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BTO *Managementsamenvatting*

Uitgebreidere betrokkenheid van drinkwaterklanten in citizen science is vooralsnog niet nodig

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Bij citizenscienceprojecten in de Nederlandse (drink)watersector zijn klanten tot nu toe vooral betrokken bij de dataverzameling en niet in andere fases van het onderzoek. Met deze vorm van citizen science (contributory) wordt in de Nederlandse watersector sinds enkele jaren succesvol geëxperimenteerd. Deze aanpak voldoet voor de meeste klanten prima, blijkt uit een studie waarin de wenselijkheid, haalbaarheid en kansen zijn verkend voor citizen science 2.0 (ook *collaborative* of *co-created* citizen science genoemd), waarbij burgers ook betrokken worden bij definiëren van onderzoeksvragen, het samenstellen van de meetkits en/of het analyseren van data. Er is dus vooralsnog geen aanleiding om nieuwe citizenscienceprojecten in de drinkwatersector in te richten op een uitgebreidere betrokkenheid van klanten. Om de huidige aanpak van citizenscienceprojecten te versterken, is op basis van een analyse van klantvragen, enquêtes en de ervaringen van oud-citizensciencedeelnemers een toolkit samengesteld met instrumenten die aansluiten bij de meest prangende vragen en interesses van drinkwaterklanten.

Deelnemer aan een citizenscienceproject in actie

Belang: inzicht in wenselijkheid, haalbaarheid en kansen citizen science 2.0 bij drinkwaterbedrijven
Burgerschap verander, kennis democratiseert en wordt breder beschikbaar en technologische ontwikkelingen gaan snel. Met dat in gedachten zoeken steeds meer bedrijven en overheden verbinding met de burger door deze te betrekken bij het vergaren, co-creëren en delen van kennis.

Binnen het BTO is in 2015 voor het eerst een verkennend onderzoek gedaan naar de mogelijkheden en waarde van zulke citizen science in de Nederlandse drinkwatersector. Een jaar later heeft deze theoretische verkenning geleid tot de eerste citizensciencepraktijkproef in de Nederlandse drinkwatersector: de Versheid van Water. In dit project heeft KWR samen met Waternet en 50 Amsterdammers de bacteriesamenstelling van kraanwater onderzocht. Mede op basis van deze positieve ervaring zijn in 2017 en 2018 meerdere nieuwe citizenscienceprojecten gestart in het drinkwaterdomein, waarin kennis wordt ontwikkeld over onder meer verschillende manieren van uitnodigen, het effect van doorlooptijd, verschillende methoden en verschillende onderzoeksdomeinen. Al deze projecten zijn zogenaamde *contributory* citizenscienceprojecten, waarbij burgers enkel betrokken worden bij het verzamelen van data. Er is nog geen enkele ervaring met bijvoorbeeld *collaborative* of *co-created* citizen science, waarbij burgers ook betrokken worden bij het definiëren van onderzoeksvragen, het samenstellen van de meetkits en/of het analyseren van data. In dit VO kraamkamerproject is onderzoek gedaan naar de wenselijkheid, haalbaarheid en kansen voor het nemen van een volgende stap op het gebied van citizen science, waarbij burgers in meer fases betrokken zijn dan enkel het verzamelen van data: citizen science 2.0.

Aanpak: literatuurstudie, meta-analyse en klantenonderzoek

Gestart is met een literatuuronderzoek. Vervolgens zijn de evaluaties, enquêtes en focusgroepen van vijf eerdere citizenscienceprojecten geanalyseerd in een meta-analyse. Tot slot zijn de beleving en klachten van drinkwaterklanten geanalyseerd door te kijken naar klachtenregisters van drinkwaterbedrijven en door twee aanverwante BTO-klantenquêtes te analyseren vanuit een citizen science 2.0-perspectief.

Resultaten: beperkte vraag naar citizen science 2.0, wel voor meer duiding van de resultaten

Uit het onderzoek blijkt dat de behoefte aan citizen science 2.0-projecten gering is, zelfs onder de deelnemers van voorgaande citizenscienceprojecten. En hoewel er aantrekkelijke voordelen zijn aan een grotere betrokkenheid van burgers, bijvoorbeeld het vergroten van de maatschappelijke relevantie van wetenschap, blijven die vaak vooral theoretisch van aard. In de wetenschappelijke literatuur uit het waterdomein zijn er weinig tot geen empirische voorbeelden te vinden van citizen-science-2.0-projecten waarin deze voordelen worden gestaafd. Daar komt bij dat citizen-science-2.0-projecten extra inspanning vragen rondom betrouwbaarheid. Uit de analyse komt wel duidelijk naar voren dat citizensciencedeelnemers behoefte hebben aan meer duiding in de terugkoppeling van de resultaten, maar dit kan ook worden opgepakt binnen de huidige *contributory* citizenscience-aanpak. Op basis van de vragen en wensen van drinkwaterklanten is een theoretische citizen science toolkit gedestilleerd, inclusief instrumenten voor het meten van de waterdruk, de hardheid, metalen, en bijvoorbeeld medicijnresten.
Ook deze toolkit is uitstekend binnen de huidige citizenscienceaanpak in te zetten.

Implementatie: betere informatievoorziening en meer aansluiting bij de klant

Hoewel het vanuit een onderzoeksperspectief interessant zou zijn de waarde van citizen science 2.0 ook in de praktijk te toetsen, laat deze studie zien dat er vooralsnog geen aanleiding is om de huidige ingeslagen weg van *contributory* citizenscienceprojecten te verwisselen voor citizen-science-2.0-projecten. Wel laat deze studie zien dat het sowieso relevant is citizensciencedeelnemers nog beter te informeren over de analyse van de resultaten. Tot slot geeft deze studie aan welke onderwerpen sterk leven bij klanten. Het meten van nieuwe stoffen, zware metalen en de waterdruk zijn bijvoorbeeld interessant om mee te nemen in een volgende citizensciencestudie. Door citizenscienceprojecten te realiseren die aansluiten bij de behoefte van klanten, kunnen drinkwaterbedrijven kennis en ervaring opdoen over de juiste manier om om te gaan met zelfmetende klanten, hoe je effectief kunt blijven communiceren en hoe je verbinding kunt blijven maken met verschillende klantengroepen.

Rapport

Dit onderzoek is beschreven in het rapport *Citizen Science 2.0* (BTO 2018.088).

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Contents

1 Citizen Science 2.0

1.1 Introduction

In recent years, public participation in science (aka "citizen science") has gained considerable pace and received widespread support and recognition from policy makers, funding institutions and scientific researchers. The participation of non-scientist in the generation of scientific knowledge has several supposed advantages, for both the general public as for institutions and/or companies initiating and/or supporting citizen science (CS) initiatives. Among others, CS may function as a useful method for collecting large-scale field data, and may facilitate the observation of otherwise difficult to quantify phenomena (Jollymore et al. 2017). Furthermore, public participation in research has the potential to generate more alternative or specific solutions, as well as to produce less contested knowledge (Irwin and Wynne 2003). Other well-known advantages for the use of CS relate to scientific literacy, the enhancement of the public understanding, public awareness for a topic of study, and societal relevance of science (Brouwer et al., 2018).

Scholars have differentiated several types of CS projects which are usually classified based on the level of participation by citizens. Bonney et al. (2009) distinguishes three types of CS:

- In *contributory* CS, participants are merely involved in collecting data
- In *collaborative* CS the participants are also involved in the analysis of the data
- In *co-created* CS participants and scientist work together on all facets of the research process.

Work by Shirk et al. (2012) expanded on the work of Bonney et al. (2009) by distinguishing two additional forms of CS on both ends of the spectrum: *contractual and collegial* CS. In the *contractual* form, the public asks scientist to answer a specific research question, but is not involved in the data collection. In *collegial* CS, on the other hand, the public is entirely in charge of the research project. All types of CS are summarized in Table 1.

TABLE 1 CITIZEN SCIENCE TYPOLOGY BASED ON BONNEY ET AL. (2009) AND SHIRK ET AL. (2012)

Type of project	Contractual	Contributory	Collaborative	Co-created	Collegial
Role of citizens	*Pose research questions to the scientific community*	*Contribute samples or data to a research project*	*Collect data and analyse results together with scientists*	*Work together with scientists to develop and execute a research project*	*Independently set-up and execute a research project*
Choose/define research question	I/P			P	I
Develop hypotheses				P	I
Design methods for data collection			(P)	P	I
Data collection		I/P	P	P	I
Data analysis		(P)	P	P	I
Interpret data & draw conclusions	(P)		(P)	P	I
Dissemination & Implementation	(P)		(P)	P	I
Evaluation	P			P	I

The letter "P" indicates that the public participates in this step of the research process, (P) that the public may participate, whereas the letter "I" indicates that the public executes this step independently.

To date, most citizen science projects can be characterized as *contributory* CS projects, projects in which involved citizens are primarily involved in the data collecting phase (Ramirez-Andreotta et al. 2015). Accordingly, it can be argued that CS has not reached its full potential. Apart from the issue that more citizen could be involved in a greater variety of projects, citizens could potentially be involved in more phases of the research other than merely collecting data, i.e. could be involved in collaborative or co-created CS. Formulating research questions, making a research design, analyzing and interpreting data are all research phases where citizens could get more involved. In addition to enhancing the scientific literacy of the public, involving citizens in other research phases than merely collecting data may increase the understanding of the societal relevance of science. Furthermore, it could be argued that collaborative/co-created CS may equip citizen better to generate more alternative or specific solutions since they are more involved in the analysis and interpretation phases of the research. Forms of collaborative/co-created CS projects can therefore be seen as the next step in the ongoing process of further developing CS to its full potential: Citizen Science 2.0.

1.2 Objective, methods and structure of report

This report is aimed at exploring the value and possibilities for developing and implementing CS 2.0 projects. By making use of: (i) available international scholarly literature; (ii) analyzing data sets from previous CS projects in the domain of drinking and surface water in The Netherlands; and (iii) assessing the wishes, questions and complaints from customers of Dutch drinking water companies, a clearer understanding will be generated into the value and feasibility for CS 2.0 projects.

This report is structured as follows: after this introductory chapter, chapter 2 presents a literature review to discover the extent of CS 2.0 in peer-reviewed literature. This is followed by chapter 3 which focusses on a meta-analyses to compare data from previous CS projects. Chapter 4 seeks to understand what the knowledge needs are of CS participants and regular customers of drinking water companies. This provides insight into which drinking water related issues raise public questions and/or concerns. A better understanding of these questions and/or concerns serves as an indirect indicator for the types of questions that could evolve in future CS 2.0 projects. Based on the findings of this chapter a theoretical “toolkit” is presented at the end of this chapter for drinking water customers to use in future CS projects. The main insights of each section are summarized in boxes that merge together in the conclusion of chapter 5.

2 Literature review

2.1 Introduction

To gain a better understanding of the value and potential of CS 2.0 projects, we conducted a systematic literature review of peer-reviewed studies published between January 2010 and April 2018 that reported about CS 2.0 in the water domain.[1] We used SCOPUS to select articles that combined the search criteria "citizen science" with either "drinking water", "tap water" or "water quality". This generated eighty three results, which were subsequently screened for their relevance. Thirty five of those search results did not involve the use CS directly as means of research, but were rather explanatory to the concept. That left forty eight relevant peer-reviewed articles that were sorted into the various types of CS as depicted in Figure 1. The results showed that only three peer-reviewed articles in the water domain could be classified as CS 2.0.[2] The vast majority of peer-reviewed CS projects to date (45) were of *contributory* nature where participants were merely involved in data collection. The three CS 2.0 peer-reviewed articles were all *collaborative*, i.e. where all about projects in which citizens collect data and analyze results together with professional scientists. There were no peer-reviewed articles that involved *co-created, collegial* or *contractual* CS. All three CS 2.0 peer-reviewed articles were published recently: two in 2017 and one in 2018. This shows that CS 2.0 projects have only recently been incorporated into peer-reviewed literature, suggesting that the implementation of this kind of projects has started only recently, or that CS data generated in this kind of projects is less well represented in peer-reviewed publications.

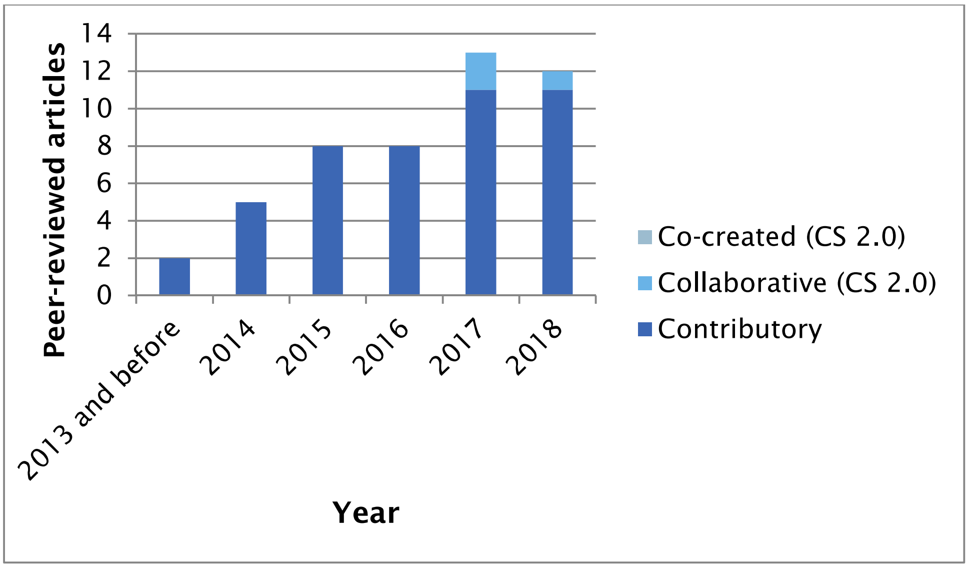

FIGURE 1: PEER REVIEWED CS (2.0) ARTICLES CONCERING DRINKING WATER AND WATER QUALITY

[1] The eight three results from the systematic literature review were generated on the 3rd of May 2018.
[2] In a recent book chapter Robinson et al. (2018) conclude that also in other domains little is published on the practice and impacts of collaborative and co-created citizen science.

2.2 CS 2.0 literature

In this section, the three peer-reviewed articles that could be classified in the previous section as CS 2.0 related to drinking water and water quality will be further elaborated. The intention is to learn from the perspectives and experiences of the three peer-reviewed articles related to CS 2.0. The three peer-reviewed articles will be discussed in the following order:

- Jollymore, A., Haines, M. J., Satterfield, T., & Johnson, M. S. (2017). Citizen science for water quality monitoring: Data implications of citizen perspectives. *Journal of Environmental Management.*
- Peters, C. B., Zhan, Y., Schwartz, M. W., Godoy, L., & Ballard, H. L. (2017). Trusting land to volunteers: How and why land trusts involve volunteers in ecological monitoring. *Biological Conservation.*
- Stepenuck, K. F., & Genskow, K. D. (2018). Characterizing the Breadth and Depth of Volunteer Water Monitoring Programs in the United States. *Environmental Management.*

The article by Jollymore et al. (2017) deals with the effects of human impacts on water quality. In this study they adopted a CS approach where citizens were trained to sample organic matter concentrations in river and streams. Although the authors refer to their approach as *contributory CS,* based on the definition by Bonney et al. (2009) we rather classify the projects as *collaborative* CS as it appears that participants had a fair amount of freedom to sample. For example, participants brought their own knowledge and concerns about their watershed into the data collection. This translated into location-specific research questions, for instance related to the effect of septic tank contamination. The overall research was affected by this development since several context-specific research questions were incorporated into the study. Questions of interest to scientist did not always coincide with that of participants. The fragmentation of research objectives between scientist and participants made it difficult to select a methodology that would satisfy both parties (Jollymore et al. 2017).

The article by Peters et al. (2017) reports about a widespread survey conducted across the United States to learn about Voluntary Based Monitoring (VBM) programmes of land trust organisations. These VBM's collect a wide variety of data, including plant species and vertebrates, as well as soil, air and water quality. Volunteers of VBM's are not only engaged with the data collection, but are also actively involved in the entry (52.6%), analysis (32.3%) and dissemination of results (24.1%) (Peters et al. 2017). It appears that the VBM's conducted by these land trust organisation are of *collaborative* or *co-created* (i.e. CS 2.0) nature since participants are involved in more aspects in the research process other than just collecting data. Unfortunately for the purpose of our study, the article does not reflect specifically on the experiences from these collaborations, which makes it difficult to draw meaningful CS 2.0 insights from it.

Stepenuck and Genskow (2018) conducted a survey in similar nature to Peters et al. (2017). It analysed 345 volunteer water monitoring programs across the United States between 1962 and 2012. Coordinators of those programs were contacted to undergo a survey that would collectively study the range, scope and outcomes of these programs. In all, 296 of the 345 program coordinators responded to the survey enquiry. Coordinators were asked to reflect on six themes: 1) program ages, sizes and geographic scopes; 2) roles of volunteers and professionals; 3) quality assurance and training; 4) perceived level of support; 5) stability of program over time; and 6) presence of monitoring efforts in the same geographic area

(Stepenuck and Genskow 2018). For the purpose of this report, the roles of volunteers and professionals was the most interesting component of this survey. Surprisingly, it appears that the majority of the water monitoring programs were either *collaborative* (53%) or *co-created* (14%) (i.e. CS 2.0). A further 29% were judged to be *contributory* and 2% *collegial* (Stepenuck and Genskow 2018). In view of our systematic search on peer-reviewed literature in which only a handful of articles were found to be CS 2.0, this result is remarkable. The low number of peer-reviewed articles incorporating CS 2.0 could be the result of longstanding peer-review procedures. Another plausible reason could be that CS 2.0 trots outside the realm of traditional science approaches which often raises questions on the credibility of the research. The latter will be further explained in the following paragraph.

Box 1 What does this mean for CS 2.0?

- CS 2.0 in peer-reviewed articles related to drinking water and water quality is limited. However, there are quite a few CS projects that are CS 2.0 worthy, but these have often not been incorporated into peer-reviewed articles up until now.
- A diversity in research objectives in CS 2.0 where participants are involved in the formulation of research questions can make it difficult to select a methodology that will satisfy all.

2.3 Credibility issue

CS in academic research has covered a wide range of topics in the last two decades. CS is often praised for bringing science closer to citizens and for equipping scientist to tackle research questions with larger spatial and/or temporal scales at lower costs (Aceves - Bueno et al. 2017).However, concerns still remain regarding the accuracy and credibility of CS. For example, the fact that scientists are able to gather large amounts of samples through the involvement of non-professionals could lead to reduced data accuracy (Gardiner et al. 2012). Besides that, CS data can be spatially widely distributed, hard to access and may contain incomplete metadata (Freitag et al. 2016). That being said, it has also been argued that large databases, such as can be generated with CS, can accommodate a proportion of error while remaining high quality (Ballard et al. 2018).

Our literature study suggests that the limited number of peer-reviewed articles concerning CS 2.0 discussed earlier, does not reflect the diversity and number of CS 2.0 projects. This was most evident in the article by Stepenuck et al. (2011) where 53% of the 296 surveyed water monitoring programs in the United States were defined as *collaborative.* The lack of CS 2.0 content in peer-reviewed articles might relate to the credibility issue affecting CS 2.0. Peer-reviewers appear to question, whether real or perceived, the quality of data obtained by citizens (Gardiner et al. 2012). Verification of CS projects may lead to increased confidence, and accordingly, more CS 2.0 studies incorporated into published peer-reviewed journals. In this regard, Freitag et al. (2016) and Zheng et al. (2017), maintain that using certain criteria to screen CS data afterwards or establishing certain credibility strategies during the research process could increase the level of acceptance among the scientific community.

Several studies focus their attention on improving credibility in CS research (Gouveia et al. 2004, Bonter and Cooper 2012, Aceves - Bueno et al. 2017, Zheng et al. 2017). A key publication is this regard is the article by Freitag et al. (2016), focussing on CS credibility during different stages of the research. In this study, twelve credibility building strategies are identified around three research stages: three in planning (early actions), four in data collection (in the field) and five in data analysis (in the office).

The necessary steps to increase credibility in the planning stage according to Freitag et al. (2016) involves working with volunteers to ensure that they have enough knowledge and equipment to answer the research question in the best possible way. Three strategies were identified: (i) prior expertise, (ii) training, and (iii) science advising. Prior expertise is related to the expectation scientists have of volunteers in terms of skill and knowledge, training involves preparing volunteers on project protocol, and science advising is meant to strengthening methods through scientific advice by ensuring standard practice in the field (Freitag et al. 2016). How these strategies will be applied have direct consequences for the number of volunteers available. For example, they maintain that prior expertise might be essential in answering a specific research question, but this will in turn decrease the size of the potential volunteer pool.

As for the data analysis stage, several other strategies are suggested that may improve the reputation and subsequent credibility of the overall research. Here, five strategies were developed: (i) validation of observations, (ii) cross-comparison, (iii) publication, (iv) management use, and (v) quality assurance protocol (Freitag et al. 2016). Validation of observations by means of statistical flagging contributes to minimising human error, cross-comparing data collected by volunteers with that of professionals could provide evidence that volunteers can collect data accurately and publishing peer-review articles with CS data will put the research through the same critique as that of professional scientists. Furthermore, encouraging managers to use CS data in their decision making is maintained to improve its trustworthiness and finally, a standard quality assurance protocol will certify volunteer capability in addition to the methods (Freitag et al. 2016).

Box 2 What does this mean for CS 2.0?

- For more CS 2.0 studies to be incorporated in peer reviewed literature, trustworthiness and credibility are important requirements.
- Verifying CS 2.0 data results could potentially diminish or resolve the credibility issue. Freitag et al. (2016) put forward several necessary steps to increase credibility for contributory CS projects.

3 Meta-analyses

3.1 Introduction

A meta-analyses was performed by evaluating survey and focus group data results of five CS projects in the (drinking) water domain in The Netherlands. Four of these CS projects were related to drinking water: “CS Freshness of Water (Waternet)”, “CS and Lime (WML)”, “CS and Lead (Dunea)” and “CS and Hardness” (Brabant Water). In addition, the CS project “The Clean Water Experiment” (Waternet), which focused on surface water quality, is incorporated in this study. The selection of these projects was guided by two considerations: (i) project relevance and (ii) the availability of data. Each of these CS projects concluded with an evaluation survey where participants were given the opportunity to reflect on their overall experience and contribution to the project. In addition, four focus group interviews were conducted for CS Freshness of Water, CS The Clean Water Experiment, CS and Lime and CS and Hardness.[3] By using focus groups to stimulate interaction among participants, a clearer understanding was developed as to why participants feel the way they do. In this way, also qualitative data was retrieved from the participants.

In order to develop and improve our understanding of where in the research design participants could be more involved and what their knowledge needs are, the meta-analyses focused primarily on more intensive involvement among participants. Results from open ended questions in the evaluation surveys and quotes from the focus groups gave insight into the perspectives of participants regarding their involvement and where they could have contributed more. This willingness to be more involved was further compared with the age and education of participants to gain a deeper understanding of the background of people open for CS2.0 projects. Other results from the surveys and focus groups gave insight into where participants would like to be more involved or required more information. Quotes from participants were sorted into categories depicting several commonly used research phases. Before reporting the results of the meta-study, the next section first introduces the five CS projects upon which this analysis is based.

3.2 Previous drinking water CS projects

To date, in the domain of (drinking) water, five different KWR CS projects have been completed in Netherlands. All of them are primarily *contributory*. These are as mentioned before: Freshness of Water, The Clean Water Experiment, Citizen Science and Lime, Citizen Science and Lead and Citizen Science and Hardness.

The Freshness of Water

This 2016 citizen science project on the microbiological stability of drinking water was the first citizen science project in the domain of drinking water in the Netherlands (Brouwer et al. 2018b). Research was conducted with citizen scientists in Amsterdam into the ‘freshness’ of their own drinking water, particularly the bacterial composition. To this end, participants took water samples at their home and performed analyses themselves. Samples were also transported to the KWR laboratory where the latest DNA techniques in the field of ‘Next Generation Sequencing’ were performed, making it possible to classify millions of bacteria at the DNA level. The project resulted in a better understanding of how the bacterial species

[3] Citizen Science and Hardness was completed during the writing of this report. The data from this project are therefore only partially incorporated into this report, namely in Table 2, Figure 2 and Figure 3. Results from the focus group of CS and Hardness are also incorporated in sections 3.2 and 3.3.

community composition in drinking water changes during transportation in the distribution system, after stagnation in the premises plumbing system, and after water is stored for several days in, for instance, a bottle. Participants were recruited via a Facebook campaign. The project received 85 complete registrations, 50 citizens were selected and 43 participants confirmed their participation. This CS project was carried out in collaboration with the drinking water company Waternet.

Contribution citizen scientists
• Sampling (two predefined drinking water samples, and one additional water sample of their own choice) • Analysing water using two different test strips (one to count cultivable bacteria and the other to count cultivable fungi) at home.

The Clean Water Experiment

A year after the Freshness of Water project, a new citizen science project was conducted in Amsterdam, now focussing on the quality of the city's surface water (van der Meulen et al. 2018). Hundreds of participants received a special toolbox, containing various instruments to carry out water quality measurements, including an *E.coli*, colour, temperature, and odour experiment. Citizens were invited to research the quality of the water in the city over a period of three months, and asked to upload their results to a dedicated website. Through the Clean Water Experiment, citizens learned more about the quality of water in their surroundings, making it easier for them to make well informed decisions about how to use it. In addition, the project resulted in a larger spatial and temporal coverage of water quality data. Similar to the Freshness of Water project, participants were recruited by means of generic invitation to the general public, both online and offline. A special feature of the recruitment process in this project was an artistic installation, allowing the people passing by to see, taste, smell and feel water. This installation was located at various locations in the city. The project received 667 complete registrations. This CS project was initiated by Deltares, Wageningen University, KWR, Waternet, Regional Public Water Authority Amstel, Gooi en Vecht, AMS Institute and Pavèl van Houten.

Contribution citizen scientists
• Carrying out surface water quality measurements • Free choice of specific location and frequency

Citizen Science and Lime

In this 2017 citizen science project, over 100 citizens participated in a scientific study of drinking water hardness and lime-scaling (Brouwer and Albert 2017). The research was conducted around the pumping station in Pey-Echt, in the South of the Netherlands. Collaboration with drinking water company WML made this CS project possible. The reason for looking at this area relates to the fact that, in the past, the responsible drinking water company received relatively frequent complaints about discoloured water, regularly accompanied by questions about the water's hardness. To improve the water quality of this pumping station, measures were taken in 2016. The citizen science project helped to get a better idea of the impact in the clients' home of the measures taken, whereas the participants gained more insight into the composition of their drinking water. Using a simplified boiled water test and a 'drop test', the participants have determined the hardness and lime-scaling of their water. The drop tests was carried out twice; once on water directly from the tap and once on 5 minutes boiled water. Invitations to participate in the project were sent to 1500 selected addresses, 134 citizens replied with a positive response, 133 participants confirmed their participation.

Contribution citizen scientists
• Carrying out a simplified boiled water test (determining hardness with a drop test, boiling, and again determining the hardness of their water).

Citizen Science and Lead

Guided by the goal to locate and remove the last residues of lead from the drinking water pipe network in the city of The Hague, this CS project involved citizens in research into lead water pipes (Brouwer et al. 2018a). Dunea was the collaborating partner in this CS project. In two measurement rounds, citizens were invited to participate in the research, which included three variants with different research steps, ranging from taking pictures, taking samples, measuring pipes, to testing for the presence of lead by using indicator strips. This project has resulted in more insight about the presence of lead water pipes, and the effectiveness and significance of the three variants of locating these pipes. In addition, it presented an opportunity to raise the home owners' awareness about lead in their home, so that they may take the appropriate measures. Invitations to participate in the project were sent to more than 1255 selected addresses with houses built before 1960, because houses built before that time, may still have in-house lead water pipes. In total, 107 citizens replied with a positive response.

Contribution citizen scientists
• Variant I: taking pictures of (possible) lead pipes • Variant II: taking pictures, measuring pipes, sampling • Variant II: taking pictures, measuring pipes, sampling, testing for the presence of lead by using indicator strips

Citizen Science and Hardness

The CS project on the hardness on drinking water is in many respects equal to the citizen science and lime project, yet differs from it in two ways (Brouwer and Vries 2018). First, participants were exclusively asked to carry out the 'hardness drop test' with water directly from the tap. Second, and this is unique in the context of Dutch water management, participants were invited to take measurements on three different occasions over a period of seven months: before, during and after the work on a particular transport pipeline. This project is situated in the region of the city Oss, where a transport pipeline is being replaced and customers will be temporarily supplied with harder water from another production site. Over the course of the research, participants got a clear insight on the variations in the drinking water's hardness. At the same time, the project generated a more refined measurement network and a better understanding of the impact of the measures on the customer at home. Invitations to participate in the project were sent to 2384 randomly selected addresses, 163 citizens replied with a positive response. This CS project was done in collaboration with the drinking water company Brabant Water.

Contribution citizen scientists
• Determining the hardness of tap water with a drop test, 3 times, over a period of several months.

3.3 Intensive Involvement

CS 2.0 projects are rooted in intensive involvement of all participants in various, if not all, research phases of a CS project, as listed in Table 1. Accordingly, it is highly relevant to analyse evaluation results from previous CS participants if they would have preferred to be more intensively involved in other research phases rather than only collecting data. By knowing *if* and *where* participants would have liked to be more intensively involved, more insight can be gained about the potential and possible design for CS 2.0. The total number of participants that chose to (partly) fill in the evaluation for each previous drinking water CS project, as well the number of participants that answered the question regarding more intensive involvement, is summarized in Table 2. The three variants of the CS and lead project are presented separately, since the contribution of citizen scientists varied extensively between the variants.

TABLE 2: MORE INTENSIVE INVOLVEMENT QUESTION

CS project	Total participated in CS project	Evaluation response rate %	Number of respondents	Number of respondents intensive involvement question
CS Freshness of Water	54	79%	43	34
CS Clean Water Experiment	667	23.5%	157	136
CS and Lime	134	53%	71	67
CS and Lead (variant 1)	15	53%	8	8
CS and Lead (variant 2)	24	33%	8	8
CS and Lead (variant 3)	52	50%	26	26
CS and Hardness	163	45%	73	69
Total	**1110**		**386**	**348**

Total number of participants per CS project that answered the "more intensive involvement" question.

Participants of all CS projects were asked to give an indication if they would have preferred to be more intensively involved during the overall research process. Their responses were grouped together into the categories "yes", "neutral", "no" and "don't know".[4] As depicted in Figure 2, there are slightly more participants that answered "yes" (22%) compared to "no" (20%), but this is only a marginal difference. Participants who wanted to do more stated that, in their view, too little was required of them throughout the project and that they easily could have contributed more to the project. As one participant puts it: *"my role was very modest. You only had to do something at one particular moment. At the beginning, I thought that you had to do something on several occasions".*[5] Another participants stated a similar feeling: *"it was very little effort, I could easily have done more".* The majority of participants, however, answered "neutral" (55%). The observation that most participants were largely undecided may perhaps be explained by the fact that participants are not sure in which

[4] Originally, participants were given a rating scale that ranged from "fully agree" to "fully disagree". For presentation purposes, it was chosen to group these rating levels into larger categories "yes", "neutral", "no" and " don't know".

[5] Quotes from participants were translated from Dutch into English by the authors.

research phase they could have contributed more, i.e. can hypothetically be explained by the fact that many participants are unfamiliar with the different phases of a research process.

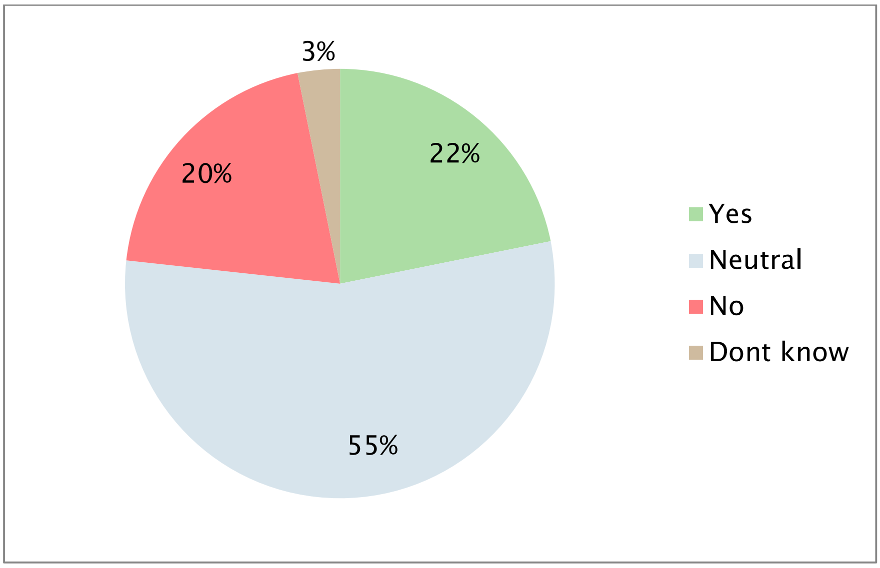

FIGURE 2: MORE INTENSIVE INVOLVEMENT TOTAL[6]

All CS projects that have so far been conducted were subsequently compared with each other based on the willingness of participants to be more intensively involved (see Figure 3). Participants in Citizen Science and Lime were most willing to be more intensively involved with 38%, followed by the participants in Freshness of Water with 25%. Citizen Science and Lead (variant 1) had no participants willing to be more intensively involved. It should, however, be mentioned that since only a limited amount of people participated in this variant (see Table 2), the percentage values are less well distributed.

[6] "Yes" = would have liked to be more involved, "neutral" = neither for or against being more involved, "No" = not willing to be more involved, "don't know", = unsure whether to be more involved.

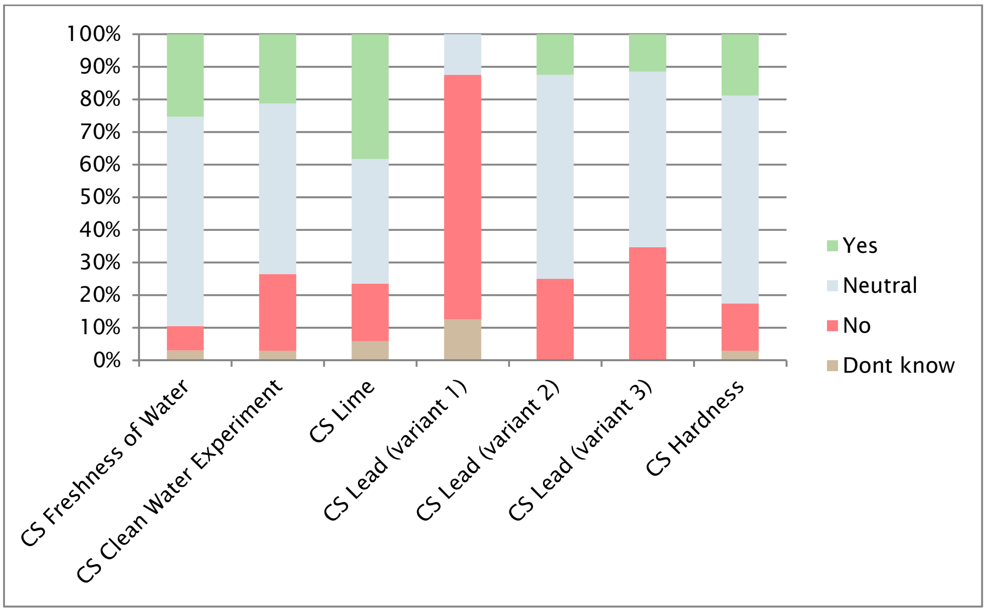

FIGURE 3: MORE INTENSIVE INVOLVEMENT COMPARISON

When we look at the wish to become more involved in relation to the requested level of participation of previous projects, it cannot be concluded that a small role by definition results in a greater desire by participants to be involved more, and vice versa. For example, the requested contribution within the CS project Freshness of Water was greater than the requested contribution within the CS Lime project, but the evaluation in Figure 3 shows that participants from CS Freshness of Water were less willing to be more intensively involved.

This result makes it plausible that the wish to become more involved is not only connected with the actual requested commitment, but also with the personal preferences of the different participants. To get a better understanding of what factors influence the level for more involvement, this study explores to what extent the age and education of participants impacts the level of willingness to be more involved.

Box 3 What does this mean for CS 2.0?

- Relatively few CS participants demand involvement in the research process; the majority of participants from previous CS projects gave a neutral response when asked whether they would have wanted to be more intensively involved during the overall research process.
- Out of previous CS projects, participants in Citizen Science and Lime were most willing to be more intensively involved. However, with regards to the level of involvement in relation to the requested level of participation, it cannot be concluded that a small role necessarily results in a greater desire to be more involved, and vice versa.
- These meta-analysis data suggest that, unless the CS 2.0 volunteer is entirely different than the “regular” CS volunteer, from a citizens perspective the need for CS 2.0 projects is limited.

Intensive involvement vs. age and education

For age, the level of willingness to be more intensively involved is quite evenly spread, and no clear pattern can be observed between the willingness to be more actively involved and age (see Figure 4). There is however, a clear percentage peak for “yes” in the 25 to 35 years category. It appears many of these young adults (36%) would like to be more involved in the research project. Participants aged between 55 and 64 years, on the other hand, have the lowest level of willingness to be more involved more intensively with only 13,5% answering “yes”. This age category 55 to 64 years also has the highest percentage participants answering “no” (29%).

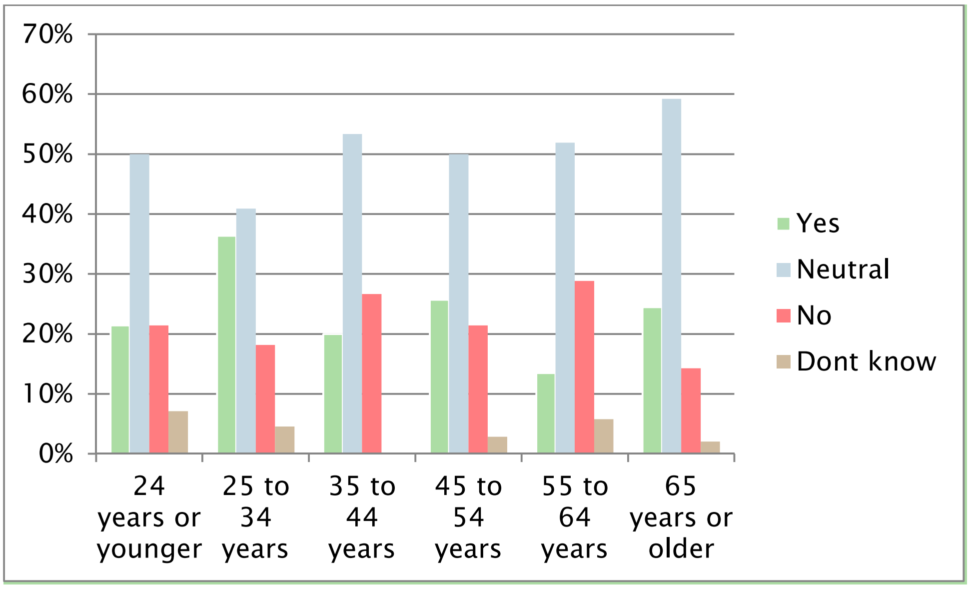

FIGURE 4: MORE INTESENSIVE INVOLVEMENT AGAINST AGE

As for education, one striking observation can be made between lower and higher educated groups. Havo/VWO, bachelor, master/doctoral can be seen as the more “higher” educated group, whereas primary school, VMBO and MBO can be seen as “lower”. When these two groups are compared, it becomes clear that the “higher” educated group are more willing to be more intensively involved. The categories primary school, VMBO and MBO have substantially lower percentage values of participants answering “yes” than compared with the categories Havo/VWO, bachelor and master/doctoral (see Figure 5).

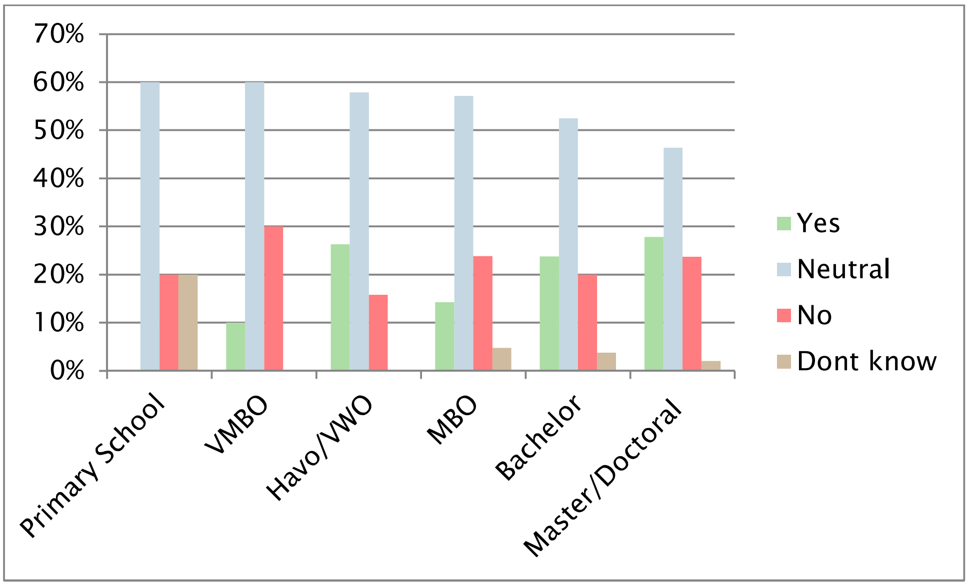

FIGURE 5: MORE INTENSIVE INVOLVEMENT AGAINST EDUCATION

Box 4 What does this mean for CS 2.0?

- Both young and higher educated citizens in the Netherlands appear to be more open to be involved in CS 2.0. If a future CS 2.0 project aims to include a diverse array of people, the older people aged between 55 and 64 years and lower educated groups should be given special attention.

Intensive involvement in different research phases

Answers from the focus groups and the open-ended question in the different evaluation questionnaires that asked participants where in the project they would have liked to be more involved gave a deeper understanding into the different research phases where CS participants could be more engaged in or required more information. Quotes from these two sources were selected and afterwards categorised into five commonly used research phases: formulation of the research question, research design, analyses, interpretation and follow-up. These research phases were based on the research phases mentioned in Table 1 by Bonney et al. (2009) and Shirk et al. (2012)[7]. Based on this categorisation and the subsequent analyses that calculated the percentage distribution of each research phase, we find that from the participants that stated to like a more intensive involvement they either would have liked to be more involved in either the analyses of data (30%), or the interpretation of the data (28%). In addition, the research design and interpretation phases both had 14% of the percentage distribution, while respectively 8 and 6% of the respondents would have liked to be involved in the question formulation and follow-up phase. Perhaps even more important than this percentage distribution is to understand what participants actually mentioned regarding a more intensive involvement, and why.

For the **research question formulation** phase, the general consensus was that participants had ideas or wanted to be more engaged with formulating relevant research questions that

[7] The first two research phases “choose/define research question” and “develop hypothesis” from Table 1 have been merged for this analyses into the research phase “formulation of research question”. Furthermore, the last two research phases of Table 1 “dissemination & implementation” and “evaluation” have been merged into the research phase “follow-up”. The data collection phase was left out since all participants already were involved in the data collection phase of their respective CS projects.

would form the basis of the research. Some participants indicated that they would have liked to collect more (different types of) data. We reasoned this to be another research question and linked these indications by participants to more involvement in the research question formulation phase.

Regarding the **research design**, several participants mentioned that they could have done more measurement in time and space. One participant, for instance, noted: *"I could have done more measurements on different days depending on the levels of water consumption"* and *"I would have liked to have done more measurements in time"*. Participants also would have preferred to do more measurements at different locations: *"I now realise that I could have done more measurements at different locations, for example at the coffee machine at my work".* It's worth to note that from the open-ended question in the questionnaire that asked where in the project participants could be more involved, only a limited amount of people spontaneously indicated that they would have wanted to be directly more involved in the question formulation or research design phase. The responses that were categorised into these two research phases mainly consisted of ideas related to these research phases. Many ideas were given by participants to further develop CS projects in the future. These ideas and knowledge interests will be further elaborated on in section 4.2.

Relatively many participants would have preferred to be more involved or required more information in the **analyses of the gathered data**. One participant puts it: *"I would have liked to have done some analyses on the measured data. Not just for myself, but also of other participants. What variations can be seen? What are the outliers?".* Having been involved in the data collection phase, participants were understandably curious how the results were measured and analyzed: *"I would have liked to have had the possibility to get to know more about the techniques of the water analyses".* Some participants also wanted to be physically involved in the analyses of their samples. Looking under the microscope and being present in the lab during the analyses phase would have brought the results more closer to the participants: *"I would have liked to have been present in the laboratory to see how the water samples were analyzed. For me, it was rather abstract".* At the end of CS projects the results of the gathered data were presented as a whole. Some of the participants would have preferred a more personal approach in the presentation of the results: *"I understand that it was not really possible, but I would have liked to have had a small committee where personal results would be discussed".* Despite many participants expressing their desire to be more involved in the analyses phase, other participants indicated that researchers should be cautious to involve participants in the analyse phase. One participant from the focus group of CS and Hardness questioned the credibility of the end results had citizens been more involved in the analyses phase: *"that would not be good for the reliability of the research. Besides the fact that I would have enjoyed it, and probably others as well, the current people [KWR researchers] doing it are highly skilled at it and can interpret the results in the right manner. Is it not that when we get more involved in the research that the results of the research will become more unreliable? I think that the end results will become more unreliable".*

Furthermore, a large proportion of the participants, required more **explanation of results** in what could be named the interpretation phase where gathered data is interpreted and conclusions are drawn. For example, some of the participants would have liked an explanation as to why the results were the way they were. One individual said for instance: *"my own conclusions from the test strips and the conclusions from the lab were so different that I wonder where the lab has looked at"* A largely similar answer was voiced by another participant: *"I am interested in the outliers. How can there be such a difference between the different measurements?"* It appears that various participants would have preferred more clarification into the differences between the results of their measurements. Furthermore, similar to the previous analyses phase, participants would have appreciated a more personal approach to the interpretation of the data. One participant formulated it as follows: *"perhaps feedback could have been given in a personal report where the bacterial differences from my sample are compared with the average sample. By knowing this, local factors can be taken into account to explain differences between results"*. The insights gained from these quotes by participants are valid for all types of CS types, not just CS 2.0. The quotes by participants do not specifically refer to more direct involvement, but rather give an impression that the participants would have liked to have had more explanation from researchers regarding the obtained data.

The **follow-up phase** was less mentioned by participants. Answers related to the follow-up phase were all related to participants requiring more information. One participant for instance would have liked to know how the generated data from the project would be used: *"I would have liked to know what will happen with the project results. Suppose the research shows that the water in a certain area is too "hard", what will happen to make the water softer?"*.

Another important conclusion from the evaluation results were that some participants were not familiar with the different research phases. In the previous CS projects, the analyses and interpretation phases were the research phases that participants were directly exposed to, whereas the other research phases remained more hidden. Possibly, this could explain why the majority of the participants commented on these two research phases. Question formulation, research design, and follow-up were not familiar to everyone. It is reasonable to assume that the lack of familiarity with the different research phases contributed to participants not spontaneously being able to indicate in which research phases they directly would have wanted to be more involved in. Not everyone of the participants had an academic background, so they understandably wanted an explanation beforehand regarding the difference research phases within the project. One of them said: *"maybe it would be a good idea to understand first what the different research phases are during a project. I cannot name them"*. Another participants mentioned how participants could be more engaged within the different research phases: *"you could have had a focus group from the beginning that was present during the whole duration of the project. A group of interested people who discuss the different phases of the research. A sort of feedback group that is present throughout the project"*.

Box 5 What does this mean for CS 2.0?

- Relatively few CS participants demand more involvement in the research process, suggesting that from a citizens perspective the need for CS 2.0 projects is limited.
- If the involvement of citizens (non-professionals) in the analyses and interpretation phase would be considered, this needs to be treated with care since it could potentially decrease the credibility of results.
- There is a need for more information in the so called analyses and interpretation phases of research processes, however, this can also be realized within non CS 2.0 projects. Many citizens appear not to be familiar with the different phases of a research process. This knowledge gap should be considered in the design of CS 2.0 projects.

4 Participant and customer interests

4.1 Introduction

Suppose that in the future, citizens within a CS 2.0 project will be asked to think about the formulation of research questions, the analysis of the knowledge interest of former participants and complaints and/or questions from regular drinking water customers can provide insight into what type of research questions may be formulated. After all, there is a strong chance that these complaints and/or questions will be similar to the questions posed towards the drinking water company and/or the issues flagged in the questionnaires. Even when citizens are not explicitly asked to think along with the formulation of the question, a better insight into the knowledge interest of people can be gained that will give practitioners and researchers guidance in designing CS projects. Having a topic that is within the interests of participants, will undoubtedly lead to more interest and involvement. In this chapter, the knowledge interests of CS participants and regular drinking water customers (non CS participants) will be discussed.

4.2 CS participants knowledge interests

To shed more light into the knowledge interests of CS participants, open ended question from the evaluation survey and quotes from the focus groups were analysed to understand which themes CS participants would deem suitable for future CS projects. These findings were subsequently sorted into seven different category themes that were determined based on the answers that were obtained from participants:[8]

- Energy
- Water efficiency & awareness
- Emerging substances or adapted parameters
- Time & space
- Infrastructure
- Other types of water
- Others

Figure 6 shows that the category “emerging substances or adapted parameters” is the most popular theme where participants would prefer future CS projects to focus their attention on (30%). Very specific parameters were mentioned which shows that participants were quite well informed of the various substances in water. Interestingly, many participants wanted to have a future CS project tailored towards measuring pharmaceuticals in water. One participant from CS Freshness of Water, for instance, said: *“how many remnants of pharmaceuticals are in the water? The increased consumption in the amount of pharmaceuticals will also end up in drinking water. That I find more frightening than a few of those bacteria”.* The measurement of heavy metals and other chemical substances were other parameters that were mentioned by participants: *“personally, I have great interest in the amount of heavy metals in drinking water”*. Some participants mentioned topics that were already covered in other CS projects where they were not involved in. For example, one participant wanted to measure the amount of lead in the water: *“testing the quality of the internal installation for example by measuring the amount of lead in the water”.*

[8] The seven categories were linked to the answers given by participants and were not predefined. The authors used their own judgement on which categories to use.

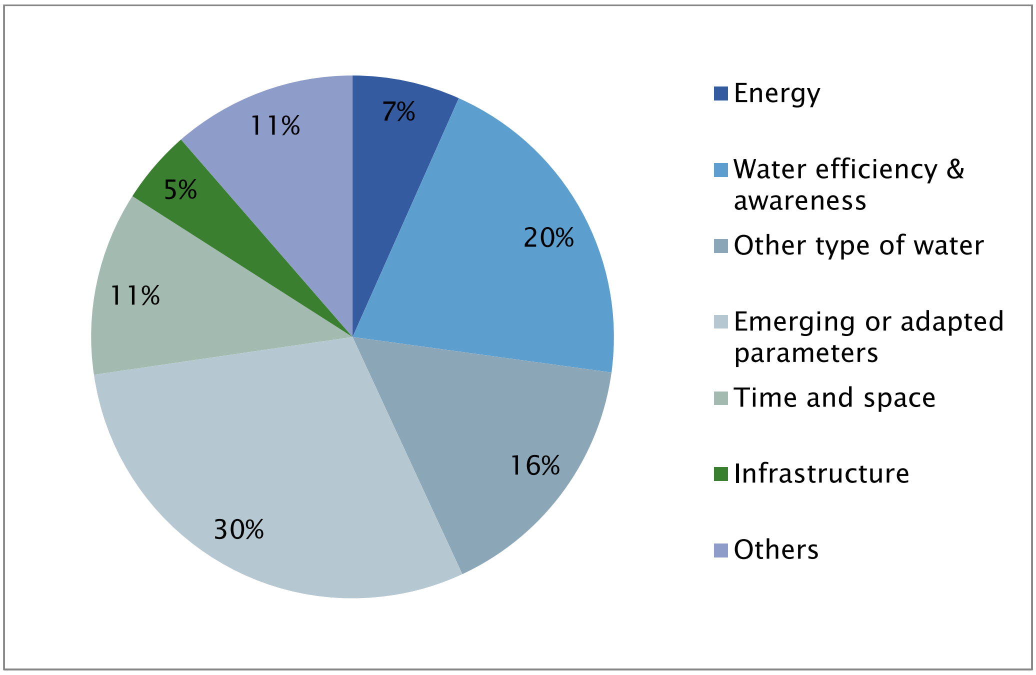

FIGURE 6: KNOWLEDGE INTERESTS AMONG PARTICIPANTS

In the category water efficiency & awareness, with a share of 20%, participants frequently mentioned the need for future CS project to be more tailored towards sustainability issues. Participants mentioned for example: *"making people more aware of how important our water is for the future"* and more related to rainwater harvesting: *"Saving drinking water by capturing rainwater".* One possible way of how such topics could be incorporated in future CS projects might be to track water use by means of installing water measurement devices in household appliances, or as one participant puts it: *"installing measuring devices, such as in showers".*

"Other types of water", was the third most popular with 16% of the percentage share. Drinking water was until now the most tested type of water during our past CS projects. In the other type of water category, new sources of water where considered. Involving participants measuring surface water was by far the most mentioned type of water: "*research about surface water*", "*quality of surface water*" and "*measurements of surface water*" were all related to surface water. Other types of water that were mentioned for water sample measurements were shower, toilet and swimming(pool) water.

The category time and space had a moderate share of 11%. One participants thought it would have been an idea to measure drinking water samples directly after the water meter instead of from the tap: *"research water quality directly after the water meter, instead of when it leaves the tap".* Other participants were interested whether time differences and seasonal change have effect on drinking water quality. As one participant puts it: *"winter and summer seems like an interesting times to measure. Between the two, there is probably a ten degrees difference in water temperature. So, do the same research, but then half a year later to see if there are variations in the results.*

The category energy had a limited share in the overall range of topics mentioned by participants with only 7%. The topics that were mentioned in this category were mostly related to the energy required for the heating of water. For example, one participant said: *"maybe tests with water that are heated within a household".*

Topics concerning infrastructure were least mentioned with only 5% of the total percentage share. However, an interesting point was put forward by one participants who questioned the control and monitoring of the drinking water supply unit: *"where does our water come from? River or ground water? Which choices give a better guarantee for our drinking water? How is drinking water quality continually monitored? Is drinking water protected from criminal activities?*

Finally, in the others category with a remaining 11% share, several new topics were put forward by participants that were not directly related to water. For example air pollution: *"air quality and various sustainability topics (waste separation, water use) that stimulate awareness".* Another participant brought the focus back to water by giving an innovative perspective to involve participants in tasting different water samples while being blind-folded: *"a taste test that is performed blindly. The participants do not know which water they drink (spring water, tap water, boiled water etc.) and have to judge this on taste, smell and appearance".*

Box 6 What does this mean for CS 2.0?

- Participants most strongly preferred to have a future CS project aimed at measuring other parameters in drinking water. Pharmaceutical and heavy metal concentrations were parameters most mentioned.
- Participants also have a strong interest in conducting a CS project concerning sustainability issues, such as water efficient practices.
- Other types of water, such as surface water, is an area where participants would also want to have a CS project tailored towards.

4.3 Customer complaints and perceptions as an indirect indicator

Besides having looked at what topics CS participants identify as interesting to incorporate in future citizen science projects, this sections looks at what topics the regular drinking water customer finds important. The regular drinking water customer is seen as a non-citizen science participant. To this end, two different datasets have been assessed: (i) the customer complains that drinking water companies receive, and (ii) results of two different large scale surveys conducted under a representative sample of Dutch drinking water customers. Both types of data sets provide insight in which drinking water related issues raise questions and concerns, and accordingly, can be used as an indirect indicator of what types of questions may evolve in future CS 2.0 research questions design development trajectories.

4.3.1 Customer complaints

In this study, three datasets of customer complaints by phone were analysed; two from Brabant Water and one from PWN. Brabant Water provided water quality customer complaint data for the whole of 2017 and for the period 1 January to 24 April 2018. PWN did the same for the period 1 March to 15 June 2018. The way customer complaints are reported among these two drinking water companies varies considerably. In the dataset analysed, most complaints at Brabant Water were given a short description, in contrast to PWN where only the type of complaint was mentioned. The total amount of complaints per theme from Brabant Water and PWN are summarised and categorised in Table 3.

TABLE 3: CUSTOMER COMPLAINTS FROM BRABANT WATER AND PWN

Brabant Water 2017		**PWN 1 March - 15 June 2018**[9]	
Deviating smell/taste	174	Deviating smell/taste	34
Deviating colour	1051	Deviating colour	54
Deviating temperature	37	Deviating temperature	0
Deviating water pressure	1308	Deviating water pressure	174
Total	**2570**	**Total**	**262**
Brabant Water 1 January - 24 April 2018			
Deviating smell/taste	46		
Deviating colour	62		
Deviating temperature	0		
Deviating water pressure	182		
Total	**290**		

Total amount of customer complaints from Brabant Water and PWN split into four different categories.

Customers from Brabant Water and PWN complained most about deviating water pressure. In all three datasets, this category had the highest number of complaints. Problems with low pressure were mentioned more often than problems with high pressure in the water delivery unit. A deviation in colour was the second most mentioned complaint. Here, customer complained mostly about the water being too brown.

Other interesting topics for future CS projects are likely to involve certain parameters in the composition of water. Therefore it was important to discover what customers were complaining about in terms of water composition. These type of complaints were usually found in the “deviating smell/taste” category. Since customer complaints by PWN did not include any description, qualitative data was limited to the customer complaint data provided by Brabant Water.

Water composition complaints from Brabant Water covered a wide range of parameters: sulphur, copper, lime, chlorine, sand, hardness, ammoniac, iron, heavy metals, silicate and microbiology. Of those, lime, sand and iron were parameters that were most commonly complained about. In terms of lime, some customers complained that excessive amounts of lime in the water caused several of their appliances to break down. Customers also complained about, what they categorized as, sand and other types of sediments they observed in their drinking water. Several customers complained that sand particles had entered their toilets and taps. In one particular case, sand was even observed in the customers water-softening device. As for iron, several customer voiced their concern of the amount of iron they were tasting in their water. One customer noted that corrosion had occurred in his/her toilet bowl due to the high amounts of iron in the water.

Box 7 What does this mean for CS 2.0?

- Since the vast majority of customer complaints were linked to deviating water pressure, future CS could be tailored towards measuring water pressure in

[9] The categorisation for PWN was done by the researcher in order to better compare results with Brabant Water.

households. Many of the customers who sent in a complaint or posed a question, can resemble themselves with this topic.

- In terms of water composition, lime, sand and iron were the parameters that were often mentioned in the customer complaints. It shows that previous CS project, such as CS & Lime and CS & Hardness, fitted well in relation to the customers complaints and/or questions. Future CS projects could also involve the measuring of these parameters in households.
- Complaints and/or questions related to temperature were also mentioned, but to a lesser extent than the other categories.

4.3.2 Customer perceptions

In a 2018 BTO survey (n = 1057) in the field of risk perception it was examined what type of information customers feel is currently lacking. This research suggests that 20% of the Dutch drinking water customers feel that there is insufficient information available about tap water. As depicted in Figure 7, two issues in particular are considered important in this regard: the composition of drinking water, and related to that, the quality of drinking water. In other words, those customers are looking for answers on the questions 'What is in my drinking water' (69%) and 'what is the quality of my drinking water' (64%)., These two topics could par excellence (partially) be answered using citizen science.

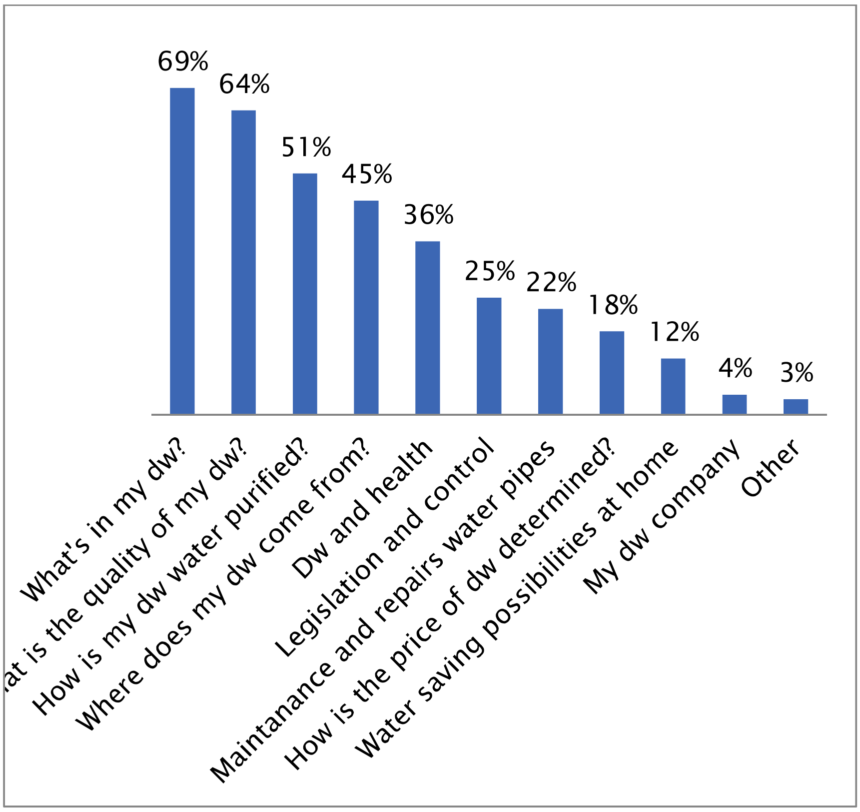

FIGURE 7: QUESTIONS/TOPCIS REGARDING DRINKING WATER (DW) ABOUT WHICH CUSTOMERS WOULD LIKT TO RECEIVE MORE INFORMATION

Also analyzing the types of concerns that drinking water customers experience, we find that most concerns (31%) are related to the composition and quality of tap water. Relatively many customers express concern about the hardness of tap water. To a lesser extent people are concerned about bacteria, plastics, hormone disrupting substances, chlorine, fluoride, the taste and transparency of tap water. Next to concerns about the quality of tap water, people are concerned about (the effects of) the contamination of groundwater and surface water, i.e. the sources of their tap water. In this regard, concerns are expressed about medicine residues, such as antibiotics, industrial discharges, pesticides, drugs (waste) and to a lesser extent about plastic, cosmetics and hormone disrupting substances.

The observation that hardness is considered a very important drinking water characteristic resonates well with the results of a second 2018 BTO survey, part of the so-called Customer Perspectives project (n = 4010). Figure 8 shows that Dutch customers, by a large majority, fully agree with the statements that their tap water is transparent (93%), inodorous (89%), and healthy (75%). In addition, 80% of Dutch drinking water customers agree (completely) with the statement that their tap water tastes good. Customer, however, are clearly less positive about the hardness of their water. Only slightly more than half (53%) of all customers consider their water soft; no less than 18% of customers even (completely) disagree with the statement that their tap water is soft.

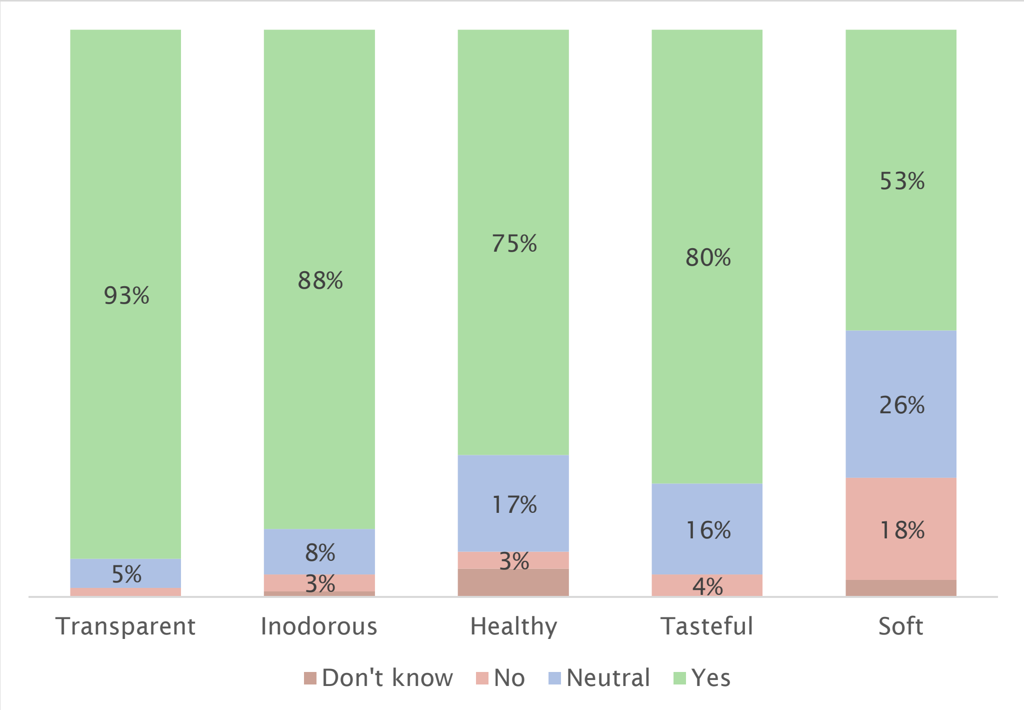

FIGURE 8: SATISFACTION WITH DRINKING WATER CHARACTERISTICS.

Box 8 What does this mean for CS 2.0?

- Customers express most interest in the composition and quality of drinking water.
- The hardness of water is considered key, and to a lesser extent non-natural anthropogenic substances.

4.4 Toolkit

Even if this study may not call for a radical shift to CS 2.0 projects, the feasibility of CS projects – including non CS 2.0 projects - gains when participants can more easily identify and resemble themselves with the topic of study. In this light we have developed a theoretical “toolkit” for future CS projects. The toolkit incorporates the wishes, questions, complaints and ideas that previous CS participants and regular drinking water customers have put forward in this report, and may enable future customers/CS participants to (independently) collect reliable data on drinking water characteristics that stand close to them.

TABLE 4: TOOLKIT FOR FUTURE DRINKING WATER CUSTOMERS.

CS drinking water toolkit
The ideal CS drinking water toolkit should, among others, include instruments that are able to detect and measure the following parameters:
Water pressure instrument: By far most of the complaints and/or questions mentioned by customers were related to deviating water pressure. Measuring the water pressure may be carried out by using an official pressure gauge or alternatively by a combination of a measuring jug and a timer.
Hardness test: Complaints and/or questions related to hardness in drinking water was an issue for both by customers of drinking water companies as well as participants of previous CS projects. Hardness in water could be measured by using a drop-test.
Iron test: The concentration levels of iron in drinking water were mostly mentioned by customers of drinking water customers. To detect the levels of iron in the drinking water a colour changing test strip could be used.
Sand: Increased levels of sand or other types of sediments were also frequently mentioned by customers of drinking water companies as a source of concern. Measuring these sediments by means of a filtration devices where solids are able to settle and accumulate at the bottom of a water column could be a way to measure the amount of sediments in drinking water.
Lead test: Both customers and CS volunteers expressed concerns and interest in measuring drinking water for heavy metals, including lead. To detect the levels of lead in water, a colour changing test strip could be used.
Legionella test kit: although not explicitly mentioned, a legionella test kit would complement the toolkit as many citizens express concern and interest into the relation health, safety and drinking water.
Non-natural anthropogenic substances (pharmaceuticals, micro-plastics): Although with the current state of the technology, it is likely difficult to measure at home, both customers and CS volunteers expressed concerns and interest in measuring pharmaceuticals and micro-plastics. To this end, water probably needs to be send to a lab.

5 Conclusion

The recent surge of CS in scientific research is noticeable in ever more research domains. More and more members of the public are participating in scientific research. Up until now, most CS projects cited in the literature have been *contributory* CS projects. These are projects in which involved citizens are primarily involved in the data collecting phase. Based on a combination of literature research and analyses of data sets from previous CS projects, customer surveys, and drinking water companies, this report explores the potential, value and feasibility for implementing CS projects wherein citizens are involved in other research phases than merely collecting data. These *collaborative/co-created* CS projects (aka "CS 2.0") in which citizen are involved in formulating research questions, making a research design, analyzing and interpreting data is believed to provide opportunities to further enhance scientific literacy among citizens, to increase the societal relevance of science, and to generate more alternative or specific solutions.

The literature study on CS 2.0 revealed two findings: (i) in the field, there are numerous CS 2.0 type of voluntary based (water) programme; yet (ii), the number of peer-reviewed articles related to CS and drinking water and CS and water quality that could be classified as CS 2.0 is very limited. This discrepancy may either be explained by lengthy peer review processes, suggesting that it is only a matter of time before CS 2.0 is represented in the literature (one argument in favour of this hypothesis is that all identified CS 2.0 studies were published only recently), or by the fact that CS 2.0 results, even more than "regular" (read *contributory*) CS studies' are accompanied by questions on the credibility of the research. Related to the latter, we have seen that trustworthiness and credibility are important requirement for more CS 2.0 studies to be incorporated in peer reviewed literature. Ensuring that CS participants have enough knowledge and equipment to answer the research question in the best possible way and verifying data results could potentially diminish the credibility issue.

In addition to the literature study, a meta-analyses was performed that evaluated survey and focus group data of five previous CS projects in the (drinking) water domain in the Netherlands. The meta-analyses focused primarily on the wish for more intensive involvement among participants. The data we have analysed uncovered that relatively few CS participants demand involvement in the research process, suggesting that, unless the CS 2.0 volunteer is entirely different than the "regular" CS volunteer, from a citizens perspective the need for CS 2.0 projects is limited. This is not to say that we think that CS 2.0 projects may find it necessarily hard to attract volunteers, but rather that, to date, most citizen science volunteers are satisfied with merely collecting data. Even in the age category 25-35 years, where the wish for more involvement was highest, two-third of the volunteers expressed no interest in more involvement in the research project. And on top of that, volunteers that expressed a wish for more involvement often did so in relation to the analyses and interpretation phases; a wish that can also very well be accommodated within *contributory* (i.e. non 2.0) CS projects. Last but not least, we have also seen that the possible involvement of non-professionals in the analyses phase might lead to a real, or almost as harmful, a perceived decrease in the credibility of results of CS volunteers themselves.

This report also looked at what topics CS participants and regular drinking water customers find important. As for the regular drinking water customers, two datasets were used to this end: I) customer complaints received by two drinking water companies; and II) two large scale surveys conducted under a representative sample of Dutch drinking water customers that analyzed customer perceptions related to drinking water. The results gained from the customer analysis could serve as an indirect indicator of what types of questions may evolve for future CS 2.0 research questions design development trajectories. The data we have examined suggest that regular drinking water customers express most interest in the composition and quality of drinking water, with special interest in the hardness of water. Formerly CS participants most strongly asked for future CS projects aimed at measuring other parameters in drinking water such as pharmaceutical and heavy metal concentrations. In addition to that, CS participants also showed a strong interest in conducting a CS project concerning sustainability issues, such as water efficient practices. Also when no CS 2.0 approach is chosen, this analysis provides insight into what kind of projects align well with the questions and concerns of drinking water customers.

Taking all the above data and considerations together, we are led to the conclusion that CS 2.0 may perhaps be feasible and offer advantages, among others, in terms of scientific literacy, societal relevance, and alternative solutions. However, the results of this study do not call for radical shift to CS 2.0, with the main argument being that citizens simply express no wish for further involvement, and appear happy with their data collection role in *contributory* projects. Moreover, we have seen that CS 2.0 studies are often burdened by issues of credibility, both among professional researchers and among citizen science volunteers. This is not to say that it would not be interesting to pilot a CS2.0 water project. It simply means that for the time being *contributory* CS seems the more viable choice.

6 Literature

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