LOOK ACADEMIC PUBLISHERS
OPEN ACCESS

INTERNATIONAL JOURNAL OF ENVIRONMENTAL & SCIENCE EDUCATION
2017, VOL. 12, NO. 10, 2153-2175

A context Specific Framework Approach to Community-Based Monitoring

Irene Muller[c]

North-West University, Vanderbijlpark Campus, SOUTH AFRICA

ABSTRACT

This paper aims to outline the development of a generic citizen science framework that can be implemented at educational institutions such as university campuses and schools. The framework was developed as a reflective practice after implementation of a community-based water-monitoring project with pre-service teachers and school learners at the North-West University (Vaal Campus), South Africa. The proposed generic citizen science framework was designed by the researcher as an application of various available citizen science models to the North-West University (Vaal Campus) water-monitoring project. The designed framework is, therefore, the product of document reviews and reflection on the real-world practice of a community-based water-monitoring project. The implementation of citizen science in communities, and specifically a community-based water-monitoring project, requires planning and implementation of diverse complex concepts at different levels. Adhering to previous research and refining recommendations with practical findings from a real-life project aid to develop a framework of citizen science that can provide guidance to plan future citizen science projects at educational institutions. The proposed framework can provide sound guidance to citizen science project leaders of different educational institutions regarding citizen science projects. The proposed framework aligns literature and practical experience to create a simplistic view on citizen science projects. The proposed framework can be considered as the "big picture" in citizen science and may guide future projects as a departure point when planning a project.

KEYWORDS
citizen science; community-based monitoring; participation; adaptive management; framework

ARTICLE HISTORY
Received 23 October 2017
Accepted 07 November 2017

Introduction

Water monitoring and water health are issues of global concern, as indicated by the notion and involvement of world leaders during different summits. In 1987 the World Commission on Environment and Development

CORRESPONDENCE Irene Muller ✉ 12765074@nwu.ac.za

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(WCED) outlined the concept of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). In 1992 The United Nations' Earth Summit at Rio de Janeiro defined sustainable development as a long-term perspective with broad-based participation in policy formulation, decision-making and implementation. Its successor, the Johannesburg Summit on Sustainable Development of 2002, posed a challenge to civil society to embrace science in order to prepare nations and communities to take responsible action regarding the environment (Potschin and Haines-Young, 2006).

Citizen science is a concept responding to the call for sustainable development. Citizen science also goes by the name of "community science" and includes community-based monitoring as an approach where concerned citizens, industries, academia, community groups and local institutions collaborate to monitor, track and respond to environmental issues (Buytaert and Zulkafli, 2014; Kruger and Shannon, 2010).

Citizen science projects are initiated by individuals, universities and global organisations (Buytaert and Zulkafli, 2014). New developments, such as inexpensive, robust sensors, new information and communication technologies such as cellular networks and the internet, provide for a more dynamic and interactive approach to citizen science (Buytaert and Zulkafli, 2014). In South Africa most citizen science projects are linked to biodiversity (SANBI, 2016).

The monitoring of physical aspects of natural resources in South Africa is reported in a less significant way. The Mvula Report, *The potential of civil society organisations in monitoring and improving water quality* (Munnik *et al.*, 2011), indicated that no large-scale citizen science monitoring on physical aspects exists in South Africa. The report indicated that citizen monitoring is an untapped and potentially valuable area in South African water quality monitoring (Munnik *et al.*, 2011).

Other South African studies include Rivett *et al.* (2012) project where borehole operators report on pH, turbidity and conductivity of groundwater supplies in boreholes via a cellular phone app. Tandlich *et al.* (2014) reported on the monitoring of rainwater quality in the Eastern Cape by using a hydrogen-sulphide test kit to detect microbial contamination in rainwater. Groundtruth, a multidisciplinary environmental company initiated The Mpophomemi Sanitation Education Project (MSEP) in Mpophomemi, KwaZulu-Natal., iniciated in 2011 focuses on sanitation and toilet etiquette, biodiversity and environmental health, as well as the monitoring and reporting of sewage spills. The MSEP accentuates education as a force in citizen science that should be harnessed (McLouglin, 2015).

Recently some South African school learners have been involved in a citizen science mini-stream assessment scoring system (SASS) project. The SASS project was run in Hilton, KwaZulu-Natal and used the composition of macro-invertebrates as an indication of water quality (Matthews, 2014). Despite the remarkably lively field of water-related monitoring in South Africa, the researcher is of the opinion that the water-monitoring project of the North-West University (Vaal Campus) has substantial prospects. It is apparent that a citizen science water-monitoring project, which focuses on the collection of physical data by both pre-service teachers and school learners, may close the gap in current citizen science practice in South Africa. Moreover, involving pre-service teachers and more than one educational institution, namely a university, a university campus and communal schools in a citizen science project, will be a first in South Africa.

This paper will emphasise the construction of a citizen science framework as reflective practice after the completion of a citizen science project in the form of community-based water monitoring at the North-West University (Vaal Campus) and communal schools. Maxwell (2013:72) indicates that to be able to construct a framework, four sources are needed, namely experiential knowledge, theory, exploratory research and thought experiments. The researcher argues that all of these sources were present in the North-West University (Vaal Campus) water-monitoring project, which enabled her to construct a framework. This is motivated as follows: the researcher performed monitoring activities with both pre-service teachers at the North-West University (Vaal Campus) water storage resource and in community school classrooms – that is, experiential knowledge. She used the models or constructions of other researchers to build on a theory regarding citizen science projects – that is, theory; she performed a concurrent, embedded mixed method research design and allowed the research study to reveal rich, descriptive data – that is, exploratory research was done and the initial reflective journal and reflective notes written by the researcher for the duration of the research enabled the researcher to have a comprehensive picture on the monitoring project.

Firstly, the background of the community-based monitoring project is discussed. Secondly, relevant concepts utilised when constructing a citizen science framework are clarified. Thirdly, the findings from available citizen science models in the creation of two framework prototypes are discussed. Finally, the relevance of the constructed citizen science framework is highlighted.

Background

The community-based water-monitoring project of the North-West University (Vaal Campus) incorporated pre-service teachers and Grade 10 school learners in physical science as participants. The North-West University (Vaal Campus) provides an ample water storage resource to perform water quality tests and was used as training ground for water-monitoring activities with pre-service teachers. All of the involved pre-services teachers were majoring in physical science in the BEd programme and needed to perform practical work as demanded by the formal curriculum. Performing water quality tests on the campus water storage resource, the pre-service teachers gained skill and knowledge regarding water quality. After performing repeated monitoring activities on the campus water storage resource, the pre-service teachers went to local schools during their work-integrated learning (WIL) opportunity and performed the same experiments on communal water samples provided by Grade 10 physical science school learners. The water quality tests were performed by using the Somerset Water Quality test kit. No laboratory was required to perform the tests and tests were performed in ordinary classrooms on the school ground. Grade 10 physical science school learners learnt from and

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worked with the pre-service teachers while performing the water quality tests on water samples at schools. The Grade 10 Physical Science Curriculum and Assessment Policy Statement (CAPS) provides for water quality tests to be performed as part of practical assessment (DBE, 2011). Rand Water, as the national expert in water quality monitoring, was involved in this research study as a guiding agent to check on monitoring activities, to validate findings of monitoring practices and to aid with the management of the water storage resource at the North-West University (Vaal Campus), that is, adaptive management. Participatory action research methodology was utilised to direct the water-monitoring project. Action research consists of four phases, namely plan, act, develop and reflect. The researcher regarded the construction of a citizen science framework as a response to the reflective phase of action research.

Concept clarification

Citizen science

Citizen science is described as a process in which members of civil society (citizens), literally novices, become actively involved in science as researchers (Buytaert and Zulkafli, 2014; Whitelaw *et al.*, 2003). The data-gathering objectives and protocols are usually established by scientists or science research managers (Conrad and Hilchey, 2011; Fernandez-Gimenez *et al.,* 2008).

Community-based monitoring

Citizen science, also known as "community science", includes *community-based monitoring* as an approach where concerned citizens, industries, academia, community groups and local institutions collaborate to monitor, track and respond to environmental issues (Buytaert and Zulkafli, 2014; Kruger and Shannon, 2010). Community-based monitoring implies the direct, active involvement of the local community in monitoring, either by participating in monitoring efforts or by training local workers to carry out the monitoring project (Conrad and Hilchey, 2011). Universities can play a collaborative role in community-based monitoring. University personnel can serve as expert advisors, facilitators, trainers and encouragers to motivate students to partake in activities. Aid from universities, in the form of available free working space, internet access and available funding, enhances community-based monitoring (Savan *et al.*, 2003). The community-based monitoring project at the North-West University (Vaal Campus) was identified as a multiparty monitoring project, which involved multiple individuals with different interests and forms of expertise in the project.

Participation

Public participation refers to the way in which role-players partake in monitoring. "Governance" is another term used for public participation (Lawrence, 2006). Participation of society comes in variable scales and has been categorised to fit either in a top-down or bottom-up governance structure (Lawrence, 2006). Participation can be:

Passive, when the public acts as a spectator and does not interfere with actions;
Through consultation, when the public contributes information to a central authority;
Functional, when the public contributes information and is engaged in implementing decisions;
Collaborative, when the public works with the government to decide what is needed, and contributes with knowledge;
Transformative, when locals make and implement decisions with expert support if needed; or
Interactive, whereby people participate by taking initiatives that are independent of institutional actions (Lawrence, 2006).

Collaborative participation refers to multi-party community-based monitoring groups and involves co- or adaptive management. This type of participation yields more decision-making power than other types of monitoring and governs from the "bottom up" (Conrad and Hilchey, 2011; Lawrence, 2006). The water-monitoring project at the North-West University (Vaal Campus) is regarded as collaborative participation. The water-monitoring team gained knowledge of the water storage resource on campus and aided campus management and technical services with adaptive management proposals.

Adaptive management

Holling (1973:23) proposes adaptive management as management that has the ability to overcome limitations of command-and-control mechanisms in natural resource management. Adaptive management treats management actions as structured experiments, which include attempts to document and learn from both planned and unplanned environmental surprises (Huitema *et al.*, 2009). Skelcher *et al.* (2005:89) distinguish between two types of adaptive management. *Technocratic adaptive management* refers to learning through experimentation and focuses on learning only, while *non-technocratic adaptive management* contains both the learning and co-management components.

The North-West University (Vaal Campus) water-monitoring project fits the description of a non-technocratic adaptive approach to management, as the project involved both learning and the provision of adaptive management proposals to manage the campus water storage resource.

Models and frameworks

In this research study, a model is regarded as an approximate representation of an object that cannot be seen (Miller and Spoolman, 2012:34). A framework is regarded as a basic conceptual structure that aligns the understanding of the researcher with existing knowledge (Nieuwenhuis, 2007:111).

Methodology

The design of a framework is relevant, as the researcher acknowledges contributions of various researchers and combines the existing knowledge in a new understanding of citizen science framework. To enable the researcher to construct a unique citizen science framework a thorough literature review was

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done on available citizen science models. The researcher reviewed seven models proposed for citizen science projects. Each of the models provided usable information. From these models the researcher created two prototype frameworks, which she tested by reflecting on the North-West University (Vaal Campus) water-monitoring project. She finally designed a unique framework by using the prototypes as well as a new approach to citizen science projects. In the next section, the models are summarised and the useful information relevant to the North-West University (Vaal Campus) community-based monitoring project is indicated.

Literature research on models and frameworks

Model 1: Monitoring schemes of Danielsen et al. (2008)

Danielsen *et al.* (2008) classified monitoring schemes in five categories, namely:

Externally driven, professionally executed monitoring does not involve local stakeholders. Government agencies and global schemes often use this type of scheme.
Externally driven monitoring with local data collectors uses local stakeholders only in data collection. The design, analysis and interpretation are done by professional researchers far from the site.
Collaborative monitoring with external data interpretation involves local stakeholders in data collection and management-oriented decision-making. The design of the scheme and data analysis is undertaken by external scientists.
Collaborative monitoring with local data interpretation involves local stakeholders in data collection, interpretation or analysis of data and management decision-making. Scientists may provide advice and training. This monitoring scheme aids with the creation of local ownership.
Autonomous monitoring involves local stakeholders in all steps of the monitoring process. There is no involvement by external agencies, except to advocate the continued relevance of the scheme.

Model 2: The three models of Pouliot (2009)

In 2009 Pouliot performed a citizen science study on cellular telephone controversies. Pouliot (2009) reported on her findings by indicating three possible models, namely:

The *deficit of public education model* indicates that scientific researchers inform the public about scientific issues. This model accentuates the dual divide between citizens' and scientists' ability to express their views.
The *public debate model* allows scientists and citizens to interact in spaces of public discussions. Pouliot (2009) indicated that referendums, surveys, focus groups and symposia act as public discussion spaces.
The *co-production of knowledge model* is characterised by the integrations of scientific knowledge into decision-making processes. This model regards scientific knowledge to be the product of processes in which scientists and citizens collaborate closely (Pouliot, 2009).

Model 3: Models for Public Participation in Scientific Research by Bonney et al. (2009a).

Bonney *et al.* (2009a) distinguished between three major categories of public participation models, namely:

Contributory projects are designed by scientists and community members may contribute data.
Collaborative projects are designed by scientists and members of the community contribute data, as well as aid in refining the project design, analysing the data and disseminating findings.
Co-created projects are designed by scientists and community members. The community members are actively involved in most or all of the steps of the research process.

Bonney *et al.* (2009a) provided a model for public participation based on the steps of the scientific process. The steps of the scientific process consist of the following:

Choose or define question(s) for study;
Gather information and resources;
Develop explanations (hypotheses);
Design data collection methodologies;
Collect samples and/or record data;
Analyse samples;
Analyse data;
Interpret data and draw conclusions;
Disseminate conclusions or translate results into action; and
Discuss results and ask new questions.

Model 4: The Citizen Science Programme Model of Bonney et al. (2009b)

In another publication, Bonney *et al.* (2009b) indicated that the citizen science programme model consists of the following nine steps:

Choose a scientific question;
Form a scientist/educator team;
Develop, test and refine protocols, data forms and educational support materials;
Recruit participants;
Train participants;
Accept, edit and display data;
Analyse and interpret data;
Disseminate results; and
Measure outcomes

From the last steps indicated by Bonney *et al.* (2009b), it can be concluded that the main difference from the publication by Bonney *et al.* (2009a) is the inclusion of the recruitment and training of participants.

Model 5: Framework for a multi-scale citizen science project by Newman et al. (2011)

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Newman *et al.* (2011) indicated that citizen science projects are designed for multiple purposes, which may include scientific research, social empowerment, environmental education and youth career development. The level of participation of citizen scientists determines the project to be contributory, collaborative or co-created (Newman *et al.*, 2011). The amount of participants in projects as well as the data management also determines the structure of the project. All citizen science projects determine their own scope, scale, activities and level of support, which is known as the "intra-project dimension". Newman *et al.* (2011) reported that effective projects include the following in their intra-project dimension:

Define/choose a research question;
Gather information and resources;
Design data collection methods;
Collect data;
Analyse data;
Interpret data and draw conclusions;
Disseminate results; and
Discuss results.

Newman *et al.* (2011) developed a second framework, which includes the scope, scale and activities of citizen science projects.

Model 6: Typology of citizen science of Wiggins and Crowston (2011)

Wiggins and Crowston (2011) indicated that all citizen science projects are concerned with scientific, organisational and technology issues. These researchers distinguished between five types of citizen science projects, namely:

Action-oriented citizen science projects encourage participants to intervene in local concerns.
Conservation projects support environmental stewardship and natural resource management.
Investigation projects focus on scientific research where data are collected from the physical environment. Education is not always an explicit goal of investigations, although educational material is provided and structures might exist which support on-going learning.
Virtual projects are all computer-based mediated with no physical elements. Tasks are performed through a web portal where participants answer related questions. This top down approach to research is often purely academic in nature.
Education projects put the emphasis on outreach, learning and the developing of scientific skills rather than the gathering of scientifically valid results. Education projects aim to provide informal learning opportunities to all participants through formal curriculum material. Education projects are organised top-down and must involve multiple types of participants.

Model 7: Public participation models of Shirk et al. (2012)

Shirk *et al.* (2012) indicated that the degree of public participation in citizen science projects can be quantified, compared and standardised. These researchers defined the *degree of participation* as the extent to which individuals are involved in the process of scientific research. To Shirk *et al.* (2012) the *quality of participation* is described as the extent, to which the goals and activities of a project align with, respond to and are relevant to the needs and interests of the public participants. High-quality participation is, therefore, supported by credibility, trust, fairness, responsiveness and relevance. The degree and quality of participation determine the categories of Shirk *et al.* (2012) for projects, namely:

Contractual projects: communities ask professional researchers to conduct a scientific investigation and report on the results.
Contributory projects: scientists design a project and members of the public contribute data.
Collaborative projects: scientists design a project, community members contribute data and aid to refine the project design, analyse the data and disseminate findings.
Co-created projects: scientists and members of the public work together and design the project. The public participants are actively involved in most or all aspects of the research process.
Collegial contributions: non-credentialed individuals conduct the research independently, with varying degrees of expected recognitions by institutionalised science or professionals.

The summary of the different citizen science models aids the researcher to conclude that the models of Bonney *et al.,* (2009a and 2009b), Newman *et al.*, (2011) and Shirk *et al.*, (2012) aim to classify citizen projects according to the involvement of participants. Bonney *et al.* (2009a and 2009b) and Newman *et al.* (2011) used a checklist approach, based on alternative steps of the scientific method as departure point for model design. The model of Danielsen *et al.* (2008) focused on monitoring practices and the collection, management and ownership of collected data. Pouliot (2009) viewed decision-making and the way in which findings are communicated in a citizen science project as the identification tool. Wiggins and Crowston (2011) regarded the aim of the citizen science project, whether it is action, conservation, investigation, virtual or education, as the identification tool.

Other aspects to take into account when designing a citizen science model

Cooper *et al.* (2007) reasoned that citizen science has the ability to become a new conservation strategy due to the dual goals of promoting learning and social change. Cooper *et al.* (2007) listed seven steps in their *Citizen Science Tool,* namely procedure to establish goals; recruitment and marketing; training of participants; retention of participants; data collection and organisation; feeding back results; and management recommendations.

Dickenson *et al.* (2012) indicated that the use of affected populations in citizen science research is a way to generate ecological knowledge, inquiry and place-based nature experiences for the public. The use of participants of different backgrounds and abilities increases the likelihood of new innovation and inventions. Alender (2016) indicated that the motivation of citizen scientists is crucial. Motivations are categorised as follows: values – concern for others;

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understanding; social; career; ego protection to escape from negative feelings and ego enhancement – personal growth and self-esteem.

Findings on literature-researched models and frameworks as applicable to the North-West University (Vaal Campus) community-based water-monitoring project

The water-monitoring project of the North-West University (Vaal Campus) agrees with the collaborative monitoring scheme with local data interpretation of Danielsen *et al.* (2008). This is motivated as follows: the pre-service teachers and Grade 10 physical science learners were the primary participants to collect and interpret data. The researcher and scientists from Rand Water, the expert group, trained the pre-service teachers and learners to perform monitoring duties. One of the notions of the research study was to raise awareness of water status and water quality – that is, local ownership.

Pouliot's (2009) co-production of knowledge model linked well with the intent of the water-monitoring project of the North-West University (Vaal Campus). Participants collaborated at different levels and with diverse impacts on the project, but all contributed towards the social knowledge gained in the project.

The researcher regards both works of Bonney *et al.* (2009a and b) to be comprehensive in providing guidance to construct a citizen science model for the water-monitoring project at the North-West University (Vaal Campus). This is motivated as follows: the *co-created model* of Bonney *et al.* (2009a) is most applicable to the water-monitoring project of the North-West University (Vaal Campus). The researcher and experts of Rand Water decided on the choice of scientific equipment and the parameters which would be monitored. The pre-service teachers developed workable procedures to collect data within an hour and a half at seven monitoring points. Pre-service teachers, who developed sound knowledge and skills, were able to assist Grade 10 learners in classrooms with monitoring activities. The researcher, Rand Water scientists, pre-service teachers and Grade 10 physical science learners analysed and interpreted the data. All of these participants were able to disseminate and communicate findings.

The researcher is of the opinion that the engagement of pre-service teachers on campus and in schools (therefore, on two levels of participation) regarding community-based monitoring can be regarded as a project with a new audience. This review and application of models and the aim to create a framework for citizen science projects also adhere to new citizen science projects.

The steps of the intra-project dimension of Newman *et al.* (2011) agree with the steps as indicated by Bonney *et al.* (2009a). The inter-project dimension indicates the degree to which projects coordinate with other programmes. Inter-project activities may include data sharing through collaborative meetings, how data meet standards, methods to address data sensitivity and the degree to which data are used to address problems. A framework developed by Newton *et al.* (2011) aided to determine the exact position of the water-monitoring project at the North-West University (Vaal Campus) regarding social, spatial and temporal scales. The main purpose of the second framework is to position a project in relation to other projects which share the same data and methods.

The education project of Wiggins and Crowston (2011) relates well with the North-West University (Vaal Campus) water-monitoring project. The informal learning opportunities between the pre-service teachers and various other participants, such as school learners, Rand Water experts and campus management representatives, provided for mutual learning between different groups of participants. The researcher initially organised the project; therefore, a top-down approach was followed. Once the pre-service teachers got involved in the project, they realised the potential of the project to impact water quality in communities and a bottom-up approach emerged, which abled the pre-service teachers to solve water quality concerns in their own communities.

The water-monitoring project at the North-West University (Vaal Campus) can be categorised as a collaborative project (Shirk *et al*., 2012). This is motivated as follows: the researcher designed the project, but the pre-service teachers and Rand Water officials, as monitoring experts, aided to refine the design. Regarding quantity, the pre-service teachers were fewer in number (eight), but they spent more time performing monitoring activities (about ten activities (one and a half hour per activity) on campus and six activities (one and a half hour each) at schools. The learners were larger in numbers (300-400), but spent less time monitoring (one and a half hour).

Regarding the work of Cooper *et al.* (2007), the researcher acknowledges the retention of volunteers and management recommendations, which relate to adaptive management as a new criterium for a framework. The notions of Dickenson *et al.* (2012) proofed to be true for the water-monitoring project of the North-West University (Vaal Campus). The participants had different backgrounds and abilities in the project. The findings of Alender (2016) are valuable for this research study, as they link well with the experience of the research study, where the researcher noticed that participant motivation is crucial for the success of the project.

Application of literature-researched finding on citizen science models and frameworks

In order to develop a citizen science framework for the North-West University (Vaal Campus) that needs to be applicable to other community-based citizen science projects, the researcher proposed a set of steps. These steps act as reflective questions on the water-monitoring project to aid with increased understanding of the project and associated concepts:

Step 1: Indicate project goals and outcomes on the template of Bonney *et al.* (2009a).
Step 2: Use the steps of the scientific method in the citizen science programme model of Bonney *et al.* (2009b) to indicate the intra-project dimension.
Step 3: Use the framework for multi-scale citizen science support of Newman *et al.* (2011) to determine the scope, scale activities and system approach.

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Step 4: Use the second framework of Newman *et al.* (2011) to determine the inter-project dimension of the water-monitoring project at the North-West University (Vaal Campus) in relation to other citizen science projects in South Africa.
Step 5: Use all available information to create prototypes of a model for citizen science.
Step 6: Test the created prototype models for citizen science by applying it to the water-monitoring project of the North-West University (Vaal Campus) and refine the prototype models.
Step 7: Construct a unique model from various prototype models.

Following the seven-step-process, the researcher created the following summary of the North-West University (Vaal Campus) monitoring project in a table of outcomes per step:

Table 1. Outcome of the seven-step-process to create a citizen science framework, as related to the North-West University (Vaal Campus) water-monitoring project

Step and related researcher	Criteria	Outcome for North-West University (Vaal Campus) water-monitoring project
1 Bonney *et al.* (2009a)	Background	Water storage resource North-West University (Vaal Campus)
	Informal science education	Knowledge: subject; scientific method; process skills
	Training	Rand Water visit; on campus
	Measurement of outcomes	Open-ended questions on experience of participants; scientific report
2 Bonney *et al.* (2009b)	Intra-project dimension Nine steps of scientific method	Follow the steps of the scientific method; deliver and communicate results in scientific format
3 Newman *et al.* (2011)	Scope	Service to the North-West University (Vaal Campus) – focused
	Scale	Short term – individuals and community
	Activities	Collaborative; local
	System approach	Experimental, innovation, design and research
4 Newman *et al.* (2011)	Inter-project comparison of North-West University (Vaal Campus) project with others in South Africa	Corresponds well with the ADU Bird Project (on-going) and Tandlich *et al.* (2014) rainwater project in South Africa
5 Prototype 1: Dimension	Focus on the three domains of	Three dimensions

framework	transdisciplinary research	Social – participation Knowledge – gained Environmental – impact on environment
5 **Prototype 2: Activity-based framework**	Focus on project, data and participants	Project type: collaborative Data: qualitative: participant experience Quantitative: water quality parameters Participants: diverse – expert to novice
6 **Test the information of the North-West University (Vaal Campus) water-monitoring project against prototypes**	Apply the information of the North-West University (Vaal Campus) water-monitoring project	Reflect on the most suitable prototype – Refine prototype

After completion of Step 4, the researcher constructed the inter-project dimension model of the water-monitoring project at the North-West University (Vaal Campus) by comparing it, regarding social, spatial and temporal scale, with three other significant citizen science projects in South Africa. Figure 1 displays the position of the North-West University (Vaal Ccampus) water-monitoring project in comparison to three other South African studies: the ADU Bird Project, which is regarded as an ongoing flagship project for biological monitoring in citizen science; the Rainwater Project of Tandlich *et al.* (2014), which was a short-term project that focused specifically on physical variables of water; and the MiniSASS Project that is ongoing and involves primary school learners as data collectors in biological monitoring. Figure 1 also displays the inter-project dimension of the mentioned projects.

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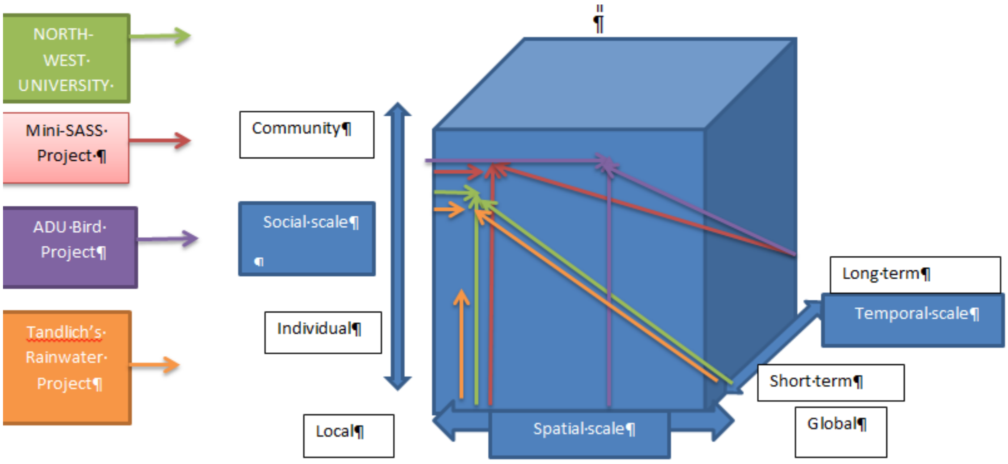

Figure 1. The inter-project dimension of the water-monitoring project (North-West University, Vaal Campus) in comparison to other citizen science projects in South Africa (Newman *et al.*, 2011:226).

From the inter-project dimension, the researcher concluded that the so-called "sweet spot" (where arrows of the three scales meet) of the North-West University (Vaal Campus) water-monitoring project corresponds with that of the Mini-SASS as well as the Rainwater Project of Tandlich *et al.* (2014). This confirms to the researcher that the North-West University (Vaal Campus) water-monitoring project was on target with other citizen science initiatives in South Africa. The ADU Bird Project, which runs over a more extended period of time, differs from the three other projects regarding spatial and temporal or long-term scales.

The researcher initiated two prototype frameworks, namely the dimension and activity-based frameworks from the available literature, as a reflective practice on the project. The dimension framework was designed according to the transdisciplinary nature of the research project by focusing on the social, knowledge and environmental dimensions. The social dimension of the dimension framework aims to display the type of participation of participants, the knowledge dimension aims to indicate what is learnt in the project and the environmental dimension displays the adaptive management initiative of the project. All three dimensions are linked and influence one another.

The activity-based framework focuses on three activities, namely the type of project; the data – how data are collected – and the objectives with the collected data; and the participants and their role in the project.

In Figures 2 and 4 the prototype frameworks are displayed. In Figures 3 and 5 each prototype framework indicates the real-world relevance of the prototype by indicating the functionality of the framework when adding information of the North-West University (Vaal Campus) water-monitoring project.

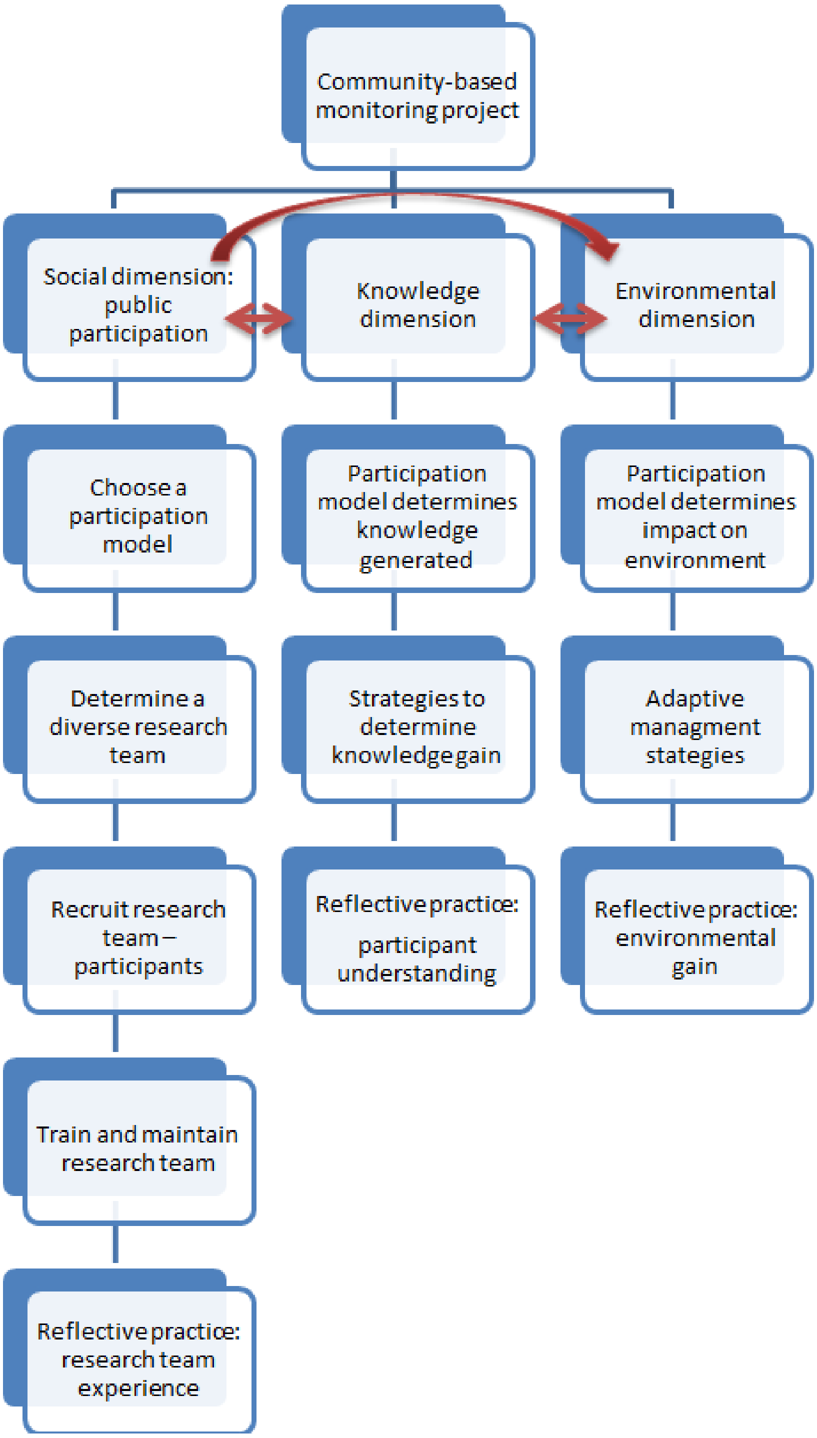

Figure 2. Prototype framework 1: The dimension framework

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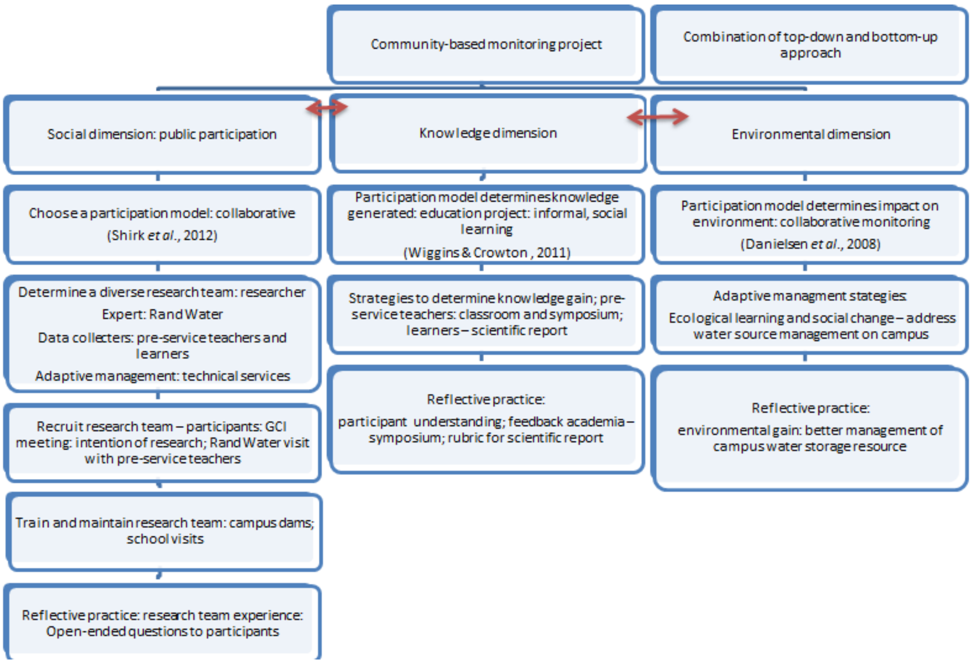

Figure 3. Application prototype framework 1: Dimension framework with the information of the North-West University (Vaal Campus) water-monitoring project

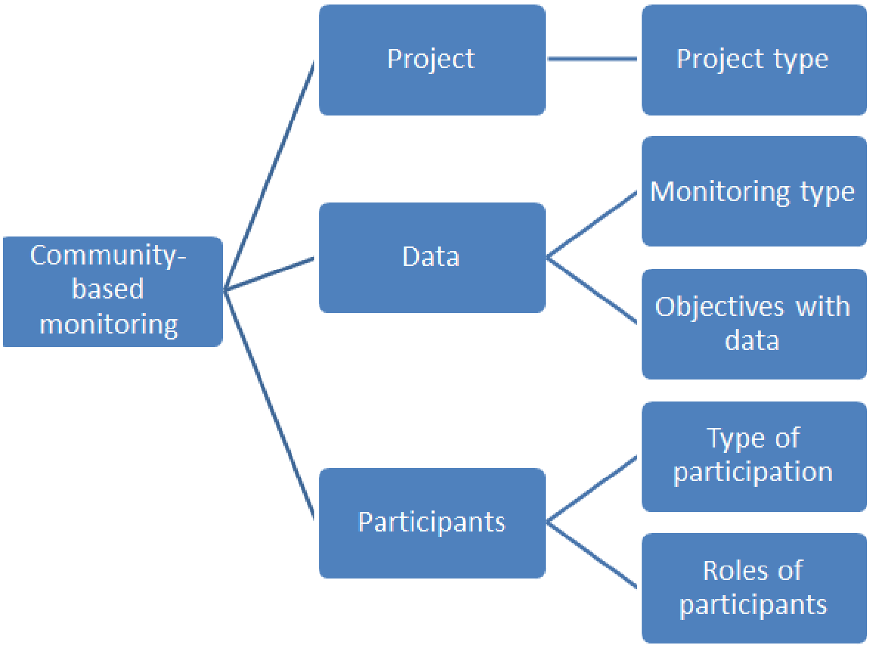

Figure 4. Prototype framework 2: The activity-based framework

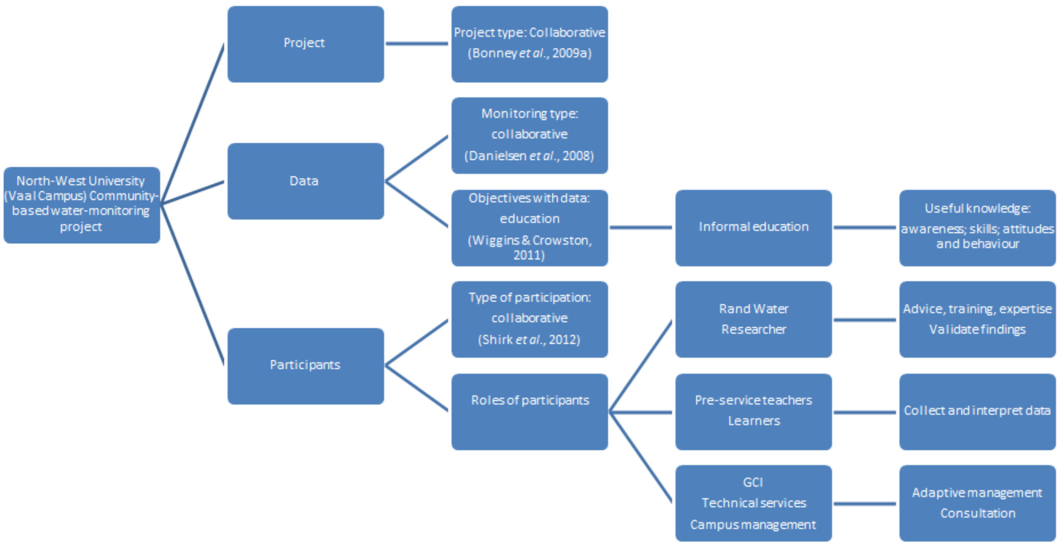

Figure 5. Application prototype framework 2: Activity-based framework with the information of the North-West University (Vaal Campus) water-monitoring project

Reflection on prototype frameworks

The researcher acknowledges that both prototype frameworks are based on current citizen science models. Most of the discussed models use the role of

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participants or the type of monitoring as their starting point. Prototype 1 focuses mainly on participants and adaptive management of the natural resource. Both social and knowledge dimensions are concerned with participant experience and understanding. Prototype 2 presents a more balanced display of current available citizen science models. The activity-based prototype provides a better view on different components of the North-West University (Vaal Campus) water-monitoring project.

To design a unique citizen science framework that links well with education as an objective, the researcher aims for a different indecent point to her model. The researcher values the comment of Lewenstein (2016), who indicated that running projects for educational purposes only, does not lead to long-term commitment and participation that infuse actual learning. To overcome the latter problematic comment, the researcher focused on context and real-life learning opportunities in her model. The notion with this focus is that educators or personnel of teaching and learning institutions need to decide on a natural resource in their immediate environment (context), which can be monitored. The position of the North-West University (Vaal Campus) and multiple water storage resources on campus aids to provide a suitable starting point for community-based monitoring.

Other contextual factors that influenced the decision to perform a water-monitoring project were:

the availability and support of Rand Water experts (*cf.* 4);
the cost and simplicity of the Somerset Water Quality kits (*cf.* 5);
the ease with which monitoring could be done at outside water storage resources and inside ordinary classrooms (*cf.* 5);
availability of water quality as a topic in both university BEd programmes and the school curriculum (*cf.* 2);
and the funding support from the North-West University through the Scholarship of Teaching and Learning (SOTL) Programme (*cf.*1)

The researcher is, therefore, of the opinion that for a citizen science framework to succeed at an education institution, whether a school or university campus, the starting point of the framework needs to relate to the context of the institution (what is available and what is the objective, other than gaining knowledge/subject content) and the real-life relevance of the monitored indicator to the audience of the institution.

Figure 6 displays the North-West University (Vaal Campus) citizen science framework with contextual and real-life relevance. Figure 7 indicates the North-West University (Vaal Campus) citizen science framework with applied information of the water-monitoring project.

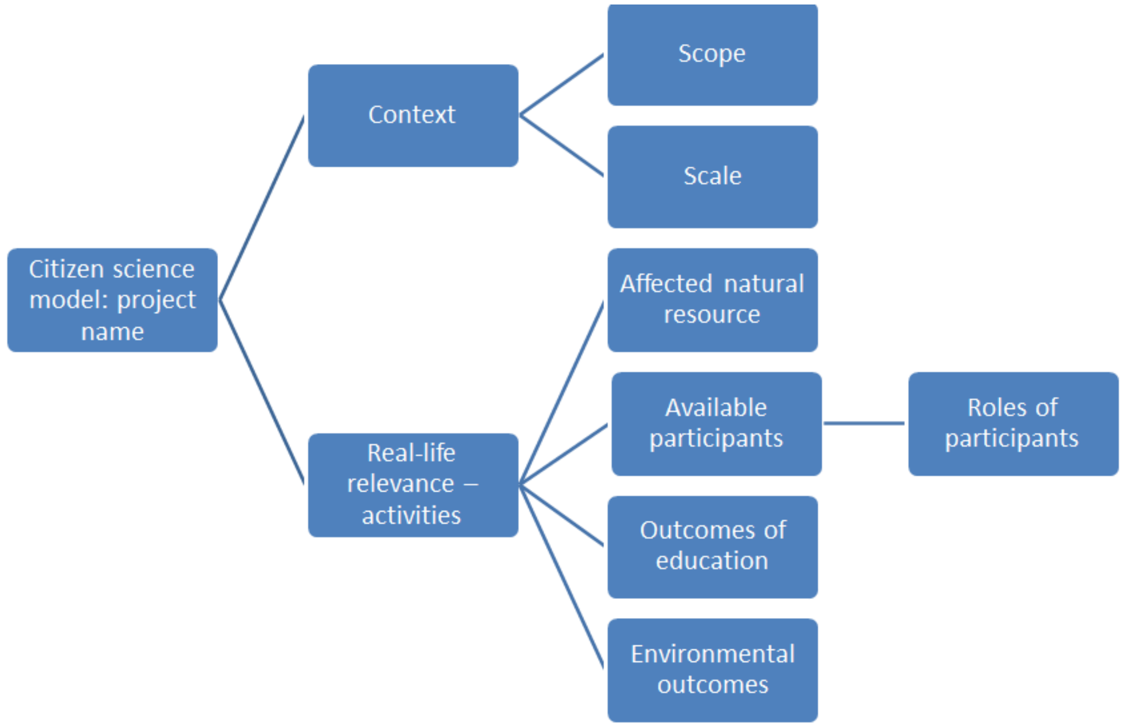

Figure 6. The designed generic North-West University (Vaal Campus) citizen science framework, indicating contextual and real-life relevance

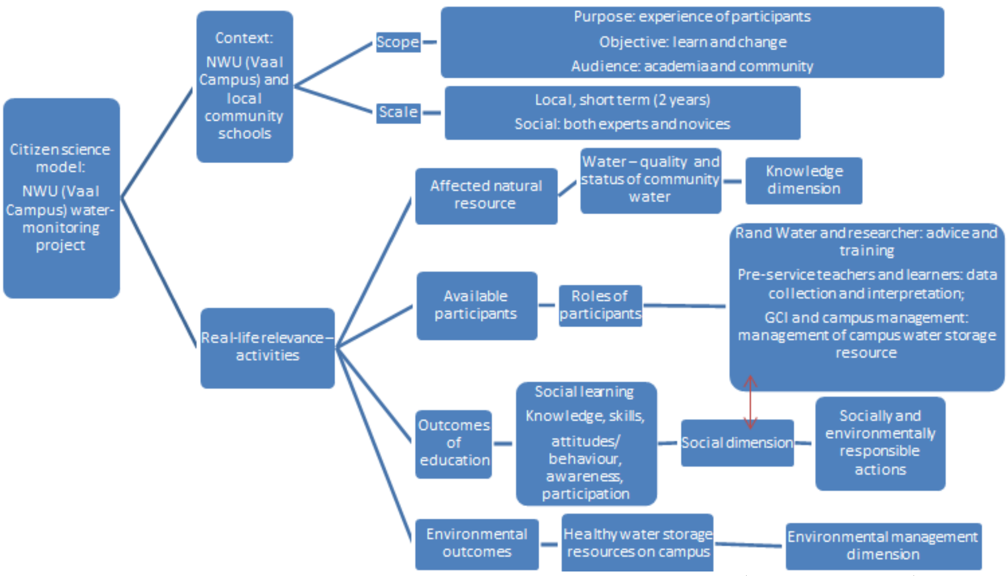

Figure 7. Apply information from the North-West University (Vaal Campus) water-monitoring project to the designed North-West University (Vaal Campus) citizen science framework: contextual and real-life relevance

Conclusion

The designed framework indicates a comprehensive view on all elements of the North-West University (Vaal Campus) water-monitoring project.

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The transdisciplinary nature of the research study is creatively displayed by incorporation of context, participants and adaptive management.

The researcher regards the creation of a citizen science framework as a complex operation. Different researchers will design different models or frameworks of the same research study, based on their personal approach to the research topic under investigation. The researcher found that the steps to create the framework served as a reflective practice in the development of the water-monitoring project. Each step to create a framework addresses different perspectives of the project. The steps of the scientific method prove to be a sound departure point for a framework. The transdisciplinary nature of the water-monitoring project determines the dimensions of the created framework. Many models/frameworks discussed in this article refer to similar properties, but researchers choose to name them differently.

The notion of the created framework is to initiate a citizen science project with the focus on context and real-life relevance to the institution. Available or problematic natural resources, the age of citizen scientists, the availability and cost of monitoring apparatus, and available funding are all contextual factors that must be taken into account. In general, the researcher believes that the created framework will be applicable to most citizen science projects at educational institutions. The initiation of a citizen science project, by incorporating context, makes it widely applicable. It remains the choice of the researcher to add more or less information in allocated spaces. The researcher acknowledges that a simpler framework that displays the basic components of a citizen science project is more user-friendly than an intricate model/framework that requires excessive information. The main idea of the created citizen science framework is to provide an overview or big picture of the water-monitoring project at the North-West University (Vaal Campus). The framework also indicates the outcomes of the project in a simplified way. The seven steps followed, are crucial to provide a comprehensive picture of the project.

Disclosure statement

No potential conflict of interest was reported by the author.

Notes on contributor

Irene Muller, Physical and Natural Science Education, Education Faculty, North-West University, Vanderbijlpark Campus, Gauteng, South Africa

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