around poor water quality in Makhanda, community knowledge was more centred on the solutions, such as knowing who should do more to alleviate the situation. This included how collaborative solutions could be developed to meet identified needs, with communities identifying the municipality as being at the centre of addressing water access and quality issues in Makhanda. As such, the evaluation highlights a more complex terrain of knowledge integration.

3.5. Applying Integrated Knowledges during the Project: Adapting the Water Testing Facility

The community voices pertaining to water-related needs and priorities for a CEWTF presented numerous critical contributions on how the water testing facility would be structured and operated to ensure that it remains community-informed. The community expressed how the water testing should be conducted, including the timing of the testing. Here, the "what, how, when, where, and how" of the community voices on conducting testing and/or collecting water samples for testing are presented according to these key themes: ensuring transparency of the water treatment process; desired frequency of testing; desired timing of testing; whether targeted/priority testing drives were preferred; the effects of leakages and sewage contamination on water quality; as well as whether water testing would be supporting community empowerment through the water testing community engagement processes and potentially lead to more sustainable approaches regarding water use.

Several participants felt that, for the CEWTF to be valuable, it had to facilitate transparency between the municipality and the community on what processes are followed to treat water in Makhanda.

> *Firstly, we have to go to the municipality water treatment site, to see how things are there. Someone must explain to us what's happening, then we want to see the health hazards with our own eyes and then see the red flags, then the testing is supposed to [occur] there. When we see there's no problem [at the treatment site], then we test [outward] from there, then it will be easier [and] then there's no need for lots of testing.* (Focus Group 3)

> *Even the chemicals, I think some of the issues are because they put too many chemicals [in the water]. I think they overuse chemicals which make[s] the water look so white.* (Focus Group 2)

The findings alluded to the importance of the community coming to know the current status of the quality of supplied water, and this is intrinsically linked to understanding the root causes of poor water quality. This includes water that is not-well treated before supply or the effects of leakages and other forms of contamination during the supply of water. In essence, resolving the water quality challenge would require open engagement between the community and the municipality on the current water treatment processes; current municipal practices were noted to have produced distrust and concern on the part of the community.

> *Because they are doing these things behind our backs, killing us, behind our backs* (Focus Group 3)

> *[. . .] because sometimes they [the municipality] do things that hurt the community. Because at the end of the day, people in the community are getting sick. You will hear that a lot of children got stomach-ache[s], they got diarrhoea because of this water.* (Focus Group 3)

> *[I know truck-supplied water is alright to drink. . .] because [it] [. . .] comes [from] a truck that's coming from outside, not from the municipality.* (Focus Group 2)

> *Can [we] be [. . .] sure that the chemical they [the municipality] use [to treat the] water. . . [is it the] original or what, is it the cheapest one? Because we have issues of corruption as well.* (Focus Group 2)

Community members further highlighted the frequency and timing of water testing as important considerations for creating an effective CEWTF. Some of this was directly linked to the fact that water shedding also affected the perceptible quality of the water when supply resumed, as was discussed above.

> *So the testing should consider the different timing*-e.g., *because of the state of the water when it has just come [back on], versus a few days later. So, a range of different tests [are needed].* (Focus Group 1)

> *I think weekly testing, because of the [water supply shedding] schedule.* (Focus Group 1)

> *I think when the water comes back [on], it would be best. Because, you [can] get [a sample] if it's dirty, if it has those bacteria* etc. *That's when we will get the proper answers immediately: when the water comes back.* (Focus Group 1)

On the other hand, the need for regular water testing was also highlighted. This was suggested so that emerging problems are identified and that testing considers the shifts in water quality over time. Participants expressed:

> *Water testing must be done regularly because it's very important [. . .] that they can see where the problem is and fix it.* (Focus Group 3)

> *Perhaps quarterly water testing, because things change.* (Focus Group 3)

> *We also need to test when there is something happening to change the water.* (Focus Group 3)

Communities additionally alluded to the importance of targeted testing drives beyond the municipal supply, such as testing the water trucks that distributed water across Makhanda during "water off" days, as it was not clear where the water delivered by these trucks originated from. The need to prioritise important community structures, such as conducting tests at clinics and schools, to safeguard communities' health and safety was also mentioned.

> *Also: testing the [water, delivered by water tankers/trucks] would be valuable, because it tastes salty.* (Focus Group 1)

> *We do have clinics; some have JoJo tanks [Author notes: i.e., large-volume rainwater storage tanks]; some don't [. . .]. That [water source] also depends on when the rain comes. It would be valuable to test that water because the tanks can also be dirty inside due to the gutters and the roofing.* (Focus Group 1)

> *. . .and testing at the schools. Because most of the schools have no [water storage] tanks, so we are concerned mostly about school children. Some children react e.g., they get rashes, cholera, diarrhoea*, etc. (Focus Group 1)

Moreover, the effects of broken pipes, leakages, and sewage contamination were highlighted as known factors affecting water quality. Some participants expressed these concerns:

> *Sometimes, it's like the water is affected by the pipes that have not been maintained for a long time, so the pipes dry out. The minute you open the tap you get the effect, sometimes we see things like algae in the water. Those are the things I think we need to look into when we test the water.* (Focus Group 2)

> *We need to also think about those [municipal water supply] pipes, because they're always bursting and they're collecting, you know. . . The leaking pipes are almost everywhere; even if you report these, they're not attended to.* (Focus Group 3)

Moreover, while community members appreciate the value of the CEWTF, an important contribution pointing to the need for the CEWTF to facilitate community empowerment and avoid creating community dependencies was also noted:

> *It won't benefit to [just] have a service, but it will benefit from having the service with us and not [having] us going to the service. If someone is to fetch water, walk a distance to go and test and find that the water is not right, perhaps that it's not clean. So, if the testing facility is with the person [i.e., community member], they can test by themselves in their homes and know what is wrong with the water and how to clean it.* (Focus Group 2)

4. Discussion

The research reported in this study established a consensus around problem identification as it pertains to water quality. This supported the notion of establishing and operating the CEWTF. We identified existing knowledges of water quality concerns, especially in the community, and identified how water quality and water access were interlinked. It was also clear that communities used their experiential knowledges to assess water quality and consequently treat the water.

4.1. Engaging Different Knowledges

In engaging different knowledges, this study initially focused on water quality; however, throughout the engagement with communities, water quality emerged as being intrinsically linked to water access, or lack thereof. The findings from the needs assessments highlighted that the lack of municipal water during water shedding determined water quality once it was resupplied to people's homes. It was clear that water quality cannot be separated from access. Information from this aspect of the FGDs was incorporated into the testing protocols adopted by the CEWTF researchers; this aspect of the work is discussed in greater detail in Section 4.3.

Throughout this study, community participants expressed a desire to establish processes that would consistently provide potable water. The "what", i.e., the tested water quality parameters informing them about the quality of their accessed water, provided a platform for the "why", i.e., how specific results from water testing could inform current water treatment practices and provide future solutions to improve their livelihoods and wellbeing. This points to similar incentives shared between researchers and communities in that testing the water quality serves as a platform for research and as a means of directing future technology development in a participatory manner.

These findings underscore the impact of engagement from the onset of a project and that a co-design process, as a critical tenet of effective CE [3,5,27], is made more likely through early engagement. As Dyer et al. [28] contend, the likelihood of a sense of ownership and community empowerment appears to increase when participants have a good understanding of project aims and when local knowledge is incorporated into the project process [4,5,28] (p. 143). Engagement between researchers (scientific knowledges) and communities (local knowledges) was shown to have a valuable role to play in building agency for sustainable development. Bergstrom et al. [29] state that "engagement brings meaning and relevance to sustainability goals across a broad spectrum of players, and it encourages local innovations in sustainable development through creative problem solving". As such, the CEWTF study was found to be a valuable space for communities to engage on their water concerns; the engagement was characterised by co-creation between the communities and the researchers on the project.

4.2. Evaluating Different Knowledges: A Community-Centric Solutions Approach to Addressing Water Challenges

In evaluating the different knowledges, the results illustrated the multiplicity of meanings within the communities and within the research team. Communities' sense of agency around water quality was evident in their extensive evaluation of the water quality and the selection of water treatment strategies. Beyond knowing the quality and safety of the water tested, communities indicated additional value in participating to co-create practical solutions with the researchers to improve water quality, for example: "*We know that the water is not safe*, *but what should we do about it*?" (Researcher notes from community site visits).

4.3. Application of Integrated Knowledges to Address Water Challenges: The Intrinsic Relationship between Water Quality and Access

The scientific knowledge and understanding of the water quality were informed by measurements of the microbial content in samples of the water [18,19]. The community and scientific knowledges both highlighted the intrinsic link between water quality and access, espousing the need for more sustained solutions, i.e., that tackling deeper contamination and water access issues is essential to addressing the quality challenges in the long run. This came to inform our research approach and shape the adaptation of the CEWTF. This illustrates the value of flexibility driven by open-ended and emergent co-learning in CE [30,31]. For example, communities expressed that the quality of their water depended strongly on when and from where they collected it; this informed the water sampling practices to be adopted, i.e., when the samples were taken (time), where they were taken (place), and to monitor what was happening around the sampling site (space). As such, the contributions from communities became a catalyst for transforming future sampling practices [12]. As a result, sampling of water for testing was to be conducted at specific times during the "water-on" days, i.e., collecting samples just after water was supplied.

Gaining a broader understanding of emerging water sources and community concerns around these issues as a result of the knowledge integration identified the need for the CEWTF to include monitoring of water delivery tankers/trucks as well as stored water, which are commonly used drinking water sources in Makhanda.

Linking water quality to access thus transformed not only the sampling practices but also informed researchers how the water challenges were understood by the participating community-affecting further engagements aimed at addressing the water challenges and how the sustainability of the CEWTF could be imagined. The study made sense of and integrated the knowledges the communities provided during the engagements, shaping subsequent scientific practices [17].

4.4. Applying Integrated Knowledges to Improve Practice: Collaborating with the Municipality in the CEWTF

As this study moved from identifying and engaging with local knowledge to integrating it with scientific knowledge in order to adapt the CEWTF, questions emerged regarding the eventual application of the integrated knowledge [17]. Crucially, this highlighted how larger, interconnected challenges and the roles of other stakeholders came into view when the researchers' attention to water extended beyond the immediate water samples and water quality results. What long-term and sustainable difference could be achieved in the lives of the communities through developing assessment solutions when the water coming out of the tap remained of poor quality? For example, in the findings above, communities emphasised how the quality of the water they had available could not be separated from the state of the water treatment plants, wastewater treatment plants, and water distribution systems that experience leaks and burst pipes.

Integrating the current community assessments of their water with the scientific water tests is key to developing and applying community-engaged approaches to the water challenges in Makhanda. This calls for prioritising the agency and ownership of communities throughout R&I initiatives like the CEWTF as a critical characteristic of science engagement. To this end, we reframed the validity and reliability of knowledge integration as internal validity in relation to the community's experiential knowledges and practices. Scientific knowledge thus needed to be accurate to and consistent with (having internal validity) the contextual experiences and practices of communities in order to create value for said communities. Future research and practice needs to improve on the application of integrated knowledges after the project, how we ensure that the WTF becomes more sustainable in addressing community challenges, and how we conduct evaluation outcomes in the medium to long term.

To this end, with the challenges and responsibilities of water quality and access reaching beyond the control of communities and researchers, the importance of key stakeholder engagement in the CEWTF came to focus on the role of the municipality. A recurring theme throughout the engagements was that the ability of communities to take responsibility and develop solutions around the challenges of water quality and access was often limited to assessing and treating what was provided through municipal service delivery-whether by the municipal water distribution system or water delivery trucks. The need to work together with the municipality to evaluate the supplied water quality emerged early from community voices and remained a crucial component and value that we attempted to address in future engagements in order to create comprehensive and sustainable solutions to the water challenges. Community concerns centred on how we would facilitate deeper engagements with the municipality to improve water access and quality, for example, to address the contaminants entering the water distribution system.

4.5. Implications of This Study

This study provides further evidence for the valuable role of communities in shaping the direction of scientific research and innovation, in support of the precepts outlined in the EU's RRI and South Africa's science engagement framework. Being a transdisciplinary group enhanced the knowledge integration process by fostering the integration of our transdisciplinary knowledges to resolve the deeper issues that the community values. We found that an effective CE process required an interpretivist approach that values the multiple perspectives within the community [32] as well as the participants' expressions of their everyday realities, supporting multiple perspectives within the research process.

The strong and sustained interest by the community participants in evaluating and treating their own supplied water indicated the inherent agency being exercised by community members to access safe water. This provided a basis for the CEWTF to further empower and support the community through scientific results/data gathering.

The engagement highlighted that the water testing results and the agency that it enabled around water safety would need to extend beyond the scientific results for true impact to be realised.

Communities looked to the longer-term security of safe water supplies, noting that quality and access to water were inextricably linked. Additional stakeholders (especially the local municipality in charge of water treatment) would need to be involved to facilitate this. Additionally, the need for training around scientific data and measurement was identified by the researchers as an avenue for further engagement.

Overall, the initial engagement through the focus group discussions, as well as site visits to community sources, opened avenues for more sustained and longer-term engagements between the scientists and communities, and the potential that this holds to explore research questions around impact for communities, in particular around sustainable water practices.

4.6. Limitations of This Study

A possible lack of representativeness of this study's findings and outcomes is a limitation of the work presented above. The small sample size of the community participants (24) in the focus group discussions is coupled with the fact that this study draws on one specific community group: community members of the PSAMs Makhanda Action for Accountability Civic Action Team. This community group is concerned with the accountability of public services, linked to municipal service delivery shortfalls experienced in the region.

The responses that were obtained through the site visits and the focus group discussions may not be broadly representative of the attitudes of the wider community in Makhanda. This is not considered to have a significant impact on the results reported above since this study was focused on developing an understanding of the efficacy of using a community engagement approach to address a practical, shared problem of water access and quality in Makhanda. Thus, the research presented in this article does not seek to generalise these findings to the broader population of Makhanda and is, therefore, not claiming representativeness.

There are challenges around access to a systematic evaluation process to evaluate knowledge integration and community engagement. A further limitation pertains to the application of integrated knowledges after project completion, which Raymond et al. (2010) [17] advocate for. The current paper sees the opportunity of studying the application of this knowledge further as another phase of engagement, which is critical to the sustainability of CE projects. There is a further need to be flexible in response to changing circumstances and emerging knowledges. The integration of knowledges is a cyclic and ongoing process; thus, we need to continuously engage with integrating knowledges to address the identified challenges. The CEWTF process is ongoing, and we will continue to reflect on these issues. These limitations in addressing the sustainability of CE initiatives present opportunities for future research and practice and will be explored in a future publication.

5. Conclusions

This study was based on the premise that scientists need to integrate the knowledges and contributions of communities at the start of the research and innovation process, echoing national and international frameworks that call for greater involvement of communities in scientific research and innovation processes. To this end, we aimed to explore community voices to develop a deeper understanding of water challenges faced in Makhanda communities and how to engage communities in the process of establishing a water testing service (as an innovation) to support communities' need for information on water quality. Acknowledging local knowledges and integrating it with scientific knowledge, we attempted to collaboratively co-create knowledge about water concerns and build capacity in the community. This paper also contributes valuable insights into newer approaches for scientists and communities to engage at the earliest stages of a research and innovation process and how the community's voices and insights shape the direction of scientific processes and innovation. Within the field of RRI, this paper also provides a case study showcasing RRI in practice, but also of scientists engaging with and being responsive to community concerns.

From our findings and the subsequent discussion, we note several lessons regarding opportunities and obstacles for collaborative CE aimed at integrating knowledges. Local knowledges dealing with optimal times and places for collecting water samples for accurate testing was identified for integration with the scientific knowledge dealing with the logistics of water testing, providing direction for the application of scientific knowledge rather than introducing new considerations and contradictions. Meanwhile, local knowledges, which extended to deeper considerations around why the water sources required testing and who was ultimately responsible for developing solutions, was more difficult to integrate. These local knowledges challenged some of the initial assumptions of this study, including expanding the purpose of the water testing to the investigation of treatment solutions; raising questions about how the communities could conduct their own water tests; and calling for engaging the municipality around the poor service delivery of water. As such, this study shows the need for further research on how to engage with these deeper knowledge questions about the why, how, and who of water testing.

While designed around collaborative engagements and focused on co-design and co-creation with communities, the operationalisation of the CEWTF brings key lessons for further research and practice: (1) broadening the engagement to include critical stakeholders, such as the municipality; and (2) deepening and sustaining engagement to build capacity in the community around community-centric treatment solutions.

In conclusion, this paper demonstrates the role of communities in shaping scientific research and innovation, providing an important case study for exploring the RRI framework and demonstrating a core outcome. Lessons for advancing CE research and practice focused on how co-created knowledge and meaning are subsequently applied, especially in working with communities to resolve the water challenges in a region where the municipality plays a leading role. Through continuous engagement—both in breadth and depth—future research could explore community empowerment; bridge the gap between communities and municipalities; and permit studies on the longer-term impacts that RRI approaches hold for communities.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16010459/s1, Document S1: Semi-structured interview guide applied in focus group discussions.

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