How to get and keep citizens involved in mobile crowd sensing for water management? A review of key success factors and motivational aspects

Rutten, Martine; Minkman, Ellen; van der Sanden, Maarten

DOI
10.1002/wat2.1218

Publication date
2017

Document Version
Final published version

Published in
Wiley Interdisciplinary Reviews: Water

Overview

How to get and keep citizens involved in mobile crowd sensing for water management? A review of key success factors and motivational aspects

Martine Rutten,[1*] Ellen Minkman[1,3] and Maarten van der Sanden[2]

Citizen science and particularly mobile crowd sourcing (MCS) has large potential in water resources management for data collection and awareness raising. Concerns about data quality, and initiating and sustaining citizen involvement hamper incorporation of citizen science in water monitoring, together with a lack of practical guidance how to set up citizen science monitoring programs. This review presents an overview of key success factors for citizen science including MCS. Specific attention is paid to motivational aspects. Success factors were organized according to project phase and motivations according to self-determination theory. The presented overviews provide practical guidelines for setting up citizen science projects. © 2017 The Authors. *WIREs Water* published by Wiley Periodicals, Inc.

How to cite this article:
WIREs Water 2017, 4:e1218. doi: 10.1002/wat2.1218

INTRODUCTION

Climate change, population growth, and economic development are major challenges for water resources management. For example, for the Netherlands rising of sea level, higher river discharges, more prolonged periods of droughts, and increasing water quality challenges are foreseen.[1] Salinization, acidification, eutrophication, and habitat fragmentation will further increase the pressure on ecosystem and environment.[1] It is expected that innovations in water monitoring are needed to generate knowledge to address the challenges and develop effective water resource management.[2]

An additional challenge for water resources management is lack of citizen awareness. Case studies in the Netherlands and the United Kingdom suggest that citizens consider flood protection and water quality management as a task of the authorities and not a community task.[3] In 2014, the OECD[4] warned of 'a striking awareness gap among Dutch citizens related to key water management functions, how they are performed and by whom.' Citizen science can be an attractive instrument to address these challenges, because it offers new monitoring options and can contribute to awareness raising.

Citizen science is not a new phenomenon, but revived in the 20th century and gained popularity worldwide over the past two decades.[5–7] Many scientific fields adopted citizen science and water resource management is about to join.[2] Involvement of citizens in scientific processes entered a new era in the 20th century with the most well-known citizen science project: the Christmas Bird Count,[6,8] which started in 1900 as a

*Correspondence to: m.m.rutten@tudelft.nl

[1]Department of Water Resources, Technische Universiteit Delft, Delft, The Netherlands

[2]Science Communication and Education, Technische Universiteit Delft, Delft, The Netherlands

[3]Department of Public Administration and Sociology, Erasmus University Rotterdam, Burgemeester Oudlaan 50, 3062 PA Rotterdam, the Netherlands

Conflict of interest: The authors have declared no conflicts of interest for this article.

volunteer-based inventory of winter bird populations. Renewed attention for citizen science in the past 20 years has been fuelled by the knowledge-driven society[9] and by changing scientific grant regulations.[6]

Easy to use equipment may enhance citizen science in water monitoring, mobile phones increase the set of opportunities as well. Mobile crowd sensing (MCS), citizen science using mobile devices for monitoring purposes, has large potential. An average phone has more computational power and sensors than the whole of NASA in 1969.[10] Common smartphones are equipped with sensors for inertia, acceleration, sound (microphone), location (GPS), ambient light, and proximity, and have additional functionalities such as a compass, camera, gyroscope, and light.[11] Such sensors have the potential to replace many conventional instruments used in science, such as traditional compasses and GPS devices.[11] These emerging sensing technologies could enhance the development of smart water management, which integrates anticipative and integrative water management.[12] Buytaert et al.[2] describe the potential for hydrology (including water quality monitoring) in terms of obtaining more data and increased data coverage over remote areas. An example is the plugin sensor of Sensorex (www.sensorex.com). This is a multifunctional monitoring device that combines the collection of information on pH, oxidation reduction potential (ORP), temperature, electric conductivity (EC), and GPS locations.

Recognition of the importance and application of citizen science in water management is upcoming, but implementation is lingering.[8,13] Major concerns are how to get and keep citizens engaged and data quality. In this review, we aim to contribute to understanding on how to set up a successful citizen science project. First, we identify key success factors for citizen science projects and specifically MCS. Second, we discuss citizen's motivation in more detail. The presented overviews can be used as practical guidelines in design of citizen science campaigns.

METHODS

A systematic literature review was carried out, as it is less prone to bias than a narrative review.[14] The literature was assessed with a protocol following the dimensions suggested by Bryman[14]: (1) year conducted, (2) location, (3) sample size, (4) data collection methods, and (5) main findings. All items found were assessed on their relevance and validity. Literature was only included if:

- It is a peer-reviewed article, conference paper, or research report of a trusted organization (further explained below);
- It is published in the year 2005 or later;
- The success factors/motivations are mentioned in the results, discussion, or conclusion section;
- The topic is related to environmental monitoring (including ecology and atmospheric sciences);
- The study took place in a developed country. This was included because an apparent difference in goals of citizen science projects in developed and developing countries[2]: citizen science projects in developed countries focus more on raising awareness and scientific literacy, whereas in developing countries the focus is more on the well-being of communities.

Three types of documents were taken into account: peer-reviewed scientific articles, conference papers, and reports. Three main topics were included: the goals of the party organizing citizen science; the citizens' motivations to participate and experienced barriers; and key success factors when organizing citizen science. The search was restricted to documents published between 2005 and 2015 because it was assumed that the use of mobile devices in citizen science only really took off after 2015 and the first version of this manuscript was submitted early 2016.

The starting point for each search was the following advanced search in Web of Science:

> TS = ("citizen science" OR "participatory monitoring" OR "participatory sensing" OR "human sensing" OR "human computing" OR crowdsensing OR "crowd sensing" OR crowdsourcing OR "crowd sourcing" OR "public participation" OR “community based monitoring”) AND SU = (Environmental Sciences & Ecology OR Computer Science OR Behaviroral Science OR Water Resources OR Government & Law OR Plant Studies OR Remote Sensing OR Meteorology & Atmospheric Sciences OR Urban Studies OR Biodiversity OR Science & Technology Other Topics OR Engineering OR Communication). Refined by: Document types: ARTICLE

Synonyms of and concepts related to citizen science were included in this search, including online crowd sourcing. The initial search integrated results from all fields that engage in citizen science. This resulted in over 8000 results, which were not feasible to study in depth. The terms public participation, human computing, and human sensing were omitted after a quick scan of the results. Additionally specific search terms were added, accompanied with their synonyms. Within the results was searched for

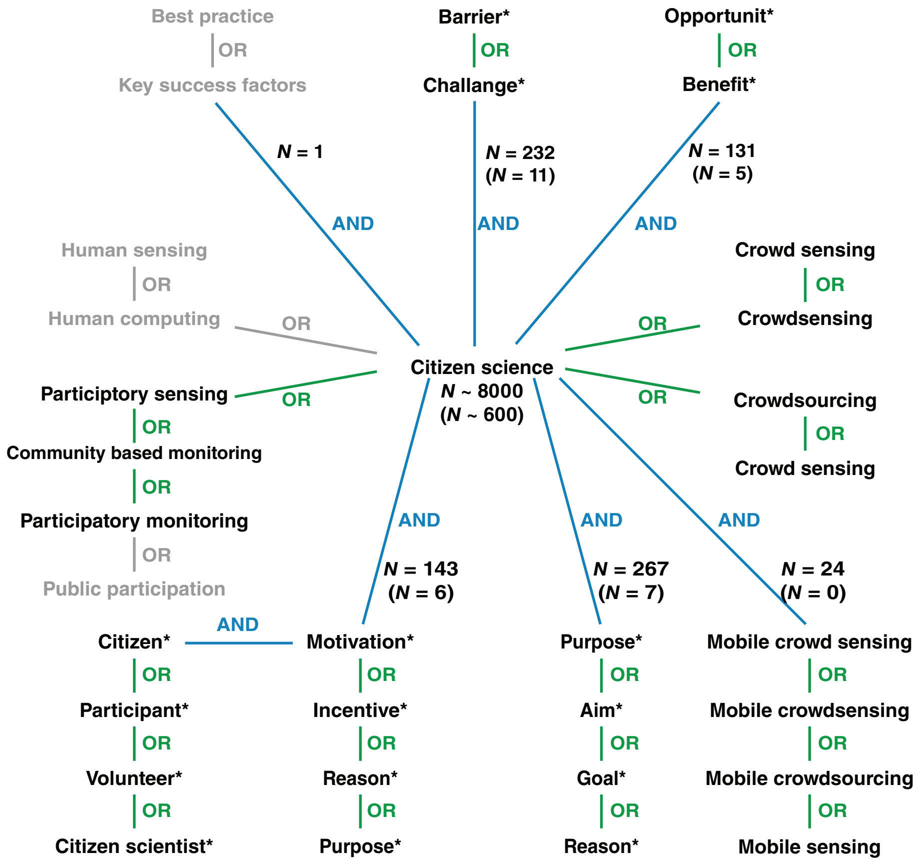

FIGURE 1 | Overview of search terms (numbers as in August 2015). Terms in gray were omitted. OR indicates synonyms, which were incorporated parallel in each search. Topics connected via AND indicate different searches. Asterisks (*) indicate that any character, a group of characters, or nobs character at all can follow. *N* indicates the total number of studies retrieved and (*N*) represents the results filtered on 'water.'

'water.' An overview of the initial and specific search terms can be found in Figure 1 accompanied by the number of results per search.

A further selection took place to choose studies to include in the review. Abstracts and conclusions were read to assess articles' relevance. It was decided to include articles covering all types of citizen science, including online crowdsourcing, to cover the full specter of success factors and motivations. Next, relevant articles were fully read and assessed on methods used. Only articles with a clear method description and original results were included and, to avoid double counting, only success factors and motivations mentioned in the result section were included. A total of 16 articles were included based on the search and additional selection criteria. Three other items were included in the review that were not peer-reviewed, being the report by Roy et al.[7] and two conference papers.[15,16] These were included because they appeared frequently in references, because they are written by authors with publications on the topic and because the studies were assessed to be well-designed.

KEY SUCCESS FACTORS

Several other authors mention success factors for citizen science in environmental monitoring and for water resources[6,7,16] or climate studies.[2] The result is a long list of key success factors, originating from various project types, view angles, and contexts. Three time frames can be extracted: during project design, at the project start, and during implementation. Success factors were organized according to these phases in Figure 2 and are discussed below.

Project Formulation Phase

The project formulation phase is used to define and develop the project. At the start of setting up a citizen science scheme, the project outlines have to be defined as the facilitating organization formulates goals.[6,19] A main challenge is the low acceptance of citizen science data by end users, related to issues of accuracy and reliability.[7] The low cost instrumentation used in citizen science places additional

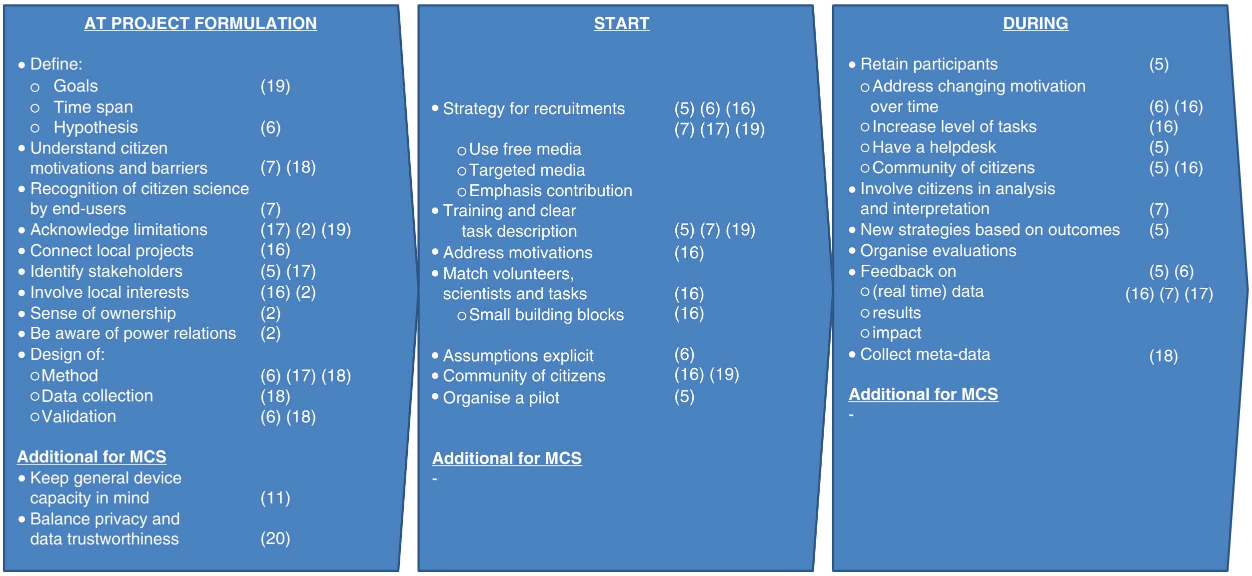

FIGURE 2 | Key success factors of citizen science projects and mobile crowd sensing. Numbers refer to cited literature.

challenges on precision and accuracy.[20] Methods of data collection therefore should be well-designed.[5–7,16–18] Silvertown[6] notes that virtually all projects validate the incoming data, although methods are not always standardized or well-designed. Rotman et al.[16] suggest standardized methods, so that local projects can be integrated and to allow for data validation. Organizations may set certain locations to collect data or accept data from random locations. The first appears more important if an explicit hypothesis is tested, although Silvertown[6] believes that all organizations should have a hypothesis in mind, even if it is superficial.

Several authors state that the possibilities for methods are restricted by internal and external limitations,[16,18,19] listing various organizational, economic, social, physical, cultural, and ethical barriers. Cooper et al.[19] consider the organizational capacity of the constraining factor, as it determines the extent to which data can be collected, analyzed, and stored. Rotman et al.[16] mainly stress the importance of motivational limitations. Specifically for water quality sampling participant safety can be of concern. Conrad and Hilchey[17] suggest that the organization identifies its skills and resources including funding. The ones lacking are limitations to the project, but could be filled by strategic partnerships. These partnerships are part of a stakeholder assessment that should always take place.[17] Connecting local projects, such as happens with the annual bird count, will lead to a large data pool.[16] Shared standards for data collection, analysis, and sharing will create a large-scale effort.

An important factor is that the end user should acknowledge the importance of the citizen science project,[16] in order for the project to be successful. End users often have a perception of low quality of citizen science information[7] and data are often not used in the end.[17] Managers focus on the utility of data.[17] Issues with data accuracy include data fragmentation and lack of participant objectivity.[17] Particularly for a regulatory of statuary cause, such as water management, data can have direct implications for participants themselves and other stakeholders and objectivity can be of concern. Projects often lack pilot studies, sample sizes are not determined adequately, or quality control is poor, which fortify these issues.[17] However, a focus on protocols that provide optimal data for end users could make the project unattractive or too demanding for participants.[7] Data collection protocols should focus on processes alongside monitoring tasks.[17]

With respect to citizens, it is mainly important to acknowledge possible power relations[2] and incorporate interests to allow for ownership of the project.[2,16] The ethical dimension of power relationship between the professional and the volunteer becomes especially apparent when balancing the privacy and use of citizen scientists' personal data.[13,18,20] The use of citizen data should be explicitly discussed in the project formulation and participants should agree on the use to create transparency and trust. Again this appears more crucial for a regularly or statuary cause, such as water management, than for example for bird counts. Rotman et al.[16] suggest incorporating local issues to trigger citizen interest. It further offers an opportunity to show citizens why their (continuous) contribution is needed.

Two additional key success factors can be added specifically for MCS. The scalability of MCS[20,21] offers a lot of opportunities, more than in general citizen science, but these should be thought-out. It should be kept in mind that devices differ in communication features and storage and processing capacity.[21] An application should be able to take these differences into account and adapt to system updates or new models. The hardware of the used mobile devices and the sensors built-in were not designed for these kinds of activities.[20] Muller et al.[18] mention as advantage that MCS enables monitoring on a high spatial resolution. This can be, e.g., useful in urban areas. Additionally, there are more and more devices on the market that can be connected to a smartphone. Examples are the plugin sensors of Sensorex (www.sensorex.com) and iQwtr: a device to measure the Secchi depth using a smartphone extension box.[22] However, a reliance on novel technologies may lead to an exclusion of potential participants.[7]

In MCS, data accuracy is a major concern as well.[11,20,21] Methods to increase data accuracy, such as participant reputation building and exclusion of participants that repeatedly enter erroneous data, can conflict with privacy.[20] Privacy is of a larger concern than in general citizen science, because more sensitive data are available.[20] For example, IP addresses and participant's movements may disclose someone's home address or office. Especially in situations in which images or audio material is shared, personal information may be disclosed as well.

Launch Phase

A lack of interest by the public in general is one of the main bottlenecks for citizen science projects.[17] At the start of the project, the organizing party should put effort in marketing and recruitment of participants.[5,16,19] A variety of media can be used to this end, ranging from press releases and magazine articles to flyers and presentations.[5] This recruitment strategy can be general or targeted at specific groups within society.[19] In the latter case, it is important that the recruitment methods match the desired audience and strategic partnering can be useful to reach the target audience.[5] This notion is important, as the typical profile of citizen scientists is far from a cross-section of society. Citizen scientists, like other volunteers, are higher educated, middle-aged, and employed.[23] Citizens with jobs related to environment are more likely to actively participate.[24] As a consequence, socioeconomically deprived areas are underrepresented in citizen science participants,[25] which was reflected in studies concluding that volunteers often have higher level incomes.[24] A large opportunity can be found reaching new groups of citizen scientists and increase their literacy.[7,17] These community groups may be difficult to reach though, as they are less involved with science[16] or cannot afford to accept unpaid work. This ethical concerns that the citizen science concept excludes people who cannot afford to work for free and that citizen science may lead to unfair job competition for junior scientists, stressed by Riesch and Potter,[26] were not explicitly mentioned in the literature included in our query.

Once participants are recruited, the participating citizens should be instructed how to collect data.[5,7,19] Training participants are important for three reasons. First, it is essential to have participants digest the materials.[5,7] Second, it provides citizens with safe practices and confidence in their own data collection skills.[5,7,19] Third, it ensures that citizens continue skill development.[7] Several authors agree on the two types of training given, ranging from supportive material (e.g., instruction videos or example material) to personal instructions (e.g., workshops).[5,7,19] In case of projects on a large geographic scale, it is beneficial to offer training regionally.[5,7]

In the launch of the campaign, motivations to start participating should be addressed.[16] The organization should communicate clearly about assumptions and expectations[6] in such a way that trust and legitimacy between actors are established.[2] More details on citizen's motivation can be found in *Citizen Motivation* section. Participants should be matched to suitable tasks, which can be performed in two ways.[16] Creating a pool of citizen science projects could serve this, as the citizens can choose which projects suit them best. Additionally, breaking down tasks into smaller building blocks would allow a better match between citizens and tasks as well and allows citizen to have control over their level of contribution. This second option will also enhance recruitment, as it implies offering a concrete task.

During Project Execution

As soon as the project is running, measurements will be flowing into a database and have to be treated according to the developed protocols for data analysis and interpretation.[5] During the project execution, it is important that the used tools enable the collection of metadata[18] and dissemination. The results should not only be disseminated within a professional circle, but also provided to citizens in an understandable manner. This key success factor as well as requirement to ensure common meta-ethical values (transparency, thrust, autonomy, and mutual learning[27]) was fairly mentioned by all authors.[2,6,7,16,17,19] Results should be actively distributed among citizens.[19] Several authors suggest a graphical representation of the results. Spatial maps were the most common method to display results of environmental citizen science monitoring according to Roy et al.[7] Bonney et al.[5] stress the importance of visualization in result feedback. Providing citizens insight into trend lines is suggested to increase the activity of participants.[5] Some authors[16,17] suggest that not just the results should be communicated, but also the use in management; i.e., how, where, and to what extent the results were applied in practice.

The organization can involve citizens in the interpretation and analysis of outcomes as an educational means according to Bonney et al.[5] Buytaert et al.[2] merely see this as a way to increase citizen power in decision making. It may empower citizens in discussions on the implications of science and technology to critically and autonomously consider the relevance and validity of research at stake and the authority of science.[9] This may lead to a better informed dialogue or debate instead of polarized discussions during which scientific truth is downsized to a simple for or against, yes or no.

In long-term projects, the participants should be retained as much as possible, as it leads to participants with a higher level of experience and consequently more reliable data.[19] Two lines of thought can be distinguished here. Cooper et al.[19] emphasize on organizational support for participants. They advise to provide rapid response to questions via a helpdesk and to establish an online community for participants. Rotman et al.[16] emphasize to increase task levels to keep challenging participants and to acknowledge the role of citizen motivations and how they change over time. Organizations should identify points where citizens reconsider their participation, such as after an initial monitoring cycle, and identify which motivational factors are important at that time. The program should be adapted accordingly. A more detailed description on (changing) citizen motivation is given in the next section.

Although citizen science data have the potential to overcome spatial and temporal representativeness of standard data,[18] the need for adequate documentation of the observation context challenges the composition of a sampling strategy.[2] In general, the processing, interpretation, and use of citizen science data in assimilation to traditional knowledge are difficult, especially because it is hard to quantify uncertainties.[2] Defining the role of citizen science data in decision support is a challenge as well.[2]

After the project is terminated, the output should be measured, the project should be evaluated, and results disseminated.[5] An evaluation could measure scientific outcomes, such as journal publications and educational outcomes, i.e., whether scientific literacy (the understanding of scientific content and processes) increased. Methods to measure scientific literacy can include[5] surveys, analysis of communication streams, in-depth interviews, and focus groups. The organizing party should formulate new strategies based on the outcome.[19]

CITIZEN MOTIVATION

Over 40 motivations and a-motivations (discouragements) were found and clustered based on the Self Determination Theory (SDT) of Ryan and Deci.[28] SDT proposes a classification based on an interpretation of psychological needs in social contexts. In their model, Ryan and Deci distinguish between intrinsic, extrinsic, and a-motivation. Intrinsic motivation stimulates behavior that is performed out of enjoyment or interest. Extrinsic motivation leads to behavior because it is instrumental to some separable consequence. Processes of internalization and integration are used to make behavior that is extrinsically motivated more self-determined. a-Motivational factors discourage to perform certain behaviors. The model in Table 1 is an extension of the model proposed by Kaufmann et al.[29] with addition of motivations found in literature on citizen science in environmental monitoring and volunteering. Furthermore, the classification is changed and tailored to the source of a motivational factor, which could be internal, external, or impersonal.[28]

Intrinsic Motivation

Intrinsic motivation is said to be the strongest,[28] which will make that citizens put a greater effort in the activity considered.[32] Intrinsic motivation is completely intrinsically regulated and means an activity is undertaken out of interest, enjoyment, or inherent satisfaction.[28] A reason often mentioned to participate in citizen science is enjoyment.[7,30,31] Whether an activity is 'fun' is personal. Kaufmann et al.[29] defined five factors that contribute to having fun. A variety in skills to be used, a tangible and complete task, autonomy in performing the task, receiving direct feedback from the job, and using the task to kill time are mentioned. Kaufmann et al. only distinguish

TABLE 1 | Citizen Motivations and Barriers Found in Literature and Categorized According to the Self-Determination Theory of Ryan and Deci (2000)

Motivation	a-Motivation	Extrinsic Motivation				Intrinsic Motivation
Regulatory styles	Nonregulation	External regulation	Introjected regulation	Identified regulation	Integrated regulation	Intrinsic regulation
Source	Impersonal	External	Somewhat external	Somewhat internal	Internal	Internal
Mechanisms	Nonintentional, nonvaluing, incompetence, and lack of control	Compliance, external rewards and punishments	Self-control, ego-involvement, and internal rewards or punishments	Personal importanceand conscious valuing	Congruence, awareness, and synthesis with goals of self	Interest, enjoyment, and inherent satisfaction
Motivations	Data not being used[16]	Payment[15,29]	Gaining reputation[29]	Feel responsible to do so[16,25]	Learn new skills[23]	Enjoyment-based (fun)[29–31]
	Not willing to collect for policy needs[7]	Human capital advancement/ improve skills[29]	Community identification[30]	Contribute to important cause[2,23,25,30,32]	Use variety of skills[23,29,33]	Pastime[23,29,30]
	Lack of confidence[33]	Action significance (external obligations or norms)[29]	I feel needed[30]	Contribute to science[31]	Learning new things[2,16,25,30,31,33]	It is beautiful/ amazing[7,25,31]
	Lack of resources[33]	Direct feedback[29]		Willingness to help or improve things[23,30]	Discover new things[31]	Was doing the activity already[16,25]
		Self-promotion/ signaling[2,16,29]		Joining with friends[2,30]	Do scientific research[16,31]	Interest in topic[16,25,31,33]
		Gain political influence[2,16]		Use it to teach others[31]	Social contact (meet others)[7,30,31]	Interest in particular project[7,31]
	Recording process[25]	Depth of involvement[7]	Complete work done by me[29]	Community impact involvement[16,30]	Exchange knowledge[33]	
	Power gap between scientist and volunteer[16]	Recognition of contribution[16]	Feeling control over scientific process[7]	Feedback on group contribution[16]	Task autonomy[7]	
		Scientific training[16]	Trust[16]			

Notes: Motivations in gray are applicable when participants reconsider their participation. Numbers refer to cited literature.

between intrinsic and extrinsic motivation, thus some of these factors will be placed under integrated regulation in the SDT framework.

Besides enjoyment, a personal interest in the topic[16,25,31,33] or in the particular project[7,31] could motivate people to participate as well. Participants in environmental monitoring mention that they have an interest in nature or in the case of ecological monitoring in the species they monitor. Interest in wildlife is reported to be the main motivation of participants in bird counts in the United Kingdom.[25] In the Leeds Garden Pond Survey and the BTO Garden Bird Watch, 38 and 53% of the participants respectively reported an interest in wildlife as their main motivation to participate. In Galaxy Zoo, 46% of participants reported to participate out of interest in astronomy.[31] Additionally, people may be impressed by the topic or area of the tasks.[7,25,31] For example, 25% of participants in the Galaxy Zoo project indicated that the beauty of the universe triggered participation.[31] Citizens are also considered to be intrinsically motivated for a citizen science activity if it matches their hobbies[16] or existing activities.[31] Examples can be nature photographers who combine photography with monitoring.[16] Equivalents for water monitoring could be sports fishermen who report on the fish population or water sports enthusiasts who measure water quality indicators while being out on the water.

Extrinsic Motivation

Integrated Regulation

Integrated regulations internalize motivations to a great extent and these motivational factors are considered fully internal as well and are driven by a desire for congruence and synthesis with goals or the self.[28] Besides enjoyment or personal interest, learning is considered a common motivation to participate as well.[16,23,25,30,31,33] Specifications of learning are discovery,[31] knowledge exchange,[33] and skill-related learning.[7] Such learning could focus on learning new skills[23] or combining several skills.[23,29,33]

A high skill variety in the tasks to be performed has a positive influence on the quality of results in online crowdsourcing.[29] Whether this applies as well to citizen science in environmental monitoring is unknown. Getting the chance to do scientific research can be a major motivation for citizens to participate as well.[16,31] This may be related to the fact that many participants are higher educated and have experience in science or environmental monitoring.[23]

Identified Regulation

Motivational factors that have a personal importance or appeal to the conscious values of a person are considered to be extrinsic motivations of the identified regulation type.[28] Participants in citizen science indicate that they want to make a contribution. This contribution could be to a cause that is important to them.[23,25,30] For example, one in five participants in bird counting indicate to participate because they want to make a contribution to nature conservation.[25] Contribution could also be aimed at enhancing scientific research, such as 22% of participants in Galaxy Zoo indicated.[31] This urge to make a contribution may originate from a moral obligation. Participants may feel responsible to make this contribution[16,25] or a need to help people or improve things.[23,30] Fifty-three percent of British volunteers indicated to volunteer because they want to help.[23] This feeling of contribution is important and should not be neglected by organizers of citizen science. After a while, people will reconsider participation.[28] Feedback on the contribution of the group to the cause of the project and seeing the impact of citizen science efforts on communities were identified as important.[16,30] In online crowdsourcing a test with equal tasks in three different level of meaning, there were lower dropout rates in groups that were given a meaningful context while performing the tasks.[29] Not only making a contribution on community level is important. Participants also indicated to participate in citizen science to do the activity together with friends[25,30] use it to educate other people.[31]

Introjected Regulation

Motivational factors that focus on self-control and ego-involvement are of the introjected type of extrinsic motivation and are driven by internal rewards or punishments.[28]Participation in citizen science can influence the reputation or self-esteem of participants. Participants can have a feeling that they are needed[30] or that their friends will think positively about them if they participate. Being part of a community when participating can be a motivation to join a program as well.[30] To continue participation, it is important that participants have a feeling of control over the scientific process.[7]

External Regulation

Externally regulated motivation is triggered by compliance to (social) norms or by external rewards and punishments.[28] In most projects in citizen science, there is some form of compensation. A financial reward though may work counterproductive. In online crowdsourcing, financial compensation is more common than in citizen science in environmental monitoring. Studies on Mechanical Turk (MTurk, an online marketplace) reveal that financial compensation may increase speed of task performance, but decrease quality.[15,32]A nonfinancial reward could be when citizens view participation as a career-building step.[16] Participation can be used to improve human capital by advancing one's skills[29] or to increase one's visibility on the job market.[16,29]

Participants may also be driven by external obligations or norms. Although they appear volunteers, external parties or social norms drive participation. Examples could be students who participate because their professor expects them to do so.[29] Feedback on the recorded process can be considered a form of external reward as well.[16,29] This feedback is of even greater importance when participants reconsider their participation. Rotman et al.[16] found that citizens are more likely to continue participation if their individual contribution is valued throughout the project. Important motivational factors in on-going participation are further a deeper involvement, e.g., by taking part in data analysis,[7] and having the opportunity to get advanced scientific training.[16] In water resource management contexts, citizens may participate to gain political leverage in the community.[2] Rotman et al.[16] describe this as self-efficacy, a desire to have scientific influence and to be known.

a-Motivation

a-Motivational factors are of the impersonal type. They originate from a lack of control or a feeling of incompetence or not being valued.[28] Not using the collected data is the most important a-motivational factor in citizen science. Citizens may decide not to participate if they see no personal application for the collected data,[33] but also if they feel there is no intention of the authority to use the data.[16] More individual factors, such as a lack of confidence in one's ability to participate or a lack of resources,[33] may hamper participation as well. In the phase of reconsidering participation, Hobbs and White[25] reported that volunteers dropped out bird counting programs because the recording process did not appeal to them. If participants experience a power gap between the expert and themselves and if they feel undervalued they may dropout as well.[16]

CONCLUDING REMARKS

We performed a structured literature review to find key success factors for citizen science and motivations for citizens to engage and keep interest in citizen science projects. Success factors were categorized according to the project phase with a specific focus on MCS. At project formulations, success factors include clear definition of goals, methods, and roles and responsibilities. At the project start, recruitment and training that address citizen motivation are keys. During project execution, feedback to citizens, actual use of the data, and process evaluation are essential. In all phases, common meta-ethical values trust, transparency, autonomy, and mutual beneficial practice need to be ensured. Motivations were categorized according to Self-Determination Motivation Theory. Intrinsic motivations include interest in topic and pastime. Extrinsic motivations include social contacts, reputation, learning, and payment. Data not being used, lack of confidence in the use of the data or lack of resources were important motivations not to participate in citizen science campaigns.

The presented overviews provide helpful instruments for designers and implementers of citizen science campaigns, but are no blueprint. User-centered design approaches and pilot studies are strongly recommended when initiating a citizen science project for data collection and awareness raising.

ACKNOWLEDGMENT

We thank two anonymous reviewers for their valuable comments on an earlier version of this manuscript.

REFERENCES

1. RIVM. *Impact of Climate Change on Water Quality in the Netherlands*. RIVM, Bilthoven, the Netherlands; 2010.
2. Buytaert W, Zulkafli Z, Grainger S, et al. Citizen science in hydrology and water resource management: opportunities for knowledge generation, ecosystem service management and sustainable development. *Front Earth Sci* 2014, 2:26.
3. Wehn U, Evers J. Citizen observatories of water: social innovation via eParticipation. *ICT Sustain* 2014, 4S:10.
4. OECD. *Water Governance in the Netherlands: Fit for the Future? OECD Studies on Water*. Paris, France: OECD Publishing; 2014.
5. Bonney R, Cooper CB, Dickinson J, Kelling S, Phillips T, Rosenberg KV, Shirk J. Citizen science: a developing tool for expanding science knowledge and scientific literacy. *BioScience* 2009, 59:977–984.
6. Silvertown J. A new dawn for citizen science. *Trends Ecol Evol* 2009, 24:5.
7. Roy HE, Pocock MJO, Preston CD, Roy DB, Savage J, Tweddle JC, Robinson LD. Understanding citizen science and environmental monitoring. Final report on behalf of UK-EOF. NERC Centre for Ecology & Hydrology and Natural History Museum; 2012.
8. Cohn JP. Citizen science: can volunteers do real research? *BioScience* 2008, 58:192–197.
9. Lidskog R. Scientised citizens and democratised science: re-assessing the expert-lay divide. *J Risk Res* 2008, 11:69–86.
10. Kaku M. *Physics of the Future: How Science Will Shape Human Destiny and Our Daily Lives by the Year 2100*. Westminster: Random House LLC; 2012.

11. Lane ND, Miluzzo E, Lu H, Peebles D, Choudhury T, Campbell AT. A survey of mobile phone sensing. *IEEE Trans Commun Mag* 2010, 48:140–150.

12. Hill D, Kerkez B, Rasekh A, Ostfeld A, Minsker B, Banks MK. Sensing and cyberinfrastructure for smarter water management: the promise and challenge of ubiquity. *J Water Resour Plan Manage* 2014, 140:01814002.

13. Fraternali P, Castelletti A, Soncini-Sessa R, Vaca Ruiz C, Rizzoli AE. Putting humans in the loop: social computing for water resources management. *Environ Model Software* 2012, 37:68–77.

14. Bryman A. *Social Research Methods*. 4th ed. Oxford, United Kingdom: Oxford University Press; 2012.

15. Rogstadius J, Kostakos V, Kittur A, Smus B, Laredo J, Vukovic M. An assessment of intrinsic and extrinsic motivation on task performance in crowdsourcing markets. In: *ICWSM*; 2011.

16. Rotman D, Preece J, Hammock J, Procita K, Hansen D, Parr C, Jacobs D. Dynamic changes in motivation in collaborative citizen-science projects. In: *ACM*; 2012.

17. Conrad CC, Hilchey KG. A review of citizen science and community-based environmental monitoring: issues and opportunities. *Environ Monit Assess* 2011, 176:273–291.

18. Muller CL, Chapman L, Johnston S, Kidd C, Illingworth S, Foody G, Leigh RR. Crowdsourcing for climate and atmospheric sciences: current status and future potential. *Int J Climatol* 2015, 35:3185–3203.

19. Cooper CB, Dickinson J, Phillips T, Bonney R. *Citizen Science as a Tool for Conservation in Residential Ecosystems*. *Ecology and Society* 2007, **12**:11.

20. He D, Chan S, Guizani M. User privacy and data trustworthiness in mobile crowd sensing. *IEEE Trans Wirel Commun* 2015, 22:28–34.

21. Khan WZ, Xiang Y, Aalsalem MY, Arshad Q. Mobile phone sensing systems: a survey. *IEEE Commun Surv Tut* 2013, 15:402–427.

22. Ghezehegn SG, Steef P, Hommersoma A, Nils DR, Culceab O, Krommendijk B. Hyperspectral remote sensing for estimating coastal water quality: case study in coast of Black Sea, Romania. In: *Proceedings of SPIE*; 2014, 9239.

23. Edwards RG. The 'citizens' in citizen science projects: educational and conceptual issues. *Int J Sci Educ B* 2014, 17:376–391.

24. Koehler BK, Koontz TM. Citizen participation in collaborative watershed partnerships. *Environ Manage* 2008, 41:143–154.

25. Hobbs SJ, White PCL. Motivations and barriers in relation to community participation in biodiversity recording. *J Nat Conserv* 2012, 20:364–373.

26. Riesch H, Potter C. Citizen science as seen by scientists: methodological, epistemological and ethical dimensions. *Public Underst Sci* 2014, 23:107–120.

27. Davies SR, Horst M. *Science Communication: Culture, Idenity and Citizenship*. London: Palgrave MacMillan; 2016.

28. Ryan RM, Deci EL. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *Am Psychol* 2000, 55:68.

29. Kaufmann N, Schulze T, Veit D. More than fun and money: worker motivation in crowdsourcing—a study on mechanical turk.In: *Proceedings of the 17th American Conference on Information Systems*; 2011.

30. Bramston P, Pretty G, Zammit C. Assessing environmental stewardship motivation. *Environ Behav* 2011, 43:776–788.

31. Raddick MJ, Bracey G, Gay PL, Lintott CJ, Murray P, Schawinski K, Vandenberg J. Galaxy zoo: exploring the motivations of citizen science volunteers. *Astron Educ Rev* 2010, 18.

32. Chandler D, Kapelner A. Breaking monotony with meaning: motivation in crowdsourcing markets. *J Econ BehavOrg* 2013, 90:123–133.

33. Gharesifard M, Wehn U. To share or not to share: drivers and barriers for sharing data via online amateur weather networks. *J Hydrol* 2016, 535:181–190.

