CITIZEN SCIENCE ONLINE TRAINING AND LEARNING SYSTEM

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Citizen Science Online Training and Learning System

Report to the
Water Research Commission

by

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EXECUTIVE SUMMARY

BACKGROUND

A "toolbox" of citizen science tools aimed at the biological monitoring of water resources was previously developed in South Africa, through the support of the WRC. The pedagogy to support the teaching of these tools incorporated an Action Learning approach that leveraged off the benefits of social learning. This approach, and the associated tools, have received much interest from international bodies like the UN in terms of empowering people to take action towards, and report against SDG 6. The facilitation of learning during this process, however, has been heavily reliant on in-person training. Due to this, citizen science training to monitor water-related issues saw a marked decrease during the recent Covid-19 pandemic. A similar effect is likely in the event of climate change with the potential increase of local disasters. This highlighted the importance of adapting the current pedagogy to facilitate remote learning, whilst retaining the existing benefits of the Action Learning approach.

The use of digital learning is becoming more widespread globally, but marginalised communities are at risk of being left behind or excluded due to a lack of access to the "online"; and because of the high costs involved in participating in this form of education, especially in Southern Africa. These same communities are the most at risk from the effects of climate change, biodiversity loss, and ecosystem collapse; and are therefore, ideal users of citizen science. These reasons reinforced the need to develop a remote learning system for citizen science, and for that system to be trialled within a marginalised community. This research facilitated the development of online learning materials; and documents how a group of participants, from a community that struggled to access the internet, were able to use these materials to learn about citizen science tools for the biological monitoring of water systems.

AIMS

The intended outcome of this research project was the adapted and tested remote learning system for the citizen science tools for the biological monitoring of water systems. The development of the learning materials for online learning and a researched system into how they should best be used was achieved through this project. Remote learning will facilitate a wider access to citizen science training within the Water Sector, thereby bolstering economic development within this division, and ecosystem resilience. The development of this content for remote learning is regarded as a new product.

The aims of the project were:

1) To develop and evaluate a remote learning support system to empower communities being trained in citizen science.
2) To assess the effectiveness of different remote learning support applications (i.e. WhatsApp, Pluto, YouTube-style videos).
3) To refine and document how participants engage with citizen science on a remote platform.
4) To increase the participant's knowledge and understanding of citizen science, water issues, the meaning of the data, what to do with it once it has been collected, and how to upload the data on an existing database.
5) To adapt, update, and scale citizen science tools and learning pathways to enable these to be used in the most marginalised and remote communities who are also generally the most under served by educational/learning resources.

Additionally, two further objectives of the research were:

- the professional development of an emerging practitioner through the employment and mentorship of an research assistant, and;
- a contribution towards a student's research at either a Masters or Doctorate level.

The aims and objectives of the project were achieved:

- The current manner in which learning about the citizen science tools was assessed and eight (8) guiding principles were extracted from the evaluation,
- These guiding principles were used to design content for a remote learning system,
- The tools from the citizen science "toolbox" were adapted for online use within a marginalised community,
- A community was selected to pilot the remote learning system with. This community faced socio-economic and environmental challenges, water risks, and difficulties accessing the internet,
- The remote learning system for the citizen science tools was piloted with the selected community and their learning pathway documented.
- All participants reflected that they had benefitted from the training and felt more confident in their understanding and application of citizen science.

The project facilitated the employment of a young professional, who has honed their skills as a junior researcher through their involvement in the project; and the support of two Master's students.

METHODOLOGY

This project applied an Action-Orientated Research approach where each phase was documented, evaluated, and the results used to inform the steps taken in the next phase of the research. The phases of the project are briefly outlined below:

- **Phase one**, in this phase the current state of learning about the citizen science tools was evaluated through interviews, focus groups with various users of the tools; and through document analysis of reports on the teaching and use of the citizen science toolbox. The data sets that were generated were coded for common themes, and re-assessed for evidence of these themes, and then summarised as emergent themes. The emergent themes from this process were used to generate a list of eight (8) guiding principles that were considered during the design of the remote learning system. Another focus of Phase one, was to select the community that would use the remote learning system. This community needed to be located in an area that faced water risks, environmental and socio-economic issues, and had limited or no access to the internet. The province of Kwazulu-Natal was identified as the area that the selection would be limited to, and a Multi-Criteria Analysis (MCA) using Geographic Information Systems was used to apply statistics which were allocated at a ward level within the province. The statistics were drawn from various datasets and overlayed environmental, census, and social data. A primary, and then secondary prioritisation was applied, from which the wards were ranked and a list of the top ten was generated according to the prioritisation process. To make the final selection, communities that GroundTruth had a viable connection with were identified. This resulted in the community from around Lake Sibayi in Maputaland being selected for the pilot.

- **Phase two** involved the updating of the original citizen science tools for use in remote learning. All the tools from the original citizen science toolbox were briefly reviewed, and feedback on their applicability for online use was collated. A simplified one-page image-based summary for each tool was created. The needs of the selected community were taken into account and used to select four (4) tools from the original toolbox for more in-depth updates. This involved the development of instructional video content and picture-based notes explaining the steps needed to apply each tool. Two additional citizen science tools emerged, the *E. coli* water test, and the Dragonfly Biotic Index; both which had relevance to the environment of the selected community, so video and image-based notes were developed for these tools too, and they were added to the suite of online learning content.

- **Phase three** saw the piloting of the remote learning system with the selected community. Thirty-one (31) participants were chosen from an application process that involved the Tribal Authorities (TA). These participants were split into two groups based on their location. Each group progressed through the remote learning system in a staggered approach so that the second group started later than the first. This allowed the research team to assess and adjust the course as the participants progressed so that the two groups had slightly different learning experiences. The learning journey of each group was documented in learner journals, through individual interviews and focus group discussions, and through the document analysis of their feedback surveys and WhatsApp group chats. The development of their understanding of ecological systems and citizen science was evaluated by comparing individual 'before' and 'after' assessments and personal reflections. Common themes from across these data sets were identified, and used to re-examine the data, from which the emergent themes were grouped and summarised. This process was documented in the form of a case study.

RESULTS AND DISCUSSION

Results of the evaluation of current citizen science learning.

A summative evaluation process was undertaken to assess how citizen science learning currently takes place. The following guiding principles emerged from the evaluation:

1) Relationships between the facilitators and participants, and between the participants themselves need to be organically formed and continually nurtured.

2) Learning should be contextually relevant to the participant and must link to their needs and lived experience.

3) Commonly shared environmental concerns should be investigated using the Action Learning approach and linked back to indigenous or historic practices related to the concern. The related indigenous practices can be used to inform how to address the environmental concern.

4) Citizen science could then be introduced as a monitoring and evaluation tool to assess the changes in the state of the environment.

5) Learning about the citizen science tools should involve real-life experiences; hands-on use of the tools; diverse field-based encounters; and repeated practice.

6) Learning should be gently scaffolded, building on the prior knowledge of the participant, questioning, and probing assumptions and understanding, and giving the participants time to engage amongst themselves in discourse about their learning.

7) Participants need to feel that they are making a significant difference in their community.

8) The remote citizen science learning platform needs to be accessible, user-friendly and include the charge of the internet.

These principles were used to guide the development and design of the remote learning system.

Community selection

The prioritisation process from the Multi-Criteria Analysis identified the community situated around Lake Sibayi as an ideal community for the study to take place with. This community consisted of three Tribal Authorities (TA): Mabasa TA, Zikhali TA, and Tembe TA. All three Tribal Authorities were approached, and time was granted for the research team to present to each. Of the three, Mabasa TA and Zikhali TA were favourable towards the project going forward within their regions, while Tembe TA did not show willingness to participate. The two groups of participants were selected from the regions governed by the Mabasa and Zikhali TAs.

Updates to the tools for use in online learning

The content for each tool that was created for use on an online platform can be found using this link: https://www.groundtruth.co.za/olt . The brief assessment of the tools found, that in most cases, the manual for the tool had been written using technical language which was not easy for a layperson or non-scientist to understand. The main updates to the tools were the creation of a one-page image-based summaries of the steps needed to apply each tool. Where possible the one-page summaries were created in English, isiZulu, Sesotho, and Afrikaans.

Four (4) tools were selected for more in-depth adaptation, based on their suitability for use by the selected community, these were: the clarity tube, the Transparent Velocity Head Rod (TVHR), miniSASS, and the Wetland Assessment Tool. To this suite of tools, two new tools were added due to the value that they bring when used in conjunction with the other four, these were: the *E. coli* water test, and the Dragonfly Biotic Index (DBI). Video content, and detailed, but simple notes were created for each of these six (6) tools; to facilitate learning about them on an online platform.

Case Study

A remote learning system was developed and loaded on the Pluto Learner Management System (LMS). The design of this online course was informed by the remote learning framework developed in Phase two, which incorporated the adapted tools, their re-presented content and video-teaching content. This involved not only incorporating the newly developed materials onto an online Learner Management System , but outlining planned activities for the participants, and purposeful interactions with the facilitators and amongst the participants themselves. The “remote learning system” consisted of these purposeful activities and the engagement with the online materials.

The remote learning system was piloted with the two groups from the selected community. The Mabasa Group started a few weeks before the Zikhali Group, allowing the feedback from the first group to be considered and used to adjust the remote learning system for the second group. These changes were tracked and are summarised in Section 5 of this report. This process was evaluated and documented, and resulted in an understanding of the learning journey of the participants, summarised below:

- The participants demonstrated that they were able to learn about citizen science through their engagement with the remote learning system. The results from the data collection tools provided evidence that the participants were able to learn about the citizen science tools through their engagement with the course materials and each other. Participants demonstrated an increase in understanding through the application of the citizen science tools in their change projects.

- The learning experience increased the confidence and personal agency of the participants. Participants demonstrated a growth in confidence through the evidence of acquired ‘soft skills’ such as presentation, communication, and application of research. Participants also expressed that the knowledge gained through the course empowered them to realise their personal agency in contributing to protecting the environment.

- Participants found the visual learning content (video-based content and image-based notes) the most effective for online learning of citizen science tools. Participants expressed that learning about the citizen science tools through YouTube-style videos and using image-based notes (in both isiZulu and English), enhanced their learning experience.

- Internet charges to view or download the learning content inhibited how freely the participants could interact with the course materials. Internet charges proved to be a challenge in the online learning journey of the participants, which stressed the need to appeal (to the government, or network providers within the private sector) for the reduction or removal the internet charges for learning material and downloading of educational content.

- Participants were able to overcome the challenge of access to the internet through creativity and working together. Through use of their local library Wi-Fi, sharing devices, using paid-for academic internet allocations, or working with others, they were able to access the online materials and successfully work through them. This creative approach was worked effectively and was only disrupted during scheduled loadshedding.

- In-person demonstration and hands-on use of the tools was shown to be a valuable activity that supplemented the online learning. Participants noted that they were able to learn most the effectively about the citizen science tools through a mix of online and in-person training. The in-person training provided opportunities for participants to learn about the tools from their peers through discourse and provided opportunity to practically apply the tools.

- Learning in a group enhanced and deepened the citizen science learning process for the participants. The participants highlighted that they gained the deepest understanding of the citizen science tools from the change project activity. The change project task provided a conducive learning environment for the participants to learn from each other and for them to independently apply the citizen science tools within a relevant 'real-life' example.

Discussion

The results from the study brought a few key themes to light. These have great bearing on the future development of online learning for citizen science and should be considered when using the online materials that were developed, or when developing new materials.

The value of 'learning together' is immense. Even when learning online, conscious effort needs to be made by the facilitators to provide opportunities for social learning. The following aspects of the remote learning system proved to successfully facilitate social learning processes:

- **The introduction of facilitators via the online learning platform**. This gave a face to each facilitator, and allowed the participant to identify with their facilitators, and enabled the building of trust between the participant and the facilitator. This enriched the learning experience.

- **The provision of in-person contact sessions where the participants were able to meet each other, form bonds and friendships, and interact with their facilitators**. In-person training sessions provided a conducive environment for social learning to occur within the group, and thus enhanced the learning experience of the participants. Evidence showed that even though the bulk of the learning took place in an online setting, the participants valued the time when they were brought together to do activities with their group and facilitators. This human connection is still an important component of learning and should still be incorporated into a remote learning process. The value of online learning is that the time allocated for these in-person contact sessions can be reduced substantially when compared to traditional learning. This can save costs, travel, and the expenditure of carbon.

- **The setting of group-work tasks**. Providing opportunities for and encouraging group-work opened the space for social learning. These tasks fell outside of in-person sessions and encouraged the participants to connect and communicate with each other (either on WhatsApp or in-person) to complete assignments. The challenge of having to complete a task within a group facilitates deliberation, drives active participation, and the need to reach consensus to produce a submission for an assignment. These are important components of the social learning process.

- **Using a WhatsApp group for communication within each group**. This type of communication media provided opportunity for easy discussion within a remote setting. The WhatsApp group also served as an alternative platform to share learning material and for participants to support each other's learning journey. In lieu of face-to-face interactions, the familiarity of the participants with the use of WhatsApp meant that it was their preferred mode of communication. The other mediums communication (the online forums, email, and built-in message system) were not well used.

The design of the learning pathway needs to be consciously planned. Learning needs to be gently scaffolded, starting from a 'place of knowing' and adding to concepts already understood by the participants. For example: using the picture-building activity and incorporating pictures that the participants had taken of environmental concerns from where they lived proved to work well as a starting point (or means of 'tuning-in'). Greater value from this activity was derived when the participants revisited these environmental concerns throughout the learning process, and added to how they understood them using the knowledge they had built together. For careful scaffolding of learning to take place, a facilitator needs to have a good understanding of the knowledge that the participants bring into the learning space. This can be gauged through purposeful activities like the Enviro picture-building activity which is image-based and facilitates discussion. A facilitator can then get an understanding of how to build on the prior knowledge of the participants.

The remote learning system also purposefully incorporated the '5 Ts' of Action Learning: 'Think', Talk', 'Touch', 'Take Action' and 'Tune-in'. Both in-person contact sessions, and the activities created for the online interactions, were designed with these processes in mind. Retaining the '5 Ts' within an online learning setting requires some creative thought, however, when completing a 'change project' the participants cycled through the elements of Action Learning, and as such, most reported that this was when they felt that they gained the most from the learning experience. The 'change project' activity proved a successful way in which to incorporate Action Learning, and to consolidate the knowledge that the participants had gained during their learning journey.

A key insight that was gained through the process of this study, was that people are creative and can overcome challenges when they work together and have a desire to succeed. The challenge of access to the internet was a major obstacle. This challenge was two-fold: (1) internet signal was intermittent and connectivity low in most areas, and (2) the cost of internet usage in South Africa is high. Video content for learning purposes is usually facilitated through platforms like YouTube and Vimeo. Streaming from these platforms incurs a charge for the user, as does downloading images and notes. The participants reported that these two challenges were major obstacles to the ease of their use of the online learning content. However, despite this, the participants were able to overcome these challenges, they worked together, relied on data provisions given to some of them through their registration at a learning institution, or travelled to the library to make use of the free Wi-Fi. This highlights the importance of the following:

- Provision for the formation of these social bonds must be made when designing online learning opportunities, if the individuals were working in isolation, they would find these obstacles more difficult to overcome. Through their relationships with each other they were able to devise solutions to the issue of access to the internet.

- The value of public libraries is immense. These public spaces provided an invaluable service to communities, especially in rural settings. They allow for a communal meeting space and facilitate the access to the internet that made this online learning possible for many of the participants. Municipal and governmental support of these institutions is vital for the scaling of this type of learning.

GENERAL

The outcomes of the study illustrate that remote citizen science learning is most effective when opportunities are made to facilitate social learning processes which incorporate the Action Learning approach. The design of the remote learning system provided opportunities that enhanced the learning experience of the participants. Space for meaningful communication, co-learning and co-development of solutions between and by participants, hands-on application of the tools, and the change project task demonstrated how social learning could be facilitated in a remote setting. The value of the human interaction during in-person contact sessions was shown to be a valuable part of the process, which warrants future inclusion even if it is minimal. When these aspects are considered, and carefully planned, the learning framework is effective in its applicability to guide remote citizen science learning.

The outcomes and lessons learnt from this study are already being applied in other projects. Currently, GroundTruth are facilitating an online miniSASS course in partnership with DUCT and United Nations Children's Fund (UNICEF) through a youth opportunity platform called YOMA. This project aims to have 1000 youth from across South Africa completing the online miniSASS course; and following a learning pathway to enable them to complete a monitoring plan, collect miniSASS data, report on it, share their change story, learn how to involve others in miniSASS, and ultimately to teach other people how to use the tool themselves. The design of that online training benefitted from this study immensely; and has taken the development of online learning even further for the miniSASS tool. Running parallel to this project is further research in partnership with Rhodes University, to document and develop the learning pathway developed through the YOMA miniSASS online course. The ultimate aim of this research is to apply to the Quality Council for Trades and Occupations to have the work that citizen scientists in the water sector undertake, recognised as an official occupation.

The materials that were created for online use for this project were expanded into a set of twelve videos, and incorporated into instructional content for the soon-to-be released miniSASS app. This mobile application incorporates artificial intelligence (AI) to assist the user in identifying the aquatic macro-invertebrates they find when doing miniSASS. What had been learnt through this research process was invaluable in the development of the online learning materials that were incorporated into the app.

This study has provided valuable groundwork for future provision of online training within the realm of citizen science. The 'guiding principles' and 'lessons learnt' that have emerged from this process have been summarised into a guiding document (https://www.groundtruth.co.za/s/Best-Practice-guide.pdf) to accompany the online learning materials for the Toolbox. A dialogue will be initiated with key partners (including *inter alia* Water Research Commission, GroundTruth, and SAEON) around how best to house and share these resources so that people can access them easily and apply them in a meaningful way.

CONCLUSIONS

This research documented, in-depth, the process of designing and facilitating online learning for citizen science. This was done in a very specific context, that of a rural community with little access to the internet. What emerged can be summarised as "when there is a will, there is a way", as the participants in the study showed that they were able to overcome the obstacles to learning through innovation and leveraging off each other. This highlighted the importance of facilitating opportunities for social learning processes, many of which are embedded in the practical application of the Action Learning framework. Elements from these concepts were captured and summarised into "best practice" steps and can be found in the guiding document (the Best Practice Guide) that accompanies the online learning materials.

RECOMMENDATIONS AND FURTHER RESEARCH

To further this endeavour, a suitable “home” for these learning materials needs to be found from within the citizen science community. Favourably, this community is solidifying its bonds into a formal society, which lends promise to the suitable housing to the Toolbox, its remote learning system, and future updates and adaptations of these products. The use of the online learning materials developed through this research, and of the citizen science tools for the biomonitoring of water systems, have huge potential to satisfy South Africa’s reporting needs for SDG 6.3.2 and 6b. The support of national water governing agencies, both at a national and municipal level, is critical; and could lead to the expansive collection of data to inform reporting for these institutions.

The tools in the citizen science toolbox were briefly reviewed as part of this study, which highlighted various aspects still in need of revision, further development, and extension. There is still much work to be done. A new WRC project that is currently underway though UKZN, will be investigating the use of these citizen science tools to provide information to feed directly into a National ‘State of the River Report’. It is hoped that that research project, and others, will further the review of the citizen science tools available for the biological monitoring of water systems; and that continued efforts will result in the realisation of a suite of tools that anyone, in any context within South Africa, could apply to help them understand, monitor, and illicit change for the shared benefit of our water.

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ACRONYMS & ABBREVIATIONS

4IR	Fourth Industrial Revolution
AEN	Amanzi Ethu Nobuntu
AWS	Amazon Web Services
CAPS	Curriculum Assessment Policy Statements
CBA	Critical Biodiversity Areas
CBWQM	Community Based Water Quality Management/ Monitoring
CGIAR	Consultative Group on International Agricultural Research
COP	Community of Practice
DBI	Dragonfly Biodiversity Index
DSI	Department of Science and Innovation
DUCT	Duzi uMngeni Conservation Trust
DWS	Department of Water and Sanitation
EFTEON	The Expanded Freshwater and Terrestrial Envronmental Observation Network
FBIS	Freshwater Biodiversity Information System
FEPA	Freshwater Ecosystem Priority Area
GAP	Global Action Programme
GEMS/Water	Global Environment Monitoring System for Freshwater
GIS	Geographic Information System
ICT	Information and Communication Technologies
INR	Institute of Natural Resources
IT	Information Technology
IWMI	International Water Management Institute
KZN	KwaZulu-Natal
LM	Local Municipality
MCA	Multi Criteria Analysis
miniSASS	Mini-Stream Assessment Scoring System
ML	Machine Learning
NRM	Natural Resource Management
NWM5	National Wetland Map 5
NWQP	National Water Quality Management Plan
ODK	Open Data Kit
OED	Oxford Education Dictionary
PAW	Plant Available Water
PLA	Participatory Learning and Action
PU	Planning unit
RHA	Riparian Health Audit
SAEON	South African Environmental Observation Network
SANBI	South African Biodiversity Insititute
SDGs	Sustainabile Development Goals

STATSSA	Statistics of South Africa
SWOT	Strengths, Weakness, Opportunities, and Threats
SWSAs	Strategic Water Source Areas
TA	Tribal Authority
UDM	uMkhanyakude District Municipality
UK	United Kingdom
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	The United Nations Children's Fund
UW	uMngeni-uThukela Water
VCF	value creation framework
WESSA	Wildlife and Environment Society of South Africa
WfW	Working for Wetlands
WRC	Water Research Commission
WWQA	World Water Quality Alliance
WWTW	Wastewater treatment work
ZPD	Zone of Proximal Development

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CHAPTER 1: INTRODUCTION

1.1 THE SIGNIFICANCE OF THIS STUDY

Citizen Science has gained increased attention over the last two decades and is becoming a more integrated and trusted process within scientific research (Lepczyk, 2020). The need for citizen science teaching and learning has grown globally, and the approaches towards this have evolved to match the demand (Vohland *et al*., 2021). The challenges of recent years have highlighted a need for a different approach to citizen science learning. Our current pedagogy[1] and training methods need to be adapted to better meet the demands of climate change and the learning structures of a post-COVID-19 world. The COVID-19 pandemic has greatly impacted how citizen science learning takes place, which was primarily facilitated through in-person trainings which provided hands-on learning opportunities. However, the limitation posed by the pandemic, restricted in-person trainings, and subsequently hampered effective citizen science learning. Further, citizen science learning needs to be adapted to meet the requirements of marginalised and remote communities, which often experience a lack of access and limited exposure and involvement in citizen science learning. Through the benefits of technology, training in citizen science can be enhanced and upscaled to reach more people, including those marginalised due to their location, socio-economic background, ability to access to education, and accessibility to online technology.

The main intention of this research is to develop a remote learning system that enables citizen science learning through facilitating engagement with the citizen science toolbox (Graham and Taylor, 2018), created through a previous WRC research project. The toolbox consists of citizen science tools that have been designed to assist in gathering data on the health of water systems: rivers, wetlands, and estuaries. Some of the tools in the toolbox have been in use for many years, and some were newly developed in 2018. However, they all required adaptation to facilitate their use for online learning, thus allowing people from all regions in South Africa the ability to learn how to monitor, assess, and report ecological disturbances in the water systems within their regions. Engagement with citizen science in this manner has been shown to increase the agency and confidence of a community (Vallabh *et al*., 2016). The ability for more people to learn how to monitor ecological changes can potentially inform decision-making processes at a local level by highlighting water quality and sanitation issues. This could subsequently result in the strengthening of reporting structures at a local level, to improve water quality. Empowering more people by broadening their understanding of science and its applications can possibly lead to an increase in individual agency and the potential for employment; and ultimately has the consequence of an increase in human capital development within the water sector. To achieve the goal of bringing the water sector into the Fourth Industrial Revolution, some challenges need to be overcome.

Two of these key challenges include:

I. Lack of knowledge and understanding of science and technology (particularly in remote and marginalised communities); and
II. Limited or no access to digital and online platforms. Internet coverage in South Africa is poor and its usage is charged for. Access to the internet is critical to enable online learning to take place.

This research aims to address these challenges by researching systems of remote learning to support the training of communities in citizen science tools for the biological monitoring of water systems.

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[1] Pedagogy refers to the method of teaching and learning applied within an educational context, with the aim of creating an inclusive learning environment for students. Pedagogy is informed by the learning needs of students, existing learning theories, and the teaching beliefs of the teacher. An effective pedagogy is one that considers the learning context of the students so as to create an effective learning environment for the student (Loreman, 2017).

1.2 THE EVOLUTION OF CITIZEN SCIENCE

While citizen science is often considered novel, written historical research provides evidence that public participation in natural observations dates to more than a 100 years ago (McKinley *et al*., 2017). Although public participation may not have been characterised as citizen science at the time, observing and documenting the findings from public engagement in scientific research was practised and documented in the 1880s (Silwerton, 2009; Bonney *et al*., 2019). These first written projects involved the public observing and recording their observations of natural phenomena such as water quality, plant and animal distributions, and the weather (Miller-Rushing et al., 2012). A prime example of a well-planned scientific project which provided citizen scientists with a definitive role is the Christmas Bird Count, conducted by the National Audubon Society in the USA, which has taken place every year since 1900. The British Trust for Ornithology, founded in 1932, is another example in which amateur enthusiasts contributed to expanding the knowledge of science and nature conservation by recording their observations (Silwerton, 2009). Today, many researchers use these historical data sets of environmental factors to develop their understanding of the evolution of the environment and to respond to complex environmental challenges.

In addition to these formally recorded forms of participation in science, local knowledge of the land and its ecology by indigenous peoples has been in existence long before the term 'citizen science' was coined. These local practices involved ways of knowing that have been recognised as a valuable source of information of the trends in biodiversity and natural capital for science and conservation (Reyes-García and Benyei, 2019). Regarded as social capital in many communities, local knowledge is rooted in individuals' experiences which is transferred over time through conversation and practice as a way of responding to arising socio-economic and environmental challenges. Senanayake (2006), notes that local knowledge, has been the foundation of agricultural and conservation practices and education for centuries. These local practices may be more sustainable than modern practices, especially those concerning agricultural land use. Local knowledge has allowed citizens to participate in observing and addressing environmental and socio-economic challenges, which strongly aligns with the practice of citizen science. Public participation in citizen science has led to a natural interest towards scientific research or data collection amongst citizens, which subsequently increases public awareness of locally-faced environmental issues (Requier *et al*., 2020).

Consequently, there has been increased public participation in large-scale research projects led by scientific organisations with the aim of increasing the quantity of data collected (Miller-Rushing *et al*., 2012). Citizen science has the potential to address difficult research questions that require the collection of copious amounts of data (Couvet, 2008; Bonney *et al*., 2009; Silvertown, 2009; Miller-Rushing *et al*., 2012). The increased involvement in citizen science has led to the improvement of scientific literacy amongst the public and contributed to the development of scientific knowledge. Although the benefits of citizen science are evident, the contribution of citizen scientists to the field of science has often been overlooked within the science field. This is apparent in the lack of recognition of citizen scientists in the methods section of publications (Vohland *et al*., 2012).

Recently, there has been a rise in the appreciation of citizen science as an emerging and evolving field of science, with the concept being featured more frequently in academic and scientific policy documents (Weingart and Meyer, 2021; Eitzel *et al*., 2017). In the 19th century, the field of science became more distinguished, this developed a clear gap between scientists and amateurs (Weingart and Meyer, 2021). As the field of citizen science augmented, research in developed countries became more common, with less successfully documented projects in developing countries (Potts *et al*., 2021). Requier *et al.* (2020) attributes the limited documentation of successful citizen science projects in developing countries to limited internet access and technology, limited institutional capacity, lack of public participation and poor collaboration with relevant stakeholders such as government or water authorities, which are needed to implement effective, and large-scale citizen science projects.

Beyond merely "contributing" to science, citizen science has the potential to develop society, improve communities, and foster public participation (Vohland *et al*., 2021). Critics argue that the practice of developing participation in science should not be regarded as an avenue merely to cut research costs within organisations, governmental agencies, and higher education institutions. Instead, citizen science should contribute to the expansion of scientific knowledge and be regarded as a learning experience for the participants (Lepczyk, 2020). This emphasises the need for the continued development and establishment of the field of citizen science with a diverse range of stakeholders to grow the scope of the practice (Vohland *et al*., 2021). It is important to note that citizen science is not an alternative to science but serves to enhance and expand scientific knowledge. Furthermore, the science field still requires individuals who are qualified scientists who are trained to do the work, as the decisions made within the natural resource management field have severe and long-term impacts on the environment if done carelessly (Lepczyk, 2020). For citizen science work to be fully supported by researchers, there needs to be an all-encompassing definition that considers the varied contexts and purposes for which citizen science is used (Haklay *et al*., 2021 in Vohland *et al*., 2021). Therefore, it is imperative that practitioners and policymakers develop a broader understanding of these diverse contexts to fully support the practice of citizen science (Lepczyk, 2020; Vohland *et al*., 2021).

1.3 THE GLOBAL USE OF CITIZEN SCIENCE

The earliest research and publications of citizen science are found in the United Kingdom (UK), owing to citizen science being an English concept. Coined by Alan Irwin, the term was added to the Oxford Education Dictionary (OED) in 2014 (Eitzel *et al*., 2017). The OED defines citizen science as the collaboration of citizens and scientists in scientific research. Further, Irwin defined citizen science utilizing two notions. The first, that citizen science was regarded as the duty that science should contribute to society, has been referred to as the democratisation of science. The second notion was that citizen science engaged citizens in scientific research through observation or data collection (Eitzel *et al*., 2017). Although this definition emphasises the joint effort of scientists and citizens to resolve scientific inquiry, the definition is limited because it does not sufficiently encompass the activities that citizen science is associated with (Eitzel *et al.,* 2017).

Also referred to as crowd, networked, participatory or community science; citizen science can be defined as the engagement of the public in gathering and examining scientific data. Vallabh *et al*. (2021) characterises citizen science as an efficient mechanism to deliver public policy and management needs, particularly in developing countries. To fully explore the potential of citizen science, scientists, together with volunteers, managers, and decision-makers need to collaboratively come to an understanding of the influence this practice could have in addressing natural resource management. The term citizen science takes different meanings depending on individuals' experience and educational background. Previously, the term citizen science caused disagreement within the scientific community due to the varied interpretations of the term. However, presently, it has contributed to helping us understand the world and increased citizen participation in scientific research (Lepczyk, 2020). The results from a study that uses a citizen science approach follow the same rigorous testing from traditional science while considering the purpose of the research. Well-planned citizen science projects create reliable data that can be used by scientists, policymakers, and the public. With the rise of technology and the internet, there has been an increase in collecting, storing, sharing, managing, and analysing substantial amounts of data in a time-efficient manner (Lepczyk, 2020; Potts *et al*., 2021; Requier *et al*., 2020).

According to Vohland *et al.* (2021), although the field of citizen science has existed for over a decade, there is a growing interest and acknowledgement of the field within science, policy, and education. One reason for considering the citizen science approach when conducting research is the potential learning pathway it provides citizens to improve their scientific literacy. The individuals who participate in citizen science projects develop an interest in science, and their understanding of the project they are involved in, grows. Due to the powerful ability of citizen science to be used as a tool to educate people, increase participation in scientific research and develop advocacy, it should be used mindfully within carefully planned research projects (Vohland *et al*., 2021). Citizen science embodies a joint effort to benefit different fields of science, formal and informal learning. It also has the potential to unite and strengthen scientific evidence with policymaking and increase social innovation, social activism, and, most importantly, individual capability (Vohland *et al*., 2021).

1.4 CITIZEN SCIENCE FOR WATER QUALITY MONITORING IN SOUTH AFRICA

There are significant water quality challenges faced in South Africa today which are attributed to harmful anthropogenic activities in the environment. "In South Africa, over 80% of our rivers are in such a bad state that they have been classified as threatened. Of these, 44% are critically threatened." (Graham and Taylor, 2018, pg. 1, NBA, 2018). As a response to this water crisis, considerable effort to research the potential of citizen science to effect meaningful change in water resource management has been made. This is in response to the low capacity of water authorities in South Africa to monitor, manage and address the worsening and continuing water quality challenges. Additionally, there is a limited consensus regarding water resource management between different parties such as NGOs, civil society, and government institutions. The limitations associated with water quality monitoring, as detailed by Statistics South Africa (2019), include the acknowledgement that there is a lack of co-ordination across sectors, including public and government departments. This lessens the opportunity of addressing water quality issues in a collaborative manner that allows for shared responsibility of water management across different levels (civil society to water governance authorities). Furthermore, South Africa is regarded as having one of the most progressive water policies in the world, however, there is limited evidence of water policy being practically implemented on the ground (Rojas *et al*., 2020). Citizen science thus has potential to address the above-mentioned gap through providing opportunity for public participation in water management as a means of responding to water quality challenges using the citizen science tools. This is attributed to the assumption that, if citizens are more knowledgeable of the quality of their water resources and the factors that threaten them, there is significant potential for working with government structures to manage their water resources in an effective manner (Graham and Taylor, 2018). Furthermore, the understanding of water quality and its management empowers citizens to engage in action-led processes in advocating for improved water quality. Evidence of this can be found in the story of the Msunduzi Sewer Monitoring project, in which one of the outcomes emerging from the monitoring activities of the EnviroChamps, was an increase in understanding within the community of environmental issues and the ability to discuss these complex issues (Taylor, and Cenerizio, 2018). Additionally, the work of the first group of EnviroChamps from the township of Mpophomeni and how their work highlighted the need to rehabilitate the wetland between the township and Midmar Dam is another example of the impact of citizen science in effecting formidable change (Box 1). It is evident that people-centred responses to water quality issues in South Africa can result in actions that mobilise both civil society and government.

Box 1: The story of the Mpophomeni EnviroChamps

Background

Originally known as the Mpophomeni Sanitation Education Programme (MSEP), the Mpophomeni EnviroChamps initiative started in 2011, through a collaborative partnership with DUCT and the uMgungundlovu District Municipality (UMDM) and was aimed at developing a group of environmental champions to respond to environmental challenges faced within the Mpophomeni community. The major challenge faced by the community were surcharging manholes and solid waste pollution which flowed into three tributaries entering into Midmar Dam. Volunteers, who were residents of Mpophomeni, became known as EnviroChamps. They were responsible for reporting surcharging manholes and solid waste pollution, and collecting supporting data using the miniSASS citizen science tool to monitor the health of the streams that were affected by the surcharging manholes. Additionally, the EnviroChamps were responsible for conducting community education programs such as door-to-door education and school visits to raise awareness of environmental issues in the community. In November 2015, UMDM partnered with DUCT through funding from the Expanded Public Works Programme (EPWP), and twenty EnviroChamps were employed to continue the work they had begun as volunteers. The project has since gained widespread attention and has resulted in the EnviroChamps model being applied across the country (DUCT, 2018).

Outcomes

The 3-year project had positive socio-ecological impacts on the Mpophomeni community, including but not limited to:

- An enhanced awareness and understanding of risks posed by environmental issues (leaking sewers) to their health and state of water quality, resulting in more people adopting sustainable practices.
- Monitoring of leaking sewers, proved to have a great impact, as there was a huge decline of surcharging manholes between 2015 to 2017, from 180 to 40.
- The EnviroChamps were able to build relationships across different levels, from the community to local municipal authorities, councillors and private stakeholders which made it easier for them to report environmental challenges and gain support in the form of resources and raising awareness of issues.
- The project initiated the development of other citizen science tools such as the Clarity Tube.

Wetland Rehabilitation in Mpophomeni

The most evident outcome of the initiative has been the resultant rehabilitation of Mthinzima wetland. The data the EnviroChamps collected, highlighted the need to restore the wetland between the township and Midmar Dam. GroundTruth donated their time to develop a rehabilitation plan and were responsible for overseeing the implementation of the structures that were put in place to disperse and slow down the water entering into the wetland. The wetland rehabilitation project was funded by uMngeni Water and the Working for Wetlands (WfW) Programme. The restored ecological infrastructure of the wetland is now able to filter the water and remove pollutants before they enter the dam, saving the Water Board huge costs in water purification. The Mpophomeni EnviroChamps have now been permanently employed by uMngeni-uThukela Water (UW) and SANBI to continue their work and to monitor the wetland as its functionality returns.

The Place of the Waterfall video

The Place of the Waterfall video was developed to capture the story of the EnviroChamps work and the impact this has had on the community and the rehabilitation of the Mthinzima Wetland, and can be viewed using this link: https://youtu.be/jjMsNza1S-4

The statistics portraying the water quality issues in South Africa continue to worsen (DWS, 2022). Pollutants threatening water quality can be attributed to mining, industry, agriculture, the increasing deterioration of wastewater treatment, and the decline of domestic waste removal (Musingafi, 2014; Rivers-Moore, 2016; Edokpayi, Odiyo, and Durowoju, 2018). It is evident that more robust and sustainable strategies are necessary to pivot our water crisis for the better. In most organisations, public participation in water quality management has been interpreted as raising awareness of water quality issues (Graham and Taylor, 2018). While these activities are helpful, they seldom lead to action by citizens to develop more sustainable practices that benefit the environment. Furthermore, they fail to delve into context-specific and deep-seated water issues and risks many communities face (Graham and Taylor, 2018). Citizen science seeks to bridge this gap by increasing citizens' knowledge about water quality issues while capacitating citizens with the skills and tools to address them through action-led processes (Vann-Sander *et al*., 2016; Graham and Taylor, 2018).

Global policies such as the Sustainable Development Goals (SDGs) have played a vital role in emphasising the need for citizen science tools in water resource management. Citizen science, particularly miniSASS, can help realise the SDG 6 by contributing directly to monitoring the progress in achieving target 6.3.2 and 6b (Taylor *et al*., 2022). The lack of awareness of the SDGs, and the lack of agency needed to help realise these goals has been recognised by the United Nations Educational Scientific and Cultural Organisation (UNESCO) as an obstacle to overcome. This led to the establishment of Global Action Programme (GAP), in which Wildlife and Environmental Society of South Africa (WESSA) was appointed as a partner to establish and implement these learning pathways (Graham and Taylor, 2018). A large part of the practice of citizen science is the learning process that takes place amongst citizens involved in scientific research, which is the main component this study seeks to investigate. Graham and Taylor (2018) highlight the potential link between the Sustainable Development Goals and citizen science, SDG 11 and 17 were identified in the study by Graham and Taylor (2018) as among the goals that are supported by the citizen science tools in the toolbox for the biological monitoring of the health of water systems. Goal 11, which focuses on sustainable cities and communities, which makes cities and human settlements inclusive, safe, resilient, and sustainable, can be supported by these citizen science tools as they provide data on how water systems are impacted within cities. Collectively, citizen science has the potential to help citizens understand the importance of their water resources and is useful as an educational tool to raise awareness of water quality issues and risks in schools. Goal 17 looks at partnerships for the goals, which is about strengthening the means of implementing and revitalising the global partnership for sustainable development. Citizen science could potentially assist in promoting civil society partnerships, by capacitating the public with citizen science skills and tools to collect data (Graham and Taylor, 2018).

There has been considerable effort made by policy at all levels to increase public participation in water resource management. To understand the level of impact legislation has had on South Africa; it is useful to observe what is happening on the ground. A study conducted by Weingart and Meyer (2021) investigated 56 citizen science projects in South Africa. The results from the study found that the socio-economic and educational injustices which can be traced back to Apartheid, have moulded the reality of citizen science projects on the ground. The study found that majority of the individuals who participated in 56 citizen science projects mainly conducted data collection and did not involve them beyond that. Little to no effort was made by institutions who managed the citizen science projects, which were a collaboration between academic, government and NGO institutions, to involve participants in policy discussions using the project outputs. Another important finding was that majority of the citizen science projects mainly had a scientific outcome, rather than an educational one. Thus, we could potentially suggest that majority of the citizen science projects in South Africa are focused less on educating the public and more on achieving scientific goals (Weingart and Meyer, 2021). Contributory, collaborative, contractual, collegial, and co-created public participation processes are detailed by Shirk *et al* (2012) and, of these, a co-created process is the approach which involves citizens in an inclusive way and in a way which allows input from both professionals and the public. This approach has been highlighted as the ideal manner to advance the benefits of citizen science efforts (Shirk *et al.,* 2012).

The most rural and remote communities in South Africa are the most marginalised when scientific knowledge acquisition and involvement of citizens in citizen science projects is concerned. This is heightened and attributed to the previously mentioned socio-economic and educational injustices in South Africa (Weingart and Meyer, 2021). When citizens are unable to participate in citizen science projects, this lessens the possibility of them learning how to use citizen science tools and develop scientific literacy. Therefore, it is imperative to investigate how individuals learn and adapt those findings to create a learning framework that responds to limitations to citizen science learning posed by marginalised and remote communities.

With the persisting challenges of water quality in South Africa, there is an urgent need to incorporate citizens in the decision-making process of water resource management (Boakye and Akpor, 2012). Citizen science helps people understand their catchment and the water quality challenges faced within it, which in turn empowers them and gives them agency to make a formidable change in their environment (**Box 1**). A research project was conducted by Graham and Taylor (2018) aimed at investigating the potential of citizen science to bring about change in water resource management to improve the health of the catchment. This project explored the potential of the "5Ts of Action Learning" model (**Figure 1-1**) in enabling and enhancing citizen science learning and teaching.

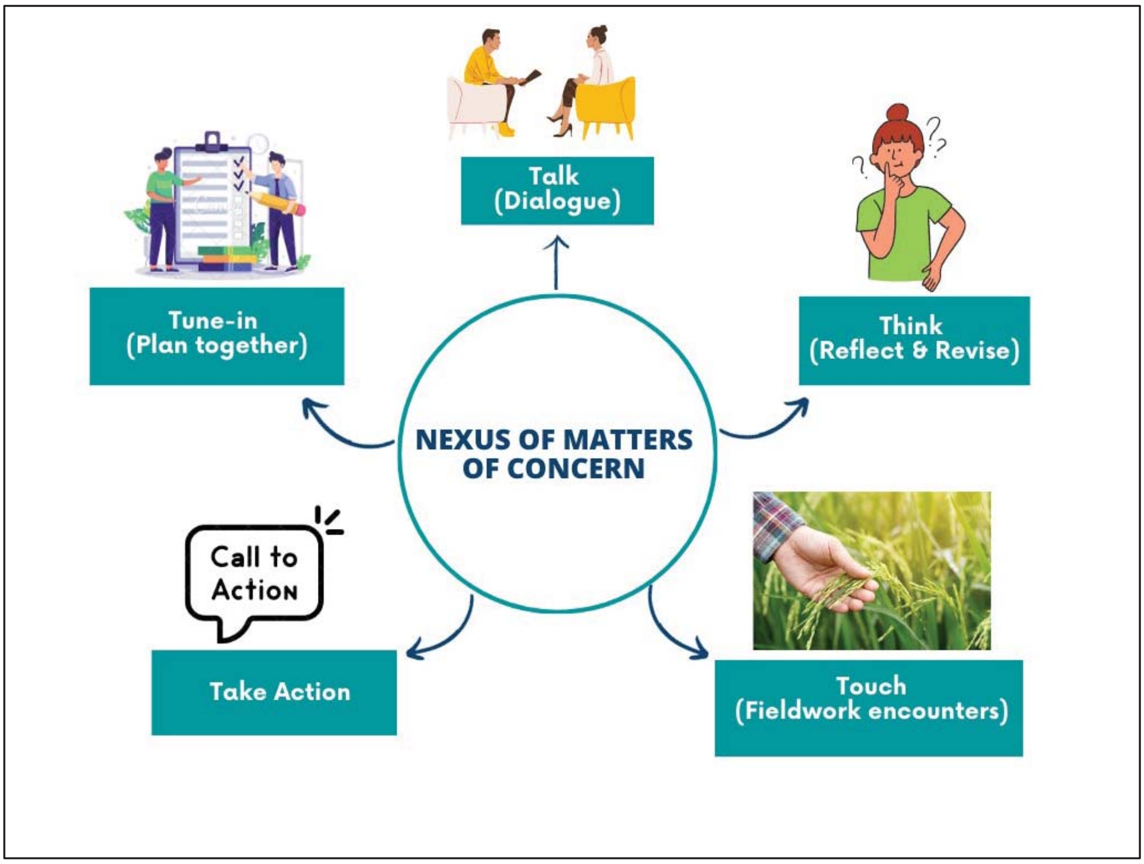

Figure 1-1: The "5Ts" of Action Learning (adapted from Graham and Taylor, 2018).

This model (**Figure 1-1**) is useful in facilitating an engaged learning process in using citizen science tools. The model is centred on the "the nexus of matters of concern" which is referred as the issue that the participants are attempting to address (Graham and Taylor. 2018; Kulundu-Bolus *et al*., 2021).

The "tuning-in" element of the model, is a critical part of establishing the prior knowledge of the participants and allows for the discussion of the matter of concern. The "Talk" aspect of the model focuses on the participants discussing and sharing their knowledge and investigating what further research they need to do to engage with the "nexus of matters of concern". This contributes to the collaborative learning process, useful in citizen science activities. The "touch" component refers to field-based encounters which are pivotal in the learning process of an individual. This provides participants with an opportunity to apply what they have learnt (in this case, citizen science tools) and is able to enhance the learning experience of individuals. For citizen science learning, the application of the tools is an important part of deepening participant's understanding of the tools. The "Think" element of the model allows citizens to be involved in the learning process, in an engaged and alert manner, which allows them to ask questions and deepen their understanding. The "Take Action" element is about going into the field and taking actionable steps to implement what you have learnt (Graham and Taylor, 2018). The 5Ts of Action Learning model includes elements that are closely linked to social learning and the Communities of Practice (CoP) theory[2], which are useful in supporting and enhancing citizen science learning and teaching. Social learning is an evolving concept that has become a standard goal in the field of natural resource management. While this notion is often misinterpreted, developing a clear understanding of the concept is critical to support social learning when it occurs.

According to Reed *et al*. (2010) for learning to be regarded as social learning, it must exhibit the following traits: learning must portray a change in one's behaviour, this can be change that has occurred at a surface or deep (internal) level; secondly, the change in behaviour of the individual, this includes learned ideas and behaviours, diffuses into the wider society in which the individual belongs. Learning must occur through interaction within a social network. Therefore, social learning can be defined as a process that results in changed behaviour in an individual, which extends to wider society through frequent interactions within small groups. Wals *et al*. (2009) argues that all learning is underpinned by social interactions (that is, interacting with oneself, your environment, and society). These interactions influence one's behaviour and attitude, resulting in the unlearning of some behaviours and the strengthening of other learned behaviour. Although this inter-relational component of learning is heavily emphasised within social learning, it is not the distinguishing factor that differentiates social learning from other forms of learning especially as used in the environmental sector.

Complex issues such as sustainability and natural resource management concerns require more than one approach to enable humanity to devise solutions. A large part of what defines social learning in the environmental sector emphasises the need to incorporate multiple ideas and ways of thinking to come up with solutions that address complex environmental issues. This key component of social learning is referred to as a diverse stakeholder group (Wals *et al*., 2009). This diversity creates an environment for new innovate ideas and solutions to challenging environmental issues. However, this process cannot occur without social cohesion. Social cohesion enables connections to be formed between stakeholders and allows for ease of communication, which is a critical part of social learning often emphasised within the literature. Another aspect that enables social learning is the ability to create an environment that enables social cohesion to occur effectively. This environment allows stakeholders with different values and ideas to coexist and engage on a common task, which leads to an understanding of different perspectives and facilitates the co-creation of innovative solutions (Wals *et al*., 2009). It is evident that social learning has potential to support and enable the 5T's of Action Learning model, through strengthening the 5 elements, specifically the "tune-in" and "talk" components. This is because it allows for social cohesion and stakeholder engagement, which enables dialogue to take place around the "nexus of matters of concern" that is being addressed.

1.5 MOVING INTO THE FOURTH INDUSTRIAL REVOLUTION

It is no surprise that the COVID-19 pandemic has had significant impact on citizen science learning and the traditional methods of training employed prior to the pandemic. This has led to several training institutions exploring online platforms to offer trainings to participants in an inclusive and interactive manner. Citizen science learning has also taken advantage of the offerings of the Fourth Industrial Revolution[3], which includes internet and technological advances. Jennett *et al.* (2016) attributes the growth in popularity and participation

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[2] Communities of Practice are considered a group of people who share a common interest or passion, they form a social learning network that drives the advancement of their practice or common interest (Wenger-Trayner, 2015).

[3] The fourth industrial revolution refers is a term that was coined by Klaus Schwab, the founder and chairman of the World Economic Forum, which is used to describe the technological advances occurring the 21st century, such as the artificial intelligence and robotics which are replacing natural functions performed by biology, humans and even the environment (Xu, David and Kim, 2018).

in citizen science projects by the public to the rise in use of digital technology. Online-based science involving and driven by the public, commonly referred to as citizen cyber science projects have gained much popularity, which has raised the profile of citizen science, through increasing its availability and visibility. Three types of citizen cyber science projects exist, namely: volunteer thinking; volunteer computing; and participatory sensing. Volunteer computing are projects where participants install software in their computers which allows them to process large amounts of data (Jennett *et al*., 2016). Volunteer thinking are citizen science projects where citizens apply their reasoning to analyse and sort data using a set of research guidelines. The third type of citizen cyber science project is the participatory sensing, in which citizens use a mobile app to collect data (Jennett *et al*., 2016); an example of this would be the popular iNaturalist app which encourages people to take a photograph (or record a call) of an organism (plant, fungi, or animal) and upload it to the app, where it is identified by more experienced users (sometimes with the help of artificial intelligence).

Despite the effort made by technology to bridge the gap of citizen science education and training, challenges persist pertaining to accessing the internet and other forms of Information and Communication Technologies (ICT). This challenge is exacerbated by poor education levels, low Information Technology (IT) skills, and an inability to afford mobile devices in rural areas (Aruleba and Jere, 2022). These issues are important to consider when deciding on the online platform to use to accommodate remote communities in citizen science training. A prime example of the “digital divide” is in the field of education, particularly in African countries, during the COVID-19 pandemic, when many schools and universities resorted to inventive forms of teaching, predominantly online, to minimise the spread of COVID-19 (Krönke, 2022). Rural communities may, in some instances been “left behind” but used other strategies to overcome their lack of access. This features the current challenges still being faced within remote communities when considering online learning. This study considered various forms of online platforms to pilot the remote citizen science training. The selection of the platform, and the pedagogical approach to online learning was chosen based on its suitability to the participants’ needs and the findings emerging from the evaluation of how citizen science currently takes place.

1.6 AIMS OF THE STUDY

The specific project aims include:

1. To develop and evaluate a remote learning support system to empower communities being trained in citizen science.
2. To assess the effectiveness of different remote learning support applications (i.e. WhatsApp, Pluto, YouTube-style videos).
3. To refine and document how participants engage with citizen science on a remote platform.
4. To increase the participants’ knowledge and understanding of citizen science, water issues, the meaning of the data, what to do with it once it has been collected, and how to upload the data to an existing database.
5. To adapt, update, and scale citizen science tools and learning pathways to enable these to be used in the most marginalised and remote communities, which are generally the most under-served by educational / learning resources.

1.7 STRUCTURE OF THE RESEARCH

The study used an Action-Orientated Research approach, in which each phase was evaluated, and the results were used to inform the steps undertaken in the next phase of the research. The details of how this was carried out during each phase is described below:

Phase One: During this phase, a summative evaluation of the ‘current’ citizen science toolbox was conducted to assess:

1) How citizen science learning was currently taking place
2) What tools were available and currently being used and
3) How the tools were used following training.

A mixed method approach to data collection (focus group discussions, questionnaires, direct observations and reflections of learning engagements, case studies and interviews) was used to solicit knowledge from users of citizen science tools. Furthermore, a SWOT (Strengths, Weaknesses, Opportunities and Threats) was applied to the current citizen science 'toolbox' to assess the shortfalls and limitations to citizen science learning during the pandemic and potentially in future due to climate change related challenges. The findings from these data sources and associated literature were assessed, summarised, and coded into emergent themes, which were summarised into eight guiding principles used to steer the development of the online learning system (https://www.groundtruth.co.za/olt). Concurrently, within this phase, a community selection process was conducted using a rigorous Geographical Information System (GIS) technique, known as a Multi-Criteria Analysis (MCA) to identify a community to trial the remote learning system with. This process was performed to highlight communities based on selection criteria, which considered various social, economic, and environmental factors.

Phase Two: In phase two, updates to the 'current' citizen science toolbox were undertaken which were informed by a detailed citizen science toolbox review. From the review, a process to adapt and improve each tool was developed according to the complexity and individual requirements for each tool. The amendments applied were intended to simplify the citizen science toolbox for use by people who have limited scientific literacy and knowledge, whilst retaining scientific integrity of the sampling methods. Thereafter, a remote learning system was developed, informed by the guiding principles that emerged from phase one, which incorporated the adapted tools, their re-presented content, and video-teaching content. These elements were compiled into an online course using Learner Management System (LMS) software, called Pluto LMS.

Phase Three: In phase three, the remote learning system was piloted, and concurrently assessed, with a group of 30 individuals from the selected community. The pedagogy used during the learning interactions was informed by the guiding principles, key educational theories and engagement approaches developed in phase one. As the participants engaged with the remote learning system, their progress and development were continuously evaluated using a mixed method approach for data collection, from which the data was coded for emergent themes. The findings that emerged from this process were used to adapt and improve the online learning system; and develop a case study documenting how learning took place in the selected community, highlighting which pedagogies and related technologies were most effective in supporting remote learning for citizen science. The outcomes of the case study were summarised into a "Best Practice" guide, aimed at facilitators, describing the process, platforms, and tools that emerged as most effective for facilitating online learning about citizen science (https://www.groundtruth.co.za/s/Best-Practice-guide.pdf).
Figure 1-2 below provides a snapshot summary of the 3 phases of this research study.

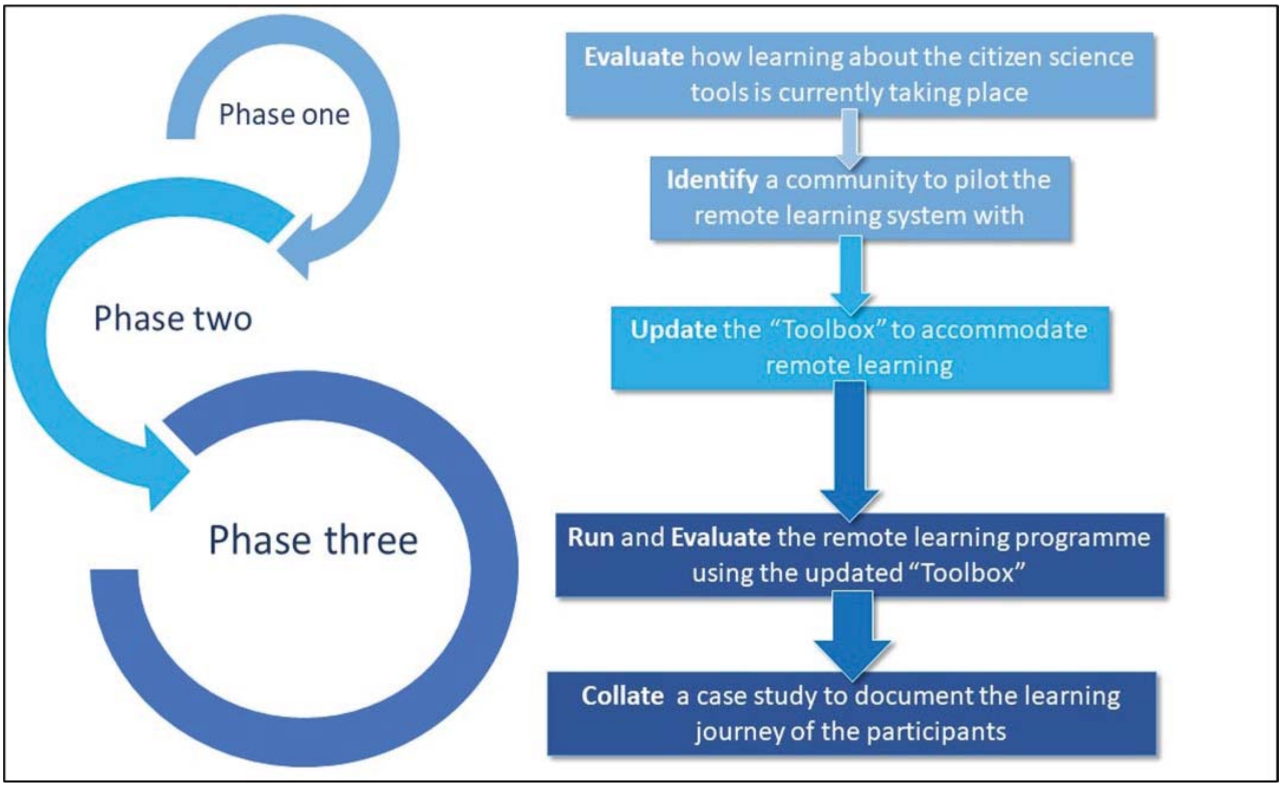

Figure 1-2: Flowchart showing the process of the research study.

CHAPTER 2: AN EVALUATION OF CITIZEN SCIENCE LEARNING IN SOUTH AFRICA

2.1 EVALUATION METHODS

An evaluation of the current state of citizen science in community-based water quality management (CBWQM) in South Africa was completed as part of this study. Community-based monitoring and management has been described as a process where people work together to monitor, identify, and respond to issues of common concern to record the effects of environmental change (Conrad and Daoust, 2008). In South Africa, community-based monitoring of the health of rivers and streams is growing in its use since the National Water Quality Management Policy (NWQP) was gazetted in 2017. The NWQMP encourages the collaboration between civil society, government, and the private sector to work together to improve the health of our water systems. The citizen science "tools" developed through the WRC are in a direct response to this call. To improve the engagement of more communities with these tools, the learning process needs to be made more accessible to South Africans from diverse circumstances. To assess the current process in which learning about these citizen science "tools" is taking place, a summative evaluation was conducted using a mixed-method approach to data collection. These methods used include:

I. semi-structured interviews,
II. focus groups discussions,
III. direct observation and reflection of learning engagements, and
IV. an appraisal of a case study.

The participants in the evaluation consisted of both the users and teachers of citizen science tools. Their thoughts, opinions, and accounts of their experiences were collected as data to use in the evaluation (**APPENDIX A – lIST OF INTERVIEW PARTICIPANTS**). As O'Brien (1998) suggests, a critical aspect of this research process is co-learning. This accounts for the data collection methods used to capture the learnings of the researchers and participants, as the broader study aims to use an action-orientated research approach, with the aim of reflecting upon and adapting the research as it is conducted.

Participants were selected using the snowball sampling method that allowed the study to start by selecting participants within existing GroundTruth networks and within the uMngeni Catchment; and then expanded the sample outwards as more connections were established and shared. The transcripts for each data set were coded for common themes. These common themes were then used to re-examine the transcripts and additional evidence was identified. The themes were then grouped as emergent themes and were used to compile a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis of the current citizen science "toolbox". The emergent themes were then used to address the research questions posed by this study, and to compile the guiding principles needed for the remote learning system. The various data sets and their sources are outlined in **Table 2-1** and are further described below.

Table 2-1: Summary of research methods and analysis.

Data Set.	Data Source	Purpose of data source	Recording method	Analyse/Use
1	Semi-structured Interviews	To capture the users' and teachers' experiences of learning and teaching the tools.	Transcripts of voice-recorded interviews	Transcripts coded for emergent themes.
2	Focus group	To understand how the AEN River Rovers[4] were learning and teaching citizen science tools.	Notes and transcripts of voice-recorded focus group session	Transcripts coded for emergent themes.
3	Observation and reflection of a school-based workshop	To observe how citizen science learning was taking place and how it was being taught.	Notes from observations.	Interactions were observed and recorded, then coded for emerging themes.
4	Outcomes of Amanzi Ethu Nobuntu (AEN) Indaba[5]	To understand how citizen science learning was taking place within the catchment	Transcript of voice recording, and notes made during the Indaba	Transcribed recordings and observations and coded for emergent themes
5	Outcomes from workshop on applying learning theory with Rob O'Donogue	To inform the learning framework of the study.	Note of reflections made during the workshop	Transcribed recordings and observations and coded for emergent themes
6	Case Study of WhatsApp-based professional practice training for project officers in the AEN programme	To capture the experiences of the AEN Project Officers using WhatsApp as a training platform.	Open-ended questionnaire forms	Feedback was coded according to emerging themes and analysed

[4] River Rovers, refers to a group of graduates who were employed under the AEN Programme, were responsible for training EnviroChamps groups employed under the Amanzi Ethu Nobuntu (AEN) programme in citizen science tool use, and data collection methods.

[5] The Amanzi Ethu Nobuntu Programme was a project funded jointly by the Department of Science and Innovation, the Presidential Office, and the Private Sector, that aimed to capacitate and employ people to use the citizen science tools of miniSASS, the Clarity Tube, and the Velocity Plank to monitor the health of streams and rivers within their communities. The project was piloted in KwaZulu-Natal, with the aim of spreading the programme nationally, and employing 10 000 people.

2.2 HOW IS THE LEARNING ABOUT CITIZEN SCIENCE TOOLS CURRENTLY TAKING PLACE?

Most of the participants commented that their first exposure and experience with citizen science tools was through participation in CBWQM projects which provided training opportunities for people (**Table 5-6**). Participants shared that WESSA and the AEN programme were among some of the organisations that provided this training (**APPENDIX B – INTERVIEW TRANSCRIPTS**). The AEN programme exposed a large group of people across KwaZulu-Natal to citizen science tools through funding from the Department of Science and Innovation (DSI) and other partner CBWQM organisations like the Duzi uMngeni Conservation Trust (DUCT), GroundTruth, WESSA, South African National Biodiversity Institute (SANBI), and the Institute of Natural Resources (INR). These findings reveal that CBWQM projects play a fundamental role in exposing people to citizen science tools, as well as teaching them how to use the tools.

To support this, participant 7 commented:

"At WESSA, we run school programs, ranging from primary schools, up to university groups, and we also do teachers training, so that is when we get to use these tools with the people."

However, most of these projects are reliant on external funding to operate (**Table 4-1**), which is often short term. Reliance on external funding to direct the introduction of the citizen science tools to people could be a limitation of the current model driving citizen science exposure in South Africa. Marginalised communities located in remote regions would only hear about the tools when the funding directs the projects to their community. Currently, there is limited capacity for people to choose to engage with the "toolbox" and a lack of opportunity to develop individual agency to learn about the tools, outside of funded projects. This perceived threat to the use of the current "toolbox", further validates the need to develop a remote learning system that can be accessed and used widely by people within marginalised communities. It also highlights the necessity to use a different medium of introduction to the citizen science tools, one that is not driven by funded projects and that could, perhaps, be driven by a system that promotes economic and individual agency and self-reliance, for example the YOMA[6] platform.

A participant from dataset 4, commented:

"The learning pathways need to be framed into economic agency. When you have economic agency, you take agency of your economy, economic opportunities, and possibilities. Unless we can do that, we cannot get out of poverty. In other words, we need to reframe poverty as economic agency. We want to review and frame the learning pathways via CBWQM into economic agency and a diversity of work opportunities within the expansive learning approach. If we do this work first, then we will be able to move."

This viewpoint supports the need for learning pathways that lead to better economic opportunities and empower citizens through citizen science work rather than making them dependent on external projects for work opportunities). This notion is supported by the work of Amartya Sen, known as the capability approach, applied in a variety of disciplines (

[6] YOMA platform: a global digital marketplace for young people to access and upskill themselves, find opportunities to earn and create social impact. Currently supported by UNICEF as a medium of engagement and uplift for youth in Africa.

APPENDIX C – CAPABILITY APPROACH). Further findings from the data revealed that teaching citizen science tools through providing background understanding of why the tools are used and how the data collected will be used, is beneficial in helping participants further appreciate the tools and their importance in water quality management. This contributes to the overall process of citizen science learning that goes beyond just learning how to use the tools but provides opportunity for participants to develop individual agency through the learning process. Which allows them to empower themselves by deepening their understanding of the science behind the tools and consequently engage with water quality challenges faced within their community.

Participant 8 commented:

“So, a lot of the university-based projects just want the citizen scientists to collect data. They don't really teach them how the science works, or how the understanding works, how the analysis works, they just focus on teaching them how to read, to collect data, and profoundly less effective. Whereas the tools that are part of a program of learning where they help people to understand therefore the tool works. Therefore, we do this to test that, you know, you kind of teach them the system of science that's around the tool, and then how to create meaning out of the data that is much more profound in terms of learning, in terms of change, in terms of dealing with environmental risks, and in terms of building confidence.”

Graham and Taylor (2018) state that this deeper understanding of the citizen science tools potentially empowers citizens as it increases their comprehension of water quality challenges faced by their community, which leads to informed decision making and action-led decisions (promoting individual agency) to improve water quality in their communities (**Box 1**). Participant 8 also highlighted that participants often have a minimal role within citizen science projects funded by academic institutions. This is affirmed by Weingart and Meyer (2021) who stated that, in general, citizen science projects in South Africa are primarily focused on achieving scientific project goals rather than educating and involving citizens in the entire process (data analysis and decision making using the data findings) of citizen science projects.

In support of this statement, Participant 8 commented:

“So, I'm probably quite a contentious person to ask this question. I don't believe in a one size fits all citizens science. And I think if we get the ethics, right, we will get better citizen science. And I think most citizen science projects, especially the former ones don't focus on that. They're very focused on getting their data. And you know, the things that the project managers want to achieve in the world.”

This provides evidence that there is a need to fortify citizen science training, by ensuring that citizens understand why they are using the tools, the science behind the tools, how to analyse the data, and how the data can be used to inform decision making and policy. Most importantly, how to use the data to take action and make changes within a community (**Table 4-1**). Participant 8 reported that citizen science training can be improved through providing additional background information on the citizen science tools. In further understanding how citizen science learning is currently taking place, findings from the data also revealed that the majority of the participants learnt how to use citizen science tools through a practical demonstration by an experienced user. The data suggests that this is often the first form of learning about the tools which occurs, before participants apply the tools themselves. Thereafter, this learning is deepened through engagement with the theory, self-practice, repetition, and application in different situations.

Participant 5 commented:

“I started teaching about CST in 2014, this was more in working with school kids on Saturdays. It was less about me telling the kids how to use them but more about engaging with them by asking questions. And then demonstrating to the kids how to use the tools by collecting samples. And then I would allow the kids to do it by themselves. They made a lot of mistakes in the beginning, and they eventually got the technique right.”

Participant 7 also alluded to the importance of citizen science learning through practical demonstration:

"Well definitely the hands-on demonstration part. Kids need to do the activity; you can't just talk about it. We play the miniSASS game[7] *before going to the river, that really helps too because once you are at the river it is difficult for the kids to concentrate, they get distracted quickly and don't listen to the whole process."*

This comment reinforces the importance of following up the demonstration of the tools with self-practice by the participants. Consistent follow up by the demonstrators of how participants are applying the tools is equally important to ensure the correct application of the tools by participants.

Another common theme that emerged from the data was the importance of repetition to strengthen citizen science learning in participants and develop their understanding of the tools.

Participant 2, from dataset 1 commented:

"*I learnt through how to use the tools through WhatsApp videos, and re-trainings we had were helpful when it was re-demonstrated to us, it was very helpful to have a good understanding." A participant from dataset 2, supported this statement by commenting, "the best way that I learn is through repetition, so I do the same when teaching others. And I ask them to explain it back to you*."

Participants shared that a "once-off" learning process of how to use citizen science tools is not sufficient to effectively learn how to use the tools. To fully grasp how the tool is used and to retain this knowledge, one must regularly apply the tool.

Participant 4 supported this statement by saying:

"*If it is a once-off learning process, a person will not grasp everything; they need to keep using the tool, practice and contact their trainer to see where they are getting things wrong. It does not work if you only go to the training once-off and come back thinking you know everything. One of the challenges is that you find that the people who do citizen science tools training are using the tools and not doing it right. At times I found that in a citizen science tools training of 20 people you find them not using them correctly. Then they pick up the mistakes done and think that is the correct way of using the tools. And then they will go train other people and then you will have a group of people not using the tools correctly*."

This finding emphasises the importance of incorporating refresher (retraining) sessions to citizen science learning which is focused on practical application of the tools. This ensures that citizen science users remain up to date with the developments of citizen science tool use and retain the knowledge of applying the tools. Furthermore, the refresher training assisted participants to stay up to date with updates related to sampling techniques of citizen science tools. The correct sampling technique is an important aspect of citizen science tool application and learning as it ensures that the quality of citizen science data that is collected is not compromised. Through this retraining process participants were able to gain confidence in their ability to apply the tool.
To deeply engage with the learning process under scrutiny in this report, an important theme emerged from the data which emphasized that valuable citizen science learning occurs when training is situated within the context of the learner. This is reinforced by the "touch" (real-life encounter or field work experience) component of the 5Ts of Action Learning model as discussed in Graham and Taylor (2018). To substantiate this point,

[7] The miniSASS game (sometimes called a "mock miniSASS") allows the participant to become familiar with the sampling procedure, the process of identifying the invertebrate that has been caught using a dichotomous key, and how to calculate the miniSASS score. Pictures of the aquatic macroinvertebrates are handed out in envelopes as the "sample" or placed upside-down on a blue cloth representing a river and the participants are encouraged to "collect a sample". They then use the miniSASS chart to identify their "sample" and work out the miniSASS score.

participants from dataset 2 reported that they learnt most about the citizen science tools during their change project tasks which was situated in the context of the participants.

Participant 12 commented that one way to improve citizen science training is by providing context for the learners that is specific and relatable to their natural environment when conducting citizen science training which will improve their understanding of citizen science tools. These participants are still engaging with citizen science teaching as something that is “given to” others, or “brought to” a community. In contrast to the manner in which Participant 4 spoke about their teaching:

“*So, I make that point and add that look if this water was really Dizi smelly, you walk to the water and sniff it, look at it and see that its green or brown. Would you take your cup and have a sip? Even if you have got no education, you would not do that. So, people intrinsically know about the health of the water. Yes, you got to get water, but you would not get dirty water because it’s like drinking poison. You wouldn’t take a bottle which says RETEX – poison and drink it. The same as dirty water, you wouldn’t even if you were very thirsty, you will know that it makes you sick. So, you got to have water, but not dirty water. How do we know if some of the water is dirty or not? Sometimes you can’t tell because it can look clean, but it is not. And then we need the citizen science tools to look at the water. These little organisms are so sensitive, if a bit of pollution touches them, they die. And a stonefly is like that, so if you find a stonefly you know that the water is clean. If you don’t find a stonefly, then you can find out what is going on. So, a river tells a story of how clean it is and makes it interesting like that. But I love taking groups to the river, and feeling the magic of the river, especially if it is a beautiful river that is clean and fresh. And if people do work a lot on dirty rivers, like the Baynspruit, Slangspruit, and in their townships, the rivers are all filthy. I think it is very important to take them to a beautiful area, like up in the Drakensberg where you can drink the water. And say that this is how God intended us to be, to have fresh water to drink. This is how it was before we started polluting the water, the water was drinkable. So, we can drink it and show people. I have taken the Enviro-champs up into the mountain, and they would say “this is the first time that I have seen this with my own eyes*”.

This highlights how the concept of situating the learning within the context of the participant extends beyond just “making the learning relevant” to the learner and ensuring that it matches their regional demographic. To fully situate the learning about these citizen science tools within the learner’s context, the learning needs to start with them, their environment, situation, and the challenges that they face. Participant 6 also highlights the need for the learners to experience a diverse range of landscapes and environmental situations, so they can add context and understanding to how rivers work within catchments and are affected by multiple influences within these spaces. This echoes the findings from Vallabh *et al.* (2016) which highlight that citizen science should be used to serve the needs of a society to resolve environmental issues, and not be "a process of taking the facts of the matter to people so that they take up pressing concerns” (Vallabh *et al.*, 2016, pg. 548). The study undertaken by Vallabh *et al.* (2016) assessed the different citizen science projects within Southern Africa and the findings stressed that science can be an important part of a successful “ethically motivated civic practice for the common good” but the emphasis needs to be on the participants, working within their contexts on addressing a ”matter of concern” and using the science as a tool to generate knowledge to drive change within that situation (Vallabh *et al.*, 2016, pg. 548). This context-driven, learner-centred, and ethically aware approach to citizen science needs to be retained in the development of a remote learning system.

Another aspect that was highlighted in the findings of this evaluation was that a teacher-learner relationship is an imperative part of citizen science learning. The development of a teacher-learner relationship improves the training and learning process of the citizen science tools, for both the teacher and the user. This is because the training can be adapted by the trainer to suit the training needs of the group of learners being taught when there is an existing working relationship. This therefore makes citizen science training and the learning process more effective as the trainers are aware of what the learning challenges are and adapt the learning process to suit the participants.

A participant form dataset 2, commented:

"*Retraining becomes easier when you already know the teams because after the first training you don't even know the people. But after the first training, we spent time with the groups and we know that this is what this group is struggling with, here are the people who are strong in which tool. You know when you go conduct retraining what it is you would like to focus on based on the team. It becomes easier to come up with a new training method because you have a better understanding of the team and the environment, they work in*."
An effective teacher-learner relationship also changes the traditional power relationships between the "learner" and the "teacher". When the relationship is treated as a learning opportunity between the teacher and the "learner" the roles are interchangeable. This reinforces the ethical approach highlighted by Vallabh *et al.* (2016) is the awareness that all people have knowledge and come into a training space as a "teacher".

The findings further revealed that the most effective learning with citizen science tools occurred through application of educationally rich teaching methods. This includes learning about the tools through understanding the theory, which is mainly content-based, context-based local enquiry, hands-on demonstration (by an experienced user), the application of the tools by the participants, and the participants teaching others. These aspects can easily be related to the 5Ts of Action Learning (**Figure 1-1**). According to the findings from this evaluation, this is what forms the foundation of how citizen science learning is currently taking place. It is important to note that some teachers of citizen science tools may only apply one or two of these techniques when teaching the tools, but the data provides evidence that the most valued component of citizen science learning, is the practical application of the tools by the users themselves.

Participant 4 commented:

"*I found that there is a difference when you tell someone how to use the tools and when they try it out for themselves. I found that it made a big difference during the time I was learning how to use tools*.''

This emphasises the need for more field-based encounters when teaching or learning how to use citizen science tools, as emphasised by the "touch" element of the 5Ts of action learning model. This finding is further supported by Graham and Taylor (2018) who reiterates the importance of incorporating the "touch" component found in the 5Ts of the Action Learning model (**Figure 1-1**) in citizen science learning. This is in the form of field-based encounters, in this case, the practical application of the citizen science tools in the actual environment by the users, which is said to enhance the learning of the participants. The research of Graham and Taylor (2018) further emphasised that "touch" (practical application of what you learn) further deepens understanding and the learning experience of individuals.

Participant 2 commented:

"*I learnt by practically applying the tools each time we are taught about them. I find as the best way to learn is through the practical application of the tools than only learning them in theory." Participant 3 reinforced this by saying, "the practical learning of citizen science tools helped me a lot as most of the time I am practically teaching people how to use CST and not theoretically*."

A final aspect of how learning about the citizen science tools currently takes place is that citizen science learning usually takes place within a community[8]. Participant 4 alluded to this by stating that learning within a community is important as you can learn from others. According to Wals *et al*. (2009) learning is characterised as social learning when it occurs within a community, amongst stakeholders who are learning with and from each other. The results from this evaluation show that participants learnt how to use citizen science tools within a community of practice (CoP) which enables social learning to occur. Wenger and Snyder (2000) define CoPs as "a group of people informally bound together by shared expertise and passion for a joint enterprise." These engagements with citizen science reflect a CoP and allow people to learn from and with each other.

[8] In the context of citizen science learning, community within this report is referring to a group of citizens coming together to engage on a commonly shared issue, through discourse, learning and application of citizen science tools.

The characteristics of social learning must be retained as citizen science learning moves onto a digital, virtual, and remote learning space. The characteristics, as listed by Wals *et al*. (2009) are:

- We learn from each other, together;
- We learn more from each other if we think differently from each other (it is okay to have different viewpoints);
- We learn when we trust each other and can accommodate the different ways people see the world;
- We need to "own" our learning processes and the solution that we generate;
- We need to come to a common understanding or collective meaning making.

Effort can be made to build these characteristics into the remote learning system, so as to retain the important aspects of social engagement in learning, even though the participants and facilitators may be far removed from each other physically, for some, or most of the time[9].

2.3 WHAT TOOLS ARE AVAILABLE AND ARE CURRENTLY BEING USED?

The findings revealed that the most frequently used citizen science tool (from the "toolbox" developed by Graham and Taylor (2018) for the WRC) was miniSASS, as it was the most mentioned by the participants of the study. The miniSASS process was developed in the early 2000s and has been updated and adapted to its current form over the years. It is fairly well known within environmental education circles in Southern Africa, which would contribute to its popularity of use. The clarity tube and velocity plank were the second and third most used tools by participants interviewed in the study. It is important to note that there are ten citizen science tools developed through the WRC as outlined in the Graham and Taylor (2018) of this suite of tools, the wetland tool, spring tool, River Health Assessment, and estuarine tool were not used by participants. This finding suggests that individuals use citizen science tools that they are exposed to; and use the tools that are most relevant to their environment and their needs.

A participant from dataset 2, alluded to this statement by commenting:

"*I think the tools used should be context-specific, there is no point in teaching a person downstream about the wetland tool that they are never going to use. Whereas someone upstream in an area like Mpendle or Mpophomeni is based in a wetland, where they would use the wetland tool and for others, it is not applicable. The citizen science tool choice should be unique for each group*."

On the second round of interviews, a Support Officer from the Amanzi Ethu Nobuntu project was asked about their experience with the full suite of tools in the "toolbox":

"*The tools can be easy to use once you understand them and have worked with them for a while. Initially they can be a bit complex. As Rovers, one of our tasks were to re-write the manuals for the Clarity Tube, Velocity plank, and the miniSASS. We had to read the manuals first, and even we had some difficulty understanding them, and we all have degrees. The language is very technical. I have looked at the other tools too, and I think that they are all very technical. You need to have had experience in those areas to really be able to pick up the manual and use it without someone training you*."

This highlights the opportunity to re-examine the tools in the "toolbox", and refine them, and update them by redesigning the manuals, adding instructional video content, and translating simple user-friendly manuals into more mother-tongue South African languages. This work has been highlighted by the broader study that this evaluation falls under; and will be completed as part of the fifth deliverable, due in November 2023. The participant's experience of trying to make sense of the tools without outside instruction, also illuminates the need for a remote learning system, that can be accessed and used independently.

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[9] It has already been mentioned that "remote learning" could include field-based engagements and could be a mixed approach of virtual and in-person encounters.

In addition to the suite of citizen science tools that were compiled by Graham and Taylor in the 2018 “Toolbox”, some participants commented that they were also exposed to other citizen science devices that have enhanced their use and engagement with the “tools in the toolbox”. Two of these additional enhancements were iNaturalist (an online platform that allows the user to upload a picture of any specimen they might find and receive help from an experienced user to identify it) and the DigiScope (a mobile microscope that you can attach to your cell phone). Both were used in collaboration with the citizen science tools that are being discussed for this evaluation.

Participant 7 commented:

“*You use [the DigiScope] alongside miniSASS and any other scientific tool. As it helps you identify, species correctly, because the purpose of a microscope is to see the characteristics you couldn’t with your naked eye. But when you put it under the microscope, you're able to see*”.

Both iNaturalist and the DigiScope enhance the user’s ability to engage with the invertebrates that are found when conducting a miniSASS. These mediums have been reported to add excitement to the process and encourage users that enjoy adding to a community of knowledge or enjoy learning how to use new technology. This highlights the importance of exposing citizens to different types of technology which could potentially help support the citizen science tools they may be using and thus, encourage the user to contribute richer data from the citizen science tools.

2.4 WHAT IS THE POTENTIAL FOR ONLINE LEARNING?

Despite the advantages that WhatsApp offered as a training platform (it is a low-data communication platform that is used by most South Africans), findings highlighted in **Box 1** revealed that data and network issues were a challenge to project officers within the AEN programme located in remote communities, as WhatsApp is a mobile application that incurs a low charge for internet usage. The cost may be low, but because it is not free, and there are limited access points to free Wi-Fi in South Africa (especially in rural areas), this hindered the project officers from participating in training modules discussions and engaging with the content on a weekly basis. The modules also incurred a cost to download the content, as the module resource pack comprised of a YouTube link (to videos related to the module topic), PowerPoint slides and voice notes). Visual media use incurs a higher charge to download, and some participants were unable to engage fully with it. These findings are important to understand, as WhatsApp was flagged as a potential platform on which remote citizen science training could possibly be conducted.

The findings also provide evidence that there is a need for more practical and situated activities (in the context of the participants) to support the module-based training. The project officers expressed that to further support their learning, activities that allowed them to implement what they have learnt within their context, would be beneficial. This finding correlates with the emergent themes outlined in **Table 5-6** highlighting the need for citizen science training to be learner-centred and based within the contextual landscape of the participant, with hands-on activities. According to Pengiran and Besar (2018) situated learning enhances an individual’s learning experience as it allows for the application of what they learnt in their real-life context. This finding emphasises the use of the 5Ts of Action Learning model, which advocates for more interactive forms of learning, using the elements of ‘Talk’, ‘Tune-in’, ‘Touch’, ‘Take Action’, and ‘Think’ to fully engage in a learning process (Graham and Taylor, 2018). More specifically, the element of Touch emphasises the importance of field-based encounters to enhance one’s learning experience. Question-guided learning was also identified by the project officers as a useful learning technique to increase interaction with the module content and with their online “classmates”. This illustrates the need for this learning technique to be strengthened and supported as it has been used throughout the training to assess whether the project officers are understanding and engaging with the content, to probe the depth of their understanding, and allow them to feel connected to their fellow participants even though they are physically distant from each other. This learning technique was also useful to gauge the project officers' prior level of knowledge or understanding of a topic which helps to scaffold[10] their learning to build new knowledge. Using the technique of guided questioning mindfully helps to fulfil the "talk" component of the 5Ts of Action Learning model.

Although these findings are specific to the WhatsApp-based training, they useful in helping us understand how online or remote learning is currently taking place. What we have learnt from the Case Study informed the development of a learning framework for remote citizen science learning.

2.5 KEY PRINCIPLES FOR THE LEARNING FRAMEWORK

The aim of the evaluation was to assess how citizen science learning has been taking place, and to find out what parts of this learning are the most beneficial, so that those elements can be retained when the remote learning system is piloted. From the emergent themes, findings of the case study, interviews, important conversations, and observations; the following elements have been highlighted to form the basis of the learning framework for remote learning about citizen science (Box 2):

Box 2: Key principles for the Learning Framework

1. Relationships between the facilitators and participants, and between the participants themselves need to be established and developed throughout the learning process.

2. Learning needs to be initiated from within the participants' community and context. Learning must start from the needs of the participants, by making links with the matters of concern that they have identified within their environments, from their own perspectives.

3. These matters of concern should be explored using Action Learning and by identifying the cultural and historical links to how practices were done in the past; how they are done in the present; and how practices could change for the future.

4. Citizen science could then be introduced as a tool to investigate the current state of the environment, with the possibility of generating accurate data with the aim of using the data to take action; and bring about change. Citizen science can be used to monitor the change as it happens.

5. Learning about the citizen science tools should involve real-life experiences; hands-on use of the tools; diverse field-based encounters; and repeated practice.

6. Learning should be gently scaffolded, building on the prior knowledge of the participant, questioning, and probing assumptions and understanding, and giving the participants time to engage amongst themselves in discourse about their learning.

7. Participants that feel that they are contributing meaningfully to the beneficial change of their environment or communities are ,more likely to continue their participation in citizen science.

8. The platform that the remote learning takes place on needs to be easily accessible and needs incorporate the charge for internet-use; or keep the internet charge at a minimum.

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[10] The theory of educational "scaffolding" emerged from the work of Jerome Bruner in the 1950s and incorporates Vygotsky's concepts of how children learn language. It has become a common approach to curriculum development in South Africa, as it emphasises starting within a learner's prior knowledge, and adding to concepts systematically over time to build more complex connections between what is known and what is new knowledge (Lotz-Sisitka, 2011).

These elements formed the foundation on which the remote learning system was designed and developed. Thereafter, a selection process to identify a suitable community to pilot the remote learning programme needed to be conducted. The community had to be situated in a rural location, have limited access to technology, and face water issues. A simple multi-criteria analysis using GIS was performed to select communities who score highly across all these factors. The final selection was made depending on the prior relationship, or potential for a strong relationship to be built.

CHAPTER 3: COMMUNITY SELECTION

3.1 SELECTION METHODS AND RESULTS

KwaZulu-Natal was selected as the province to focus the broader study as this is where the research organis33ation (GroundTruth) is located; this meant that travel for the project was minimised, and existing relationships with communities could be built upon. The province is subjected to a vast array of water, social, economic, and connectivity issues, representing other communities across South Africa.

To select a community to trial the remote citizen science learning system with, a Multi Criteria Analysis (MCA) was performed to highlight communities that meet the criteria based on the consideration of various social, economic, and environmental factors. MCA is a systematic Geographic Information System (GIS) process that allows the user to overlay different attributes against a spatial planning unit to rank and identify areas with a high priority based on the combined value of those attributes. The user selects the attributes used in the analysis based on the MCA's predetermined aim. The user also decides how each attribute is weighted in its contribution to an overa33ll priority score. The communities regarded as the most marginalised and thus considered a high priority were those facing water risks, those with limited access to technology and internet coverage, and those threatened by socio-economic factors such as poverty and unemployment. The final selection of a community also incorporated other practical factors such as existing relationships with the community, participation in existing programmes or partnerships, and distance from prioritised universities (e.g. the University of Zululand and the University of Fort Hare).

3.1.1 Prioritisation of Community Selection at Ward Level

The MCA allowed for several factors to be considered simultaneously, with differing weighting when identifying in which community to run the study. This approach accommodated the use of a range of social and environmental factors that were relevant to the research and allowed for the combination of quantitative and qualitative data to address each prioritisation criterion; this data also took the form of "hard" data (which should thus be fairly objective), and "soft" data (data that is considered more subjective, but still relevant), which related back to the selection criteria of the MCA.

The analysis needed to be referenced to a spatial planning unit to select a community. The smallest and most relevant spatial unit was the demarcation of municipal wards. Therefore, the prioritisation process was undertaken at a municipal ward spatial resolution, meaning data was collated and analysed per ward. The ranking of the ward areas within KwaZulu-Natal went through two prioritisation phases. The primary prioritisation was undertaken through the amalgamation and relativisation[11] of numerous spatial layers, which ranged from social factors, water issues, connectivity indicators, and environmental datasets (**APPENDIX D – facTORS USED FOR THE MULTI-CRITERIA ANALYSIS**). The factors used in the initial primary prioritisation were combined, with equal weighting, to generate a primary prioritisation score[12] used to preliminarily rank the wards. Those with the highest score had the highest priority (**APPENDIX E – WARDS WITH THE HIGHEST PRIORITISATION SCORES**). The wards with a prioritization score in the top 5% were extracted from this ranking. Three more data layers were added to enhance and refine the prioritisation process at a secondary prioritisation level.

The secondary prioritisation included the addition of a "proportion of ward area covered by a water feature" dataset; the "distance of a community to a priority institution (the University of Fort Hare and the University of

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[11] Relativisation refers to the process of standardising the 'unit' of each factor considered in the MCA. Each factor was relativised to be scored out of 100, such that the highest value for each factor was assigned a numerical score of 100, and the lowest value for each factor was assigned a numerical score of 0. Therefore, all factors have comparable 'units' and the problem of "data dilution" was not a concern.

[12] This was done by summing the relativized scores of all considered factors for each ward.

Zululand)” dataset; and a “Relationship factor” dataset, which refers to the rating of the existing relationships GroundTruth has with communities in KwaZulu-Natal. The scores from these three layers were relativised and combined, with equal weighting, to generate a score. This was used as the secondary prioritisation score. The secondary prioritisation scores for the wards in the top 5% were ranked from highest to lowest, and the final selection was made from the concluding list.

The secondary prioritisation included the addition of a “proportion of ward area covered by a water feature” dataset; the “distance of a community to a priority institution (the University of Fort Hare and the University of Zululand)” dataset; and a “Relationship factor” dataset, which refers to the rating of the existing relationships GroundTruth has with communities in KwaZulu-Natal. The scores from these three layers were relativised and combined, with equal weighting, to generate a score. This was used as the secondary prioritisation score. The secondary prioritisation scores for the wards in the top 5% were ranked from highest to lowest, and the final selection was made from the concluding list.

3.1.2 Planning Unit

The planning unit (PU) used to prioritise communities for piloting the remote learning system was the ward layer within KwaZulu-Natal (**Figure 3-1**). A large amount of social and economic data was available from the 2011 census at the ward level. The current census data (2021 National Census) had yet to be released at the time of this report, which meant that it could not be used[13]. Although the 2011 census data may be outdated, it was extensive and gave good coverage of the province at the ward level. In contrast, more recent socio-economic data (uMkhanyakude District Municipality [UDM], 2020) is only available at a district municipality level, losing much of the detail needed for this analysis. For this reason, wards were used as the planning unit for the MCA.

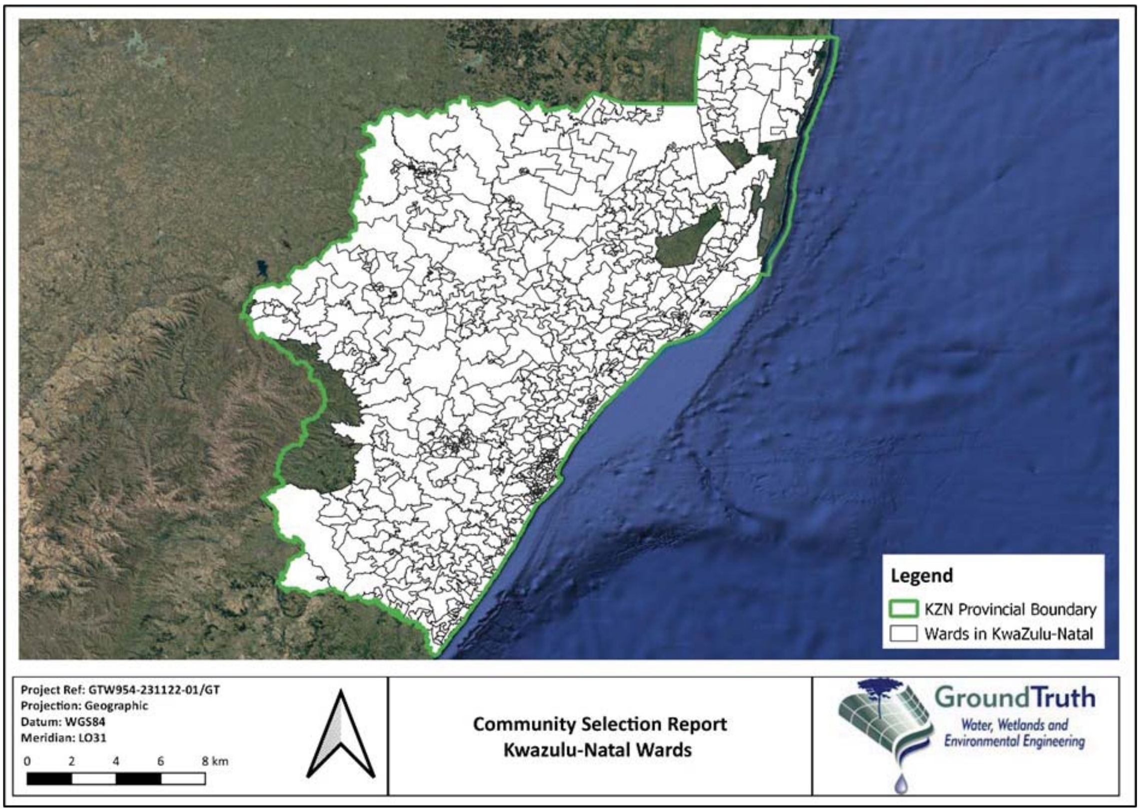

Figure 3-1: Wards of KwaZulu-Natal were used as the spatial planning unit for the MCA.

[13] The 2021 Census data is due to be released in 2023, this analysis can be updated then to include this data.

3.1.3 Base Layers

Base layers are spatial databases that provide the backdrop onto which other layers of information or data are superimposed or from which data were extracted and superimposed onto the planning unit. The base layers used for the ward areas prioritisation are listed and described in **Table 3-1** below.

Table 3-1: Base layers for the ward level prioritisation.

Data layer	Source of data	File name
KZN Boundary	Department of Transport: KwaZulu-Natal	KZN_Boundary_2016
Municipalities	Department of Transport: KwaZulu-Natal	Local_Municipalities_2016_KZN
Ward Areas	Department of Transport: KwaZulu-Natal	KZN_Wards2011
Ground Water	SANBI, Strategic Water Source Areas (SWSAs)	Ground_SWSA_2017
Surface Water	SANBI and SWSAs	Surface_SWSAs_2017
Rivers	SANBI and FEPA	River_FEPAs_KZN_2011
Dams	Working for Wetlands (WfWet) and FEPA	Dams
Estuaries	SANBI and FEPA	KZN_Estuaries
Tribal authorities	Department of Transport: KwaZulu-Natal	Tribal_Authorities_KZN
National wetlands	SANBI and FE	NWMP5_KZN_layer
Poverty Stricken Areas	National Census 2011 Statistics of South Africa (STATSSA)	Poverty_Stricken_Areas_KZN
Priority Wetlands[14]	SANBI	NFEPA_Wetlands
Critical Biodiversity Areas	Ezemvelo KZN Wildlife	Critical_biodiversity_Areas_Optimal_KZN
Ingonyama Trust Land	Department of Transport: KwaZulu-Natal	Ingonyama Trust Land2010

[14] "Priority wetlands" are those wetlands identified by SANBI of having a national significance in their ability to provide valuable ecological services. As most of the other factors included in the prioritisation process.

3.1.4 Primary Prioritisation of Wards in KwaZulu-Natal – Methodology

Several datasets were created to attribute quantitative characteristics to each ward. These datasets were categorised into four broad prioritisation themes (**Figure 3-2**), which relate to the qualities of the envisioned community. The datasets within each theme were combined, with equal weighting, to calculate the prioritisation score for each ward during the primary prioritisation process.

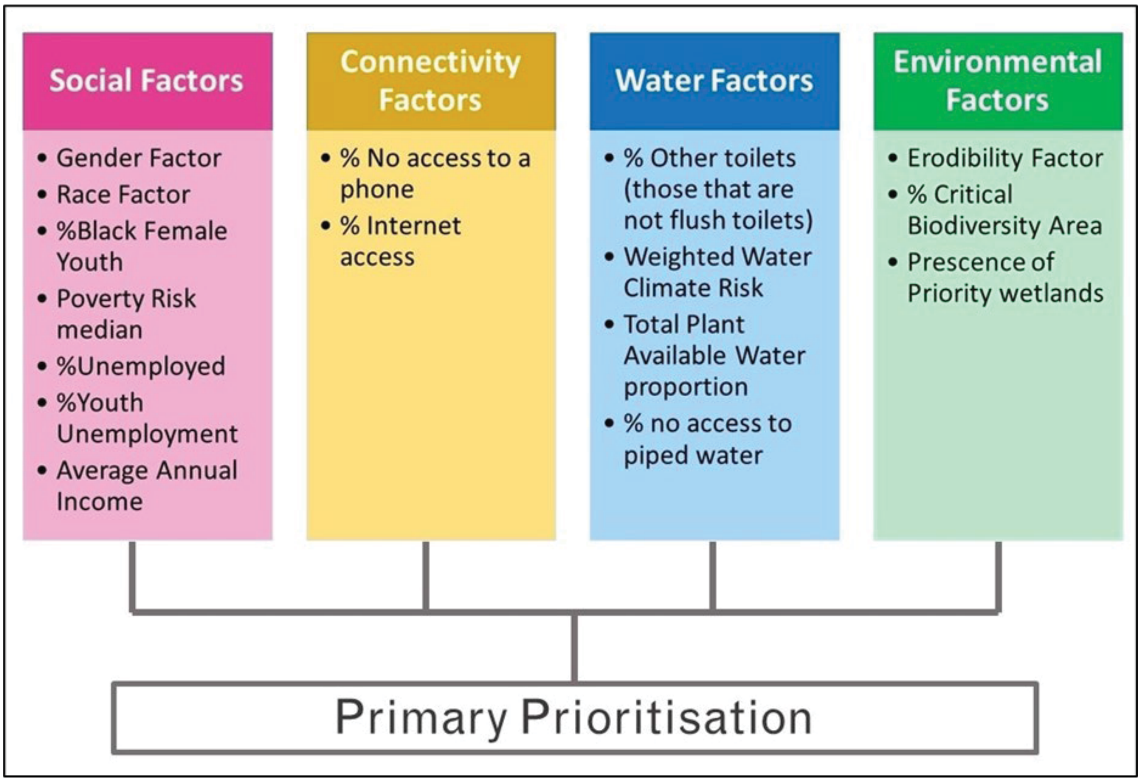

Figure 3-2: The four prioritisation themes, comprised of various factors, were combined with equal weighting to calculate the primary prioritisation score.

Each dataset, created from a base layer, went through a basic transformation to extract the relevant information and attribute it to the ward layer. These data transformations are described in **Table 3-2** below.

Table 3-2: Transformations performed on datasets for the primary prioritisation process.

Prioritisation theme	Attribute name on MCA table	Description	Transformation/ weighting	Unit/ range	Derived dataset
Primary Prioritisation					
Social Factors	GenderFACTOR	A weighted value (60% in favour of the female percentage, 40% in favour of the male percentage) of males and females of the population per ward.	Value= (%male*0.4) + (%female*0.6)	0-52	STATSSA (2010) National Census 2011
	RaceFACTOR	A weighted value (30% in favour of the African percentage, 17.5% in favour of all other race groups percentages) of race groups of the population per ward.	Value = (%African*0,3) + (%Coloured*0,175) + (White*0,175) + (Indian*0,175) + (Other*0,175)	0-30	STATSSA (2010) National Census 2011
	%BlackFEMALEyouth	A Percentage of the total ward population is Black, Female, and between the ages of 19 and 34.	A percentage	0-100	STATSSA (2010) National Census 2011
	PovertyRISKmedian	A median proportion of the population of the ward which falls under the poverty line (R945 per month).	The median proportion per ward	0-100	STATSSA (2010) National Census 2011
	%Unemployed	A percentage of the total ward population that is unemployed.	A percentage	0-100	STATSSA (2010) National Census 2011
	%YOUTHunemployment	A percentage of the population of each ward between the ages of 18 and 35 is not employed.	A percentage	0-100	STATSSA (2010) National Census 2011
	AverageANNUALincome	The average annual income per household for each ward.	A percentage	0-100	STATSSA (2010) Census 2011
Connectivity Factors	%noPhone	A percentage of households in each ward have listed that they have no access to a telephone.	A percentage	0-100	STATSSA (2010) National Census 2011
	%Internet access	The percentage of households of each ward that have internet access.	A percentage per ward is extrapolated from the percentage for each municipality.	0-100	STATSA KZN 2016
Water Factors	%otherTOILETS	A percentage of households in each ward have a toilet that is not a flushing toilet.	A percentage	0-100	STATSSA (2010) National Census 2011

Prioritisation theme	Attribute name on MCA table	Description	Transformation/ weighting	Unit/ range	Derived dataset
	WEIGHTEDwaterClimateRisk	A weighted value in favour of water sources (Borehole – 50%; Spring – 20%; Rivers – 10%; Rainwater – 10%; Dams – 10%) that would be vulnerable to drought caused by climate change.	Value = municipal% + (Borehole%*5) + (Spring%*20) + (Rivers%*10) + (Dams%*10) + (Rainwater collection%*10) + Vendor + Tanker + Other	0-1500	STATSSA (2010) National Census 2011
	totalPAWproportion	The relative combined proportion of the Plant Available Water percentage by area for each ward.	A percentage	0-100	Natural Resource Management (NRM) and WfWET
	%NOaccessPIPEDwater	A percentage of households per ward that do not have access to piped water.	A percentage	0-100	STATSSA (2010) National Census 2011
Environmental Factors	KFACTproportion	The relative combined proportion of the K-factor for erodibility by area for each ward.	A proportion	0-1	Natural Resource Management (NRM) and WfWET
	CBA%ofWARD	The percentage of land covered by a Critical Biodiversity Area in each ward.	A percentage	0-100	Ezemvelo KZNWildlife
	PRESENCEofPriorityWETLAND	The presence or absence of a priority wetland within each ward.	A presence or absence	0 or 1	NFEPA SANBI

3.1.5 Primary Prioritisation of Wards in KwaZulu-Natal – Results

The primary prioritisation process allowed the list of wards for KwaZulu-Natal to be ranked according to the primary prioritisation score (**Figure 3-3**). The areas with the highest priority scores are coloured darker blue on the map below. These are the wards with high combined values for the social, water, connectivity, and environmental factors. The characteristics considered for each of the factors are listed and explained in **APPENDIX D – facTORS USED FOR THE MULTI-CRITERIA ANALYSIS.**

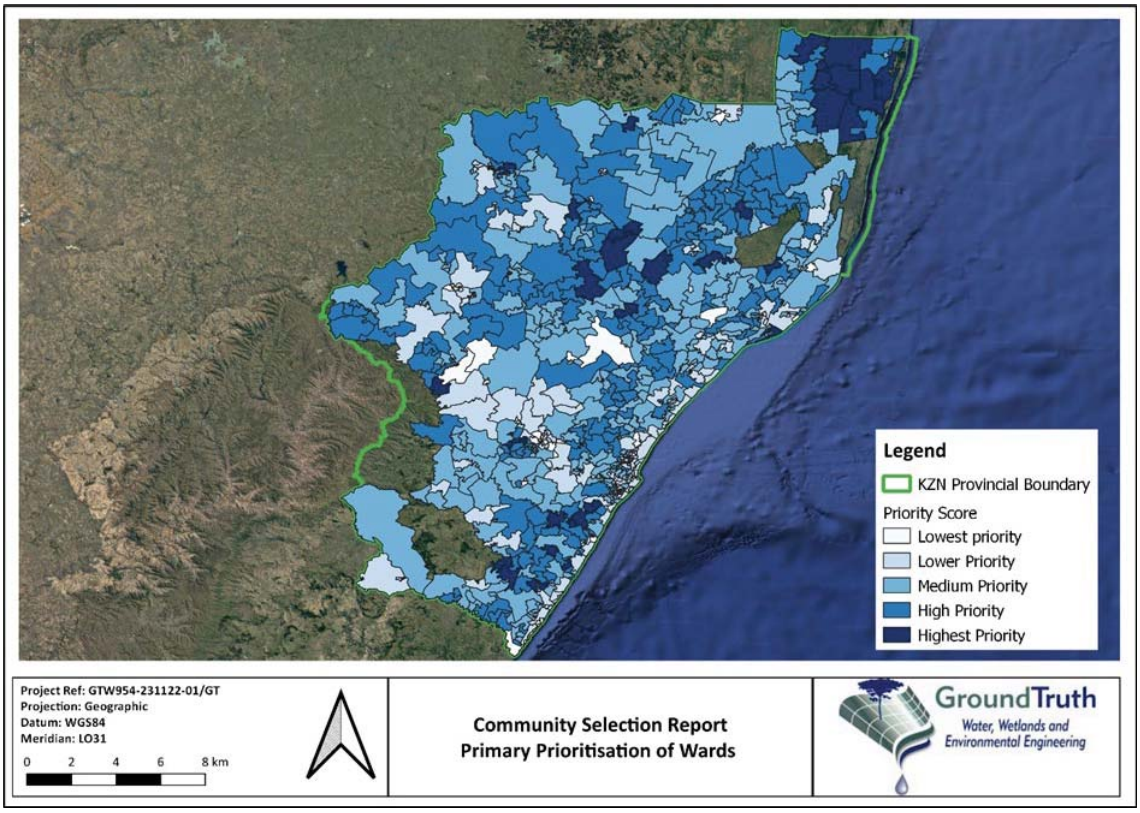

Figure 3-3: Municipal wards in KwaZulu-Natal ranked according to the primary prioritisation score.

The wards whose primary prioritisation scores fell within the highest 5% were isolated and used in the secondary prioritisation process; the location of those wards can be seen in the map below (**Figure 3-4**).

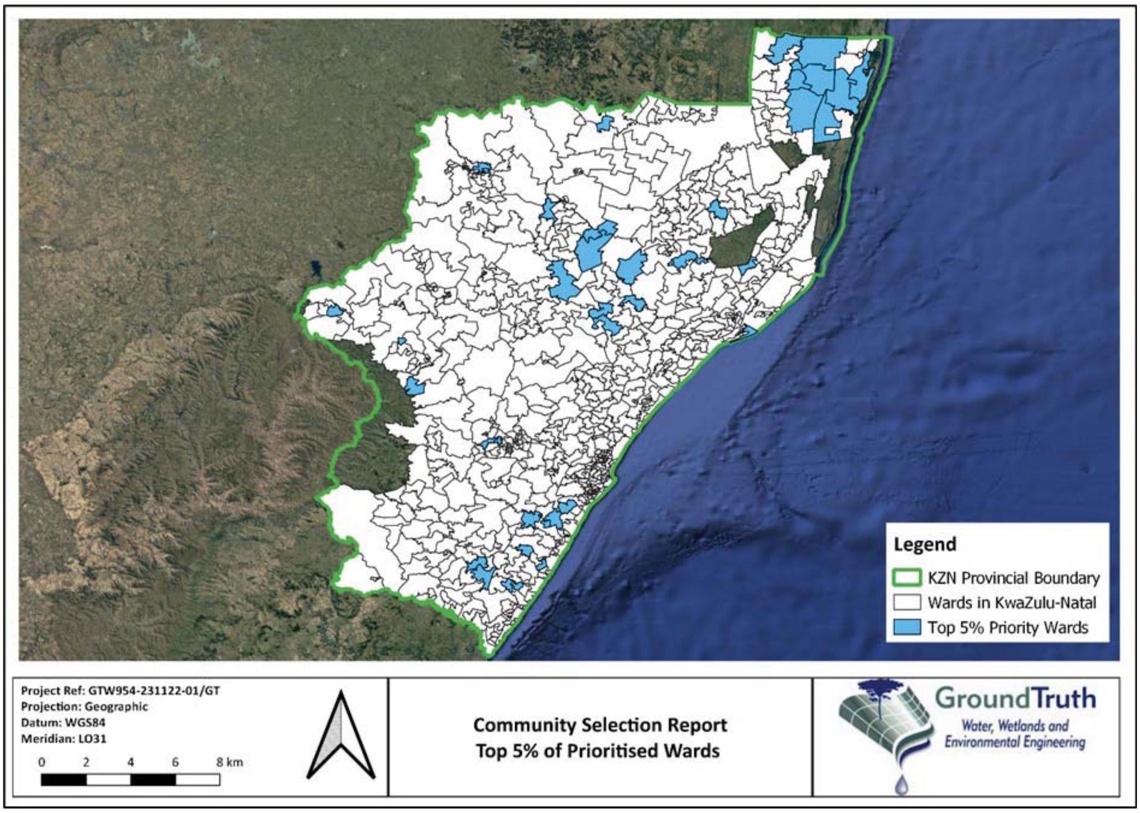

Figure 3-4: Location of wards in KwaZulu-Natal with the highest 5% primary prioritisation scores.

3.1.6 Secondary Prioritisation of Wards in KwaZulu-Natal – Methodology

The primary prioritisation score was used to rank the wards in KwaZulu-Natal in order of priority. A subset of the top 5% of wards with the highest priority score was generated from the ranked list. A secondary prioritisation score was applied to this sub-set of wards. **Figure 3-5** and **Table 3-3** below illustrate the secondary prioritisation score, which was compiled by combining, with equal weighting, the relativised score for three additional factors: a relationship factor, a connectivity factor, and a water factor.

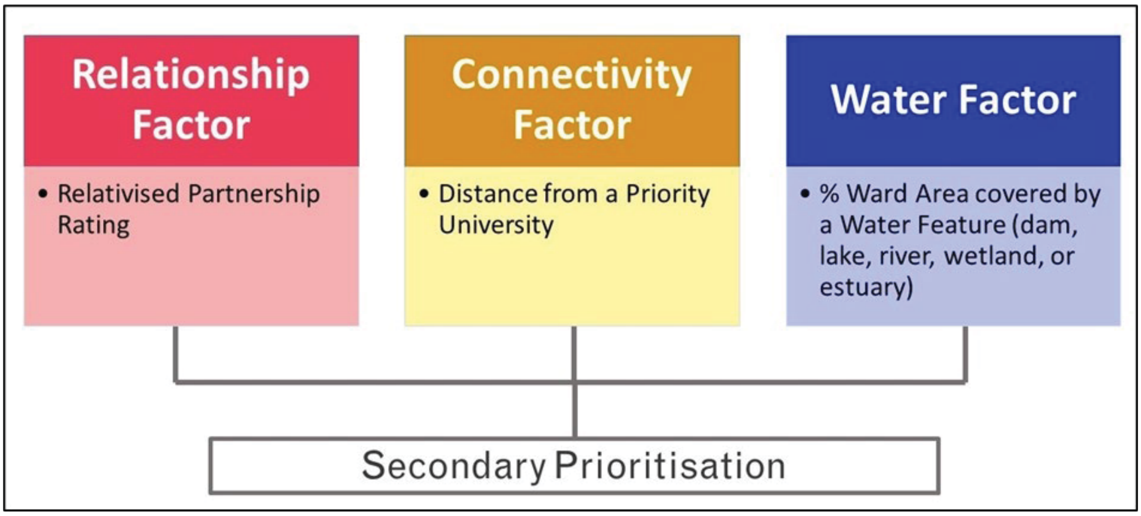

Figure 3-5: The three factors were used to generate a secondary prioritisation score to rank the top 5% of wards in order of priority.

Table 3-3: Transformations performed on datasets for the secondary prioritisation process.

Prioritisation theme	Attribute name on MCA table	Description	Transformation/ weighting	Unit/ range	Derived dataset
Secondary Prioritisation					
Relationship Factor	Partnership Factor	A score for each ward in the top 5% was calculated, out of a maximum of 20, by rating four 'relationship characteristics' out of 5. These characteristics were 'length of relationship', 'state of relationship', 'stability of relationship', and 'enthusiasm towards relationship'.	Partnership Factor = (Length of relationship score) + (state of relationship score) + (stability of relationship score) + (enthusiasm towards relationship score)	0-20	Data set generated from a list of known community projects and their location.
Connectivity Factor	Distance to University	A rated value was calculated from the minimum distance from the ward to either the University of Zululand or the University of Fort Hare. The relativised percentage of the rating score was used as the "Distance to University Factor".	Rating = **10** if min distance < 50 km; **8** if min distance 51-100 km; **6** if min distance 101-150 km; **4** if min distance 151-200 km; **2** if min distance 201-250 km; **0** if min distance > 250 km Final value = the rating score * 10	0-100	Dataset generated for this study.
Water Factor	%Water Feature	This data was calculated by combining the percentage of land cover by area in each ward for the following water features: **Rivers**, **Estuaries**, **Dams**, and **Priority Wetlands**. The total percentage of these land covers was calculated for each ward.	A percentage	0-100	(WfWet) Freshwater Ecosystem Priority Area and National Wetland Map 5 (NWM5) from South African Biodiversity Institute (SANBI)

3.1.6.1 Relationship Factor at the Secondary Prioritisation Level

Partnership Factor: This dataset was generated by systematically ranking the wards in the top 5% against four relationship characteristics (**Table 3-3**). Each characteristic was allocated a score out of five to generate a maximum score of 20. The four characteristics were:

- 'length of relationship', a higher rating was given if the relationship had existed for five years or longer;
- 'state of relationship', a rating was given to depict if the relationship between the community and the research organisation (or a partner organisation) was regarded as "good";
- 'stability of relationship', this rating ranked the stability of the political state of the community; and
- 'enthusiasm to relationship', this rating was used to denote how enthusiastic the community was towards the project or invention and indicate their dedication to participation.

There has been recognition that the success of a training programme can operate more effectively and achieve long-term sustainability when strong relationships are formed between the community members and between the community and the facilitators. Thus, the “Relationship factor” was added as a vital criterion to the secondary prioritisation process to refine the selection of a community to trial the online learning system.

3.1.6.2 Connectivity Factor at the Secondary Prioritisation Level

Distance from a Priority University: this dataset was generated for this study. The distance from each ward in the top 5% from the primary prioritisation to the University of Zululand and the University of Fort Hare was calculated by creating a GIS line feature from the University to the centre of each ward. This data was then used to apply a rating from 5 (very near) for distances less than 50 km to 0 (very far) for distances greater than 250km away. This rating was then relativised (**Table 3-3**). These two universities have been acknowledged by the WRC as universities of priority with which research relationships need to be fostered. Communities closer to either of these two institutions would be considered to have a higher priority.

3.1.6.3 Water Factor at the Secondary Prioritisation Level

%Water Feature: this dataset was generated by combining the percentage area of land cover in each ward for the following water features: Rivers, Estuaries, Dams, and Priority Wetlands. The percentage of land covered by each water feature was calculated for each ward, and those amounts were totalled to give a combined percentage of the ward area covered by a water feature (**Table 3-3**).This factor was seen as important to include at the secondary level of prioritisation because the remote learning system that the selected community will trial will focus on citizen science tools to investigate the health of water systems. It was therefore deemed important to know how much of each of the top 5% of wards was covered by a water feature.

3.1.7 Secondary Prioritisation of Wards in KwaZulu-Natal – Results

The sub-set of the wards with the highest 5% primary prioritisation scores were subjected to secondary prioritisation, where a combined score was calculated that included data is referring to the distance to a priority university, the percentage of each ward area that was covered by a water feature, and a relationship factor. The secondary prioritisation scores were ranked from highest to lowest, and the location of the wards with the highest priorities can be seen in **Figure 3-6** below.

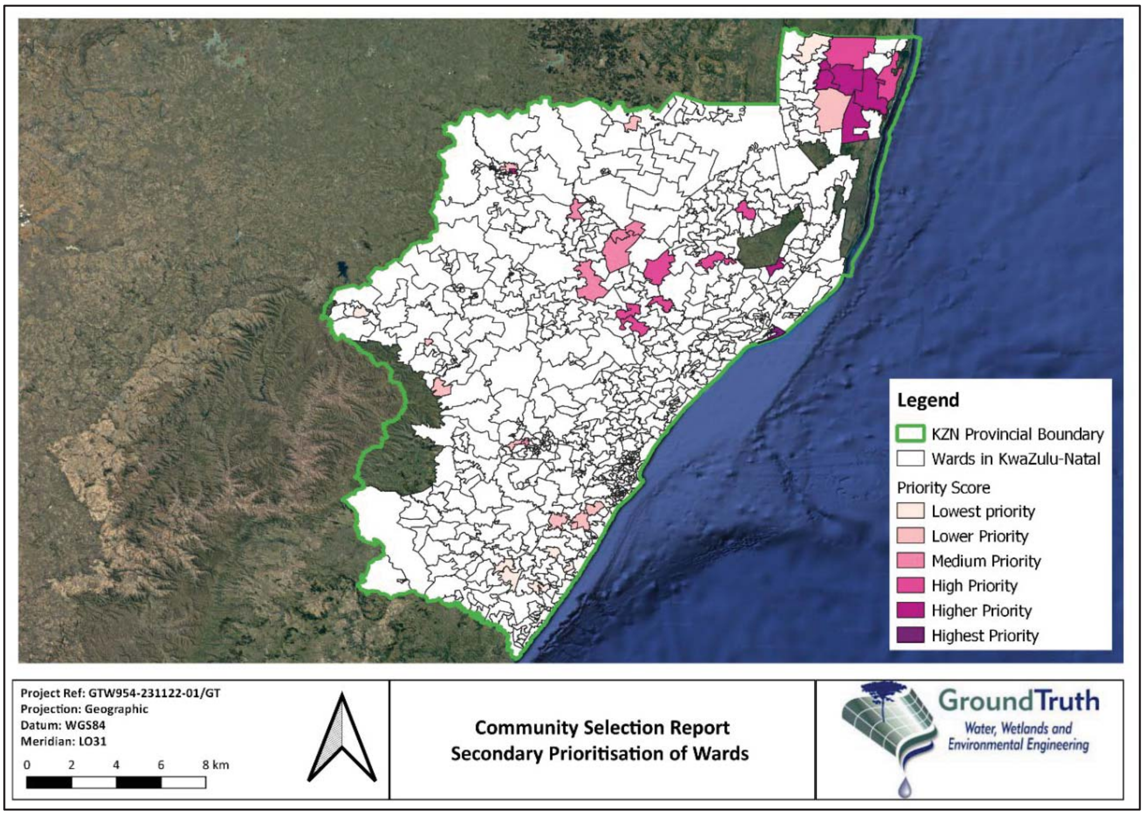

Figure 3-6: Ranking of the top 5% of wards in KwaZulu-Natal according to the secondary prioritisation score.

The wards whose primary prioritisation scores fell within the highest 5% were isolated and used in the secondary prioritisation process; the location of those wards can be seen in the map below (**Figure 3-7**). The ranking of these wards was examined, and the following wards with the highest secondary prioritisation score were listed (**Table 3-4**).

Table 3-4: Wards with the highest secondary priority scores.

Ranking	Ward Identification Number	Secondary Prioritisation Score (Rounded off)	Presence of an existing relationship
1.	52802013	58	No
2.	52502007	33	No
3.	**52701006**	32	**Yes**
4.	**52701008**	32	**Yes**
5.	**52701005**	32	**Yes**
6.	**52701002**	30	**Yes**
7.	52605010	28	No
8.	52606023	27	No
9.	52806006	27	No
10.	52606024	27	No

The wards ranked 3rd, 4th, 5th, and 6th have a pre-existing relationship with the research organisation. For this reason, these wards were considered the “selected wards” (**Figure 3-7**), as it was highlighted that there is greater success in undertaking training within a community that is already known and has shown interest in participating in such a learning activity.

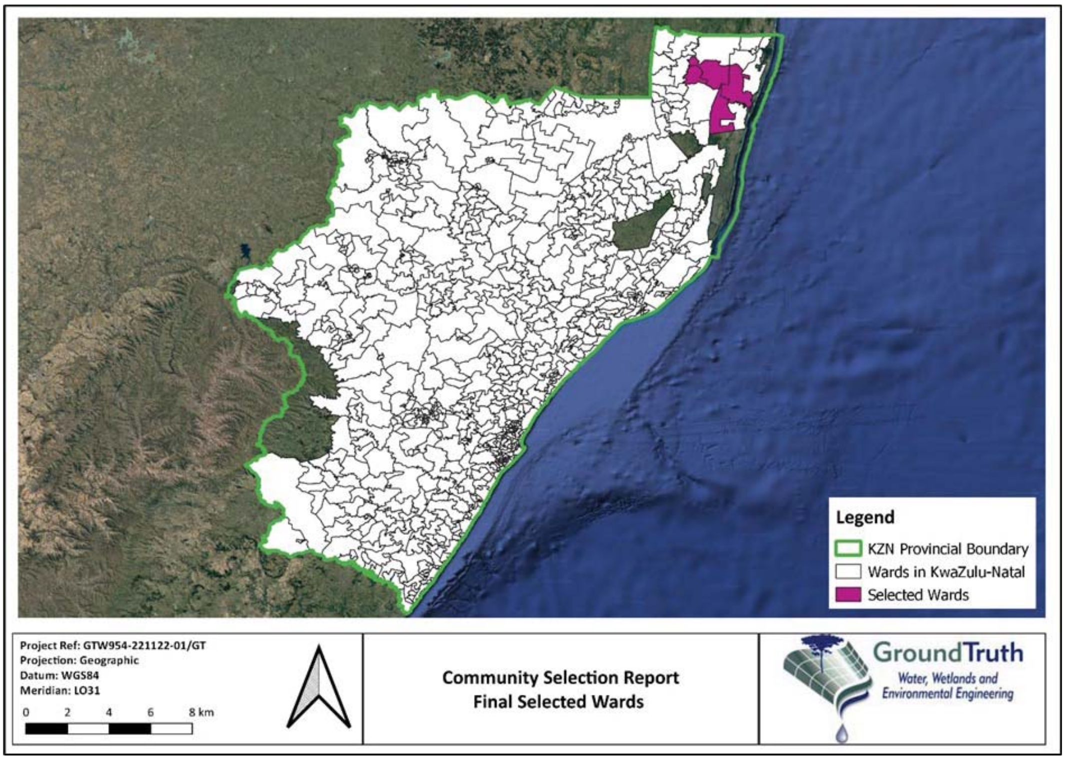

Figure 3-7: Wards with the highest secondary prioritisation score and a pre-existing relationship with the lead organisation or a partner organisation.

3.2 THE SELECTED COMMUNITY

The selected ward areas (**Figure 3-7**) with the highest priority score after the secondary prioritisation process and exhibited a pre-existing relationship were found within the Northern regions of KwaZulu-Natal, in the uMkhanyakude District. The community that is demarcated by these four wards (and others) fell under three Tribal Authorities (TA), namely: the Tembe TA, the Mabaso TA, and the Zikhali TA (**Figure 3-8**).

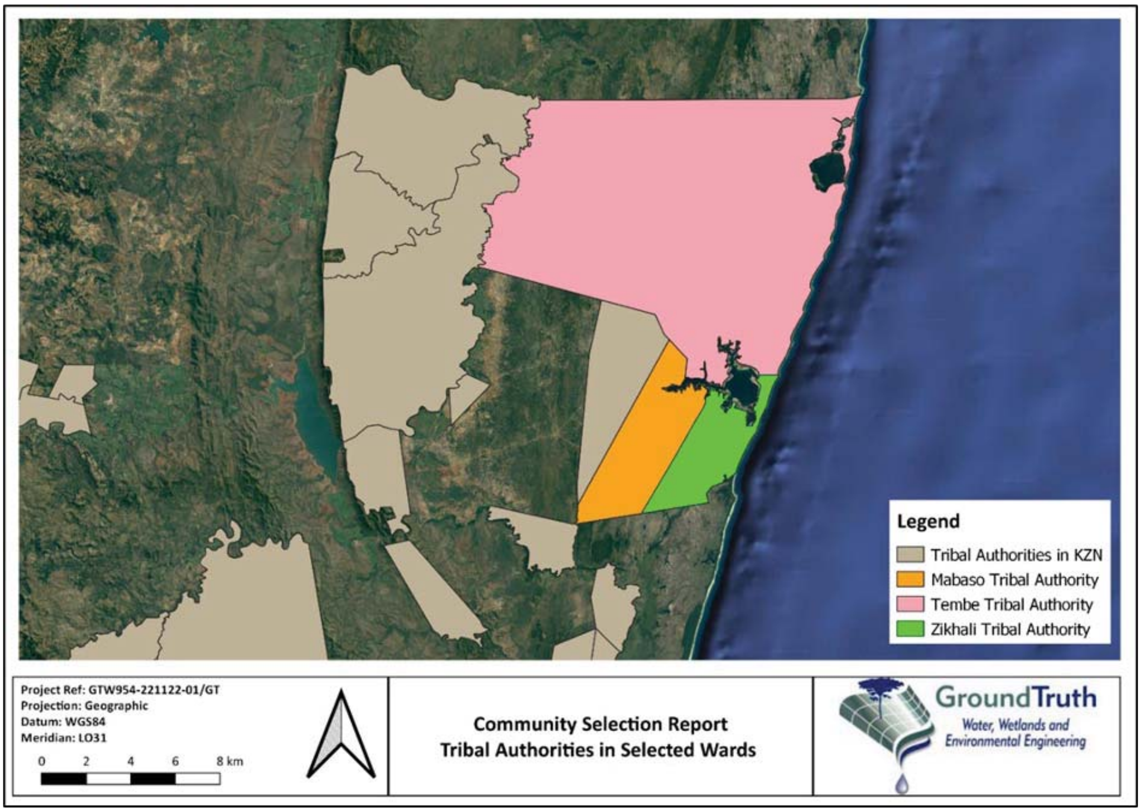

Figure 3-8: The selected community and the tribal authorities they represent.

Through the interactions that have already occurred within this community, S. Van Rensburg noted that:

"Any interventions take place within this region, that they take place equally within the three Tribal Authorities, as they are very closely related and have a complex relationship with each other" (personal communication, October 10, 2022).

These three tribal authorities[15] are situated around Lake Sibayi and share its resources. Their shared reliance on the lake has added to their collective affiliation and has increased their dependency on a positive working relationship between the three regions. The three Tribal Authorities made up the selected community in which the remote learning system was trialled, with 10 participants selected from each TA to work through the citizen training in 2023.

The uMkhanyakude District is regarded as the second largest in KZN. It is made up of four Local Municipalities (LMs), namely, uMhlabuyalingana LM, Jozini LM, The Big 5 Hlabisa LM, and Mtubatuba LM. The district comprises a total of 18 traditional leaders within each municipality. The selected community fell under the uMhlabuyalingana municipality. The youth make up the majority of the uMkhanyakude District. Subsequently, the total population of the Tembe TA, Mabaso TA and Zikhali TA under 18 years old was 50.7%, and 70% of the youth under 35 years are unemployed (Statistics South Africa [SSA], 2011; UDM, 2020). This district is also ranked amongst the ten most impoverished districts in South Africa and continues to face challenges linked to service delivery, particularly with water and sanitation (UDM, 2020).

To supplement the National 2011 Census data used to inform the MCA, an interview was conducted with a local researcher from the South African Environmental Observation Network (SAEON) (**APPENDIX F – INTERVIEW WITH LOCAL RESEARCHER**). This researcher was recently involved in a WRC Project entitled:

[15] The three tribal communities located around Lake Sibayi are managed by 3 tribal councils which are diverse, as they face different challenges relating to water access and quality and has varied internet and network access. Further, the communities emerged as the most marginalized communities in KZN from the GIS study.

“Advancing water and income security in the unique Maputaland coastal plain: a strategic decision-support tool to explore land-use impacts under a changing climate”. The researcher was responsible for collecting and analysing preliminary household data completed by the Tembe TA, Mabaso TA and Zikhali TA, thus, was regarded as having a good understanding of the current situation within the selected community.

The preliminary data that was shared from the research project (**APPENDIX G – PRELIMINARY HOUSEHOLD SURVEY DATA**) revealed that the most commonly occurring socio-economic issues in the community were:

- water shortages;
- high unemployment rates; and
- poor connectivity in relation to cellular network and internet connection.

When asked to list the concerns of the community that came up most in the surveys that were conducted, the researcher noted:

“Water shortages, the only way to get stable water supply is by getting a borehole, and it costs R21 000 to install, and only a few have the funds. High unemployment rates for most of these communities where the tourism industry is not doing too well, and there are no job opportunities. Network or reception issues. Only a few areas in the whole area have good stable internet.”

This further supports the statistics highlighted in the UDM (2020), which notes that poverty and high levels of unemployment are prevalent within the communities in this district. Directly linked to the high levels of unemployment is the average annual income of households. The data revealed that household income was very low, with most of the population depending on old-age pensions and social grants to support their livelihoods. To further provide the context of the current state of these TAs (Tembe, Mabaso and Zikhali), preliminary results of the Household surveys (**APPENDIX G – PRELIMINARY HOUSEHOLD SURVEY DATA)** were shared for the project mentioned above. The data revealed that 66% of households under the Mabaso and Zikhali TAs have access to water, whilst only 50% of households under the Tembe TA have access to water. 48%, 77%, and 68% of the households under the three TAs with water access their water from rainfall, borehole, rivers, wells, springs, or lakes. These water sources are at risk of the effects of climate change, increased population levels, and changes in land use in the region, exerting pressure and decreasing the sources’ capacity.

A letter (**aPPENDIX H – LETTER OF PERMISSION FROM THE MABASA TRIBAL COUNCIL**) from Mr L. Nxumalo, who is a member of the Lake Sibayi Conservation Trust and the Mabaso Tribal Council, stated:

“The Tribal leaders in this region have expressed an interest in learning more about citizen science techniques to monitor and regulate the health of their water systems” (Personal communication, June 04, 2021).

This further corroborated the validity of selecting this community to pilot the remote learning system for citizen science tools to monitor the health of water systems.

CHAPTER 4: TOOLBOX ADAPTATIONS FOR ONLINE LEARNING

4.1 THE CURRENT CITIZEN SCIENCE TOOLBOX

An evaluative review was conducted in phase one of the project, to assess the current process in which learning about citizen science tools was taking place. The emergent themes from the data were used to compile a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis of the current citizen science toolbox developed through the Water Research Commission in 2018 (Graham and Taylor, 2018). The weaknesses revealed by the SWOT analysis were used to identify the current needs of the toolbox and guide the process of updating the citizen science toolbox in phase 2 of the project.

Table 4-1 provides a snapshot summary of the weaknesses identified from the SWOT analysis and the associated methodology applied to update the current citizen science toolbox.

Table 4-1: Summary of the current needs of the "Toolbox" and proposed solutions

Needs	Proposed solutions (Rounded off)
Some tools are difficult to apply and comprehend.	• Identify which tools pose the biggest challenge to users, • Adapt the tools to simplify the steps involved, • Refine the language used in the manuals to reduce the technical complexity, • Re-trial the tools and document their application by users.
The manuals for the citizen science tools are technical which makes it difficult to understand them, particularly for non-English speaking individuals.	• Simplify the language used in manuals, • Reduce manual to a "one-page summary" with pictures, • Translate manuals into four different South African languages.

The results from the evaluation were summarised into key principles (**Box 2**) to guide the development of the remote learning system. These principles were considered, where relevant, when the tools were adapted.

4.2 UPDATES AND ADAPTATIONS OF THE TOOLS

According to Graham and Taylor (2018), public participation in monitoring water resources in South Africa, is reliant on the accessibility and applicability of the citizen science tools to the public. However, although the tools can be made more accessible through the use of technology, the understanding and application of the tools in their current form still remains a challenge to many South Africans. The aim of this phase of the research was to adapt and simplify the citizen science toolbox for use by people who have little formal scientific knowledge, whilst retaining scientific integrity of the sampling methods.

To inform the updating of the current citizen science toolbox, a detailed review of the tools in the citizen science toolbox was conducted, to identify how each tool could be adapted and improved. From the review, a process of updating each tool was developed, and is summarised in (**Table 4-2**) below. These amendments and additions were applied differently for each tool according to its complexity and individual requirements.

Table 4-2: Summary of amendments and additions to the citizen science Tools.

Amendments/ additions	Citizen Science Tool
One-page summaries: (a double-sided page was developed: one side with instructions on how to use the tool; and the other side with images demonstrating application of the tool). The instructions were translated into isiZulu, Afrikaans, English and Sesotho, using simple wording to increase readability and usability.	miniSASS; Velocity Plank; Clarity Tube; miniWET-Health; DBI; E-Coli test kit; Spring tool; Weather monitoring tools; School lesson plans; Enviro picture building game
Picture-based notes: a set of images and simple explanations was compiled to provide a contextual background and a step-by-step process of using the tool.	miniSASS; Velocity Plank; Clarity Tube; miniWET-Health; DBI; E-Coli test kit
Videos: *(1)* safety concerns, *(2)* site selection and *(3)* sampling procedure video was recorded in isiZulu for each tool. English subtitles were added to the tool. The intention is to also add subtitles in Afrikaans and Sesotho.	miniSASS; Velocity Plank; Clarity Tube; miniWET-Health; DBI; E-Coli test kit

To provide reasoning for the selected methodology to update the CST, there are a few factors that needed to be considered, which contributed to the varied level of detail required to update each tool in the citizen science toolbox. One factor that has attributed to the varied complexities and consequently varied levels of updating required for each tool is the frequency of use for each tool. Tools that are used more frequently like the Clarity Tube, the miniSASS toolkit, and the Velocity Plank are more likely to have been adapted to improve usability more frequently when compared to less frequently used tools like the Estuary tool and Spring tool. This is expected as frequent use allows the user to identify issues related to the application of the tool. The frequency of use for each tool also depends on the context of the user: springs are not found in the environment of all users; estuaries are also limited to specialised coastal environments. Lastly, as noted in the evaluation report the level of exposure and access of some citizen science tools to people also influences how frequently the tool is used. The abovementioned factors provide context for the differences in how each tool has been updated. The following section details the amendments made for each citizen science tool, to facilitate its use in an online learning system. Additionally, interviews (email[16] and in-person) were conducted with a range of users, developers, and project managers of the current citizen science toolbox. Table 4-2 shows additional information on the role of the interviewees and subsequently reasoning.

4.2.1 The Enviro Picture Building game

For the purposes of this study, a new Enviro-picture building tool (with stick-on icons) based on the landscape and environmental issues surrounding the Lake Sibayi region was commissioned. These amendments are summarised in **Table 5-3** below. The updated version of the tool shows a less detailed landscape picture but includes separate smaller pictures showing a range of environmental practices and concerns that the user can add to the landscape as they see fit. These environmental concerns were generated through discussions with the community members from the selected community who were selected to participate in the piloted online learning. These resources have been added to the online folder that accompanies this report.

[16] Email interviews refer to a qualitative data collection technique that uses electronic mail (e-mail) as an interviewing technique and allows for interviewing of single or multiple participants at the same time. This interviewing technique is cost-effective; and allows the participants to respond to the interview questions in their own time (Hunt and McHale, 2007).

Table 4-3: Summary review of the Enviro Picture-Building game.

Name of tool:	The Enviro Picture-Building game
Current range of use:	• The tool has been used extensively by GroundTruth and other organisations, including WESSA and DUCT, among others.
Changes required for online learning:	• Linking to interactive webpage such as the "capacity for catchments" page. • Exploring the potential for gamification.
Updates undertaken through this project:	• No changes were made to the original tool. • A new picture poster was developed representing the Lake Sibayi catchment. • Stick-on icons (pictures) representing environmental issues, activities and citizen science tools were created. • A MIRO [17]board activity was created to explore how the tool could be used online.
Proposed changes for future use:	• Its visual appeal and potential for gamification make this tool a versatile resource that fits well in the online space. The tool can also be used as a 'active' digital picture on which citizen science tools can be depicted, to provide situational context of where the tools can be used.

The Enviro Picture-building tool is one of the more difficult tools to explain to a new user. The tool can be used in a multitude of ways with the aim to generate discussion, guide reflections, and mirror what the user sees on the ground. This tool sits more in the human realm of citizen science, as opposed to most of the other tools, which are used for quantitative data collection. This tool can be used to collect qualitative descriptions on how the environments have changed and describe the current practices within different communities. As the tool is picture-based, it allows a user to use it in any language; and can be used to cross cultural and language barriers. A regular user, participant 14 (**APPENDIX B – INTERVIEW TRANSCRIPTS**) of the Enviro-picture building tool commented:

"*I have used this tool with pre-school children, learners from all grades including matric, varsity students, young adults, and even senior citizens. The detail in the picture lets the person looking at it make their own understanding, and I have used it to build on what they know, challenge their thinking, and deepen my own understanding of issues from their perspectives. It is a prized possession in my set of teaching resources, I don't think I could run a workshop without it."* (Personal communication, 30 May 2023).

Currently, an interactive or activity-based online version of the tool does not exist. The capacity for catchments website (https://capacityforcatchments.org/home), which is still under development, (or a similar platform), would be an appropriate site to host the tool. The tool could be expanded to represent catchments across South Africa and made available online. Additional features such as icons representing citizen science tools could be added and would be useful to allow for more holistic and interactive online learning. At the moment, many different versions of Enviro-picture building games exist which can be sourced in hard copy format when needed. These games are widely used and applied by various organisations and entities. At GroundTruth, the tool is often used as a situating and "tuning-in" activity-based tool when engaging with schools and communities. The creation of more context specific versions of the tool that represents the different catchments in South Africa, would also be beneficial. These different catchment types could potentially be joined or "stitched" together digitally to allow a user to explore the different landscapes of South Africa.

[17] MIRO board is a cloud based online platform that allows for the collaboration of multiple individuals on a range of collaborative activities such as development of user story maps, ideation, or research.

This tool holds much potential for online use and potential gamification. One way this tool could be adapted is through a concept called "rich pictures" which would allow participants to build their own catchment online. "Rich pictures", referred to by Bell and Morse, (2013), is a free standing, problem diagnosing tool which helps participants visualise the 'problematic situation' or in this case, their catchment. This concept lends itself well to a game-based approach or fun mobile application to encourage a user to explore their catchment by adding concepts and addressing issues using simulated applications of the citizen science tools. Other applications such as the MIRO[18] board or Mind Map may be useful to help participants visualise their catchment and environmental issues collectively and create dialogue surrounding them online. The potential of this tool, for online development is immense, and is currently only limited by funding directed to these efforts.

4.2.2 miniSASS

The aquatic biomonitoring tool – the mini-Stream Assessment Scoring System (miniSASS) has received increasing attention from international entities due to its value in monitoring and reporting for the Sustainable Development Goals (SDGs) (Taylor et al., 2022). This tool allows the user to calculate a score to indicate the health of a stream or river by identifying the groups of aquatic macroinvertebrates found in that stream. The miniSASS method has been widely applied across Southern Africa over the past ten years, and as such, the tool has been regularly revised and re-worked to improve the ease of its application. Consequently, the tool did not require many changes to its current design. To facilitate online learning about the tool, updates were undertaken and are summarised in (**Table 4-4**) below and included in the online shared folder.

Table 4-4: Summary review of the aquatic biomonitoring tool – miniSASS.

Name of tool:	**The aquatic biomonitoring tool – miniSASS**
Current range of use:	• The miniSASS method has been extensively applied particularly in South Africa. • Most scores have been recorded in the uMngeni Catchment.
Changes required for online learning:	• The simplification of the instruction manual. • The addition of data-friendly instructional video content and addition of self-assessment quizzes. • The miniSASS website (currently hosted by GroundTruth) needs to be hosted internationally[19], so that the data can be used for collective reporting against SDG 6.3.2 and SGD 6b.
Updates undertaken through this project:	• The creation of a one-page summary in isiZulu, English, Sesotho, and Afrikaans. • Short instructional video content of step-by-step guidelines for the safety concerns, site selection and sampling procedures for the tool in isiZulu, with English subtitles. • Picture-based notes (course notes) • A "context-based" video-presentation was added to share the story of the Mpophomeni EnviroChamps and how they have used miniSASS in their community.
Proposed changes for future use:	• Translation of the manuals and instructional video content to other South African languages to increase usability and applicability. • The miniSASS website to be revised and hosted by an international organisation.

[19] It is worth noting that this recommendation is not anticipated within the current project timeframe, as it is out of the project scope. However, this recommendation can be considered by other projects such as the partnership project GroundTruth has with CGIAR, IWMI and Amazon Web Services (AWS).

This tool is regarded as one of the most popular tools in the WRC citizen science toolbox and is readily increasing its global distribution through the support of international organisations. These international organisations include The United Nations Children's Fund (UNICEF), United Nations Educational, Scientific and Cultural Organization (UNESCO), The International Water Management Institute (IWMI) and the Consultative Group on Agricultural Research (CGIAR). Recently, the miniSASS tool has received a large amount of global attention (Taylor et al., 2022) as it has been featured in a recent UN progress report for SDG indicator 6.3.2 (UN Water, 2021). The attraction of miniSASS is that it is a method that can be applied by any user, even children, but has scientific rigour behind it, making the data meaningful for technical application and monitoring (Taylor et al., 2022).

A review of the miniSASS tool provided insight on the recent technological developments that have been conducted to enable online use of the tool. An email interview was carried out with a GroundTruth research scientist (participant 15, **APPENDIX B – INTERVIEW TRANSCRIPTS**) who is currently responsible for leading the development of the miniSASS mobile application (app) and updating of the miniSASS website. Below is the feedback participant 15 provided on the recent technological developments of the miniSASS app.

Participant 15 commented:

"As miniSASS currently stands, the accuracy and usefulness of a survey relies heavily on the accurate identification of macroinvertebrates to Order (or Order-level groupings) level by minimally trained citizen scientists. This leaves potential for errors in identification which may impact the accuracy of miniSASS results and ultimately of the river/stream health assessment. To combat this, GroundTruth is working in partnership with CGIAR, IWMI, and Amazon Web Services (AWS) on development of a smartphone application (app) with built in machine learning (ML) for identification of macroinvertebrates. The app will perform all the normal tasks of capturing information during a miniSASS survey, including storing photos taken of the sample site, gathering user information, location data, inputting sampling information, and generating (automatically) a miniSASS score. However, the app will also use ML to analyse smartphone images of macroinvertebrates sampled during the miniSASS survey, and provide real-time, precise and geolocated identifications. This will increase the objective accuracy of a miniSASS assessment, ease-of-use, and improve global applicability. These photos will also be stored in open-access databases such as the Freshwater Biodiversity Information System (FBIS) for further use internationally for demographic assessments. Building on the app developments, the miniSASS website (minisass.org) is also being streamlined and modernised to improve data hosting, visualisation, and to interface directly with the miniSASS app. Notably, the newly developed or upgraded miniSASS mobile app, website, and data will be hosted by AWS non-profit. However, the entity responsible for the long-term maintenance and management of the miniSASS app, website, and database is currently still under discussion. Ultimately, the aim is to have the miniSASS app, data and website operated and managed (open source) by the IWMI-CGIAR, or the within United Nations (UN) initiatives such as the World Water Quality Alliance (WWQA) or Global Environment Monitoring System for Freshwater (GEMS/Water), as part of contributions to the creative commons and common good. This migration and ongoing project will happen with the support of GroundTruth where necessary.

These developments will enhance the user experience, learning, and application of miniSASS, and although the miniSASS app development falls within a project that is outside of this study, the online learning modules for miniSASS that have been developed through this research process will be incorporated into the app. Part of the process will be to ensure that the user has the opportunity to complete the online training before they proceed with collecting a miniSASS sample and contributing data to the online database. What is learnt through developing this online learning system will be integral to the future success of miniSASS globally.

4.2.3 The Water Clarity Tube

The water clarity tube has been an effective tool for water quality monitoring, in particular for assessing the impact of wastewater treatment work (WWTW) effluent in rivers in the uMngeni catchment (Graham *et al.*, 2023). The water clarity tube has proven to be a cost-effective solution to providing water quality data for communities that struggle with WWTW management. Although the tool has proven to be useful in its current state, updates of the tool were needed for online learning. (**Table 4-5**) below provides a summary of the updates undertaken to adapt the tool for online learning.

Table 4-5: Summary review of the Water Clarity Tube.

Name of tool:	**The Water Clarity Tube**
Current range of use:	• This tool has been mainly used in South Africa, particularly in the uMngeni Catchment. • There has also been small pilot experimentation with the tool in Mexico, Ethiopia, and Lesotho (personal communication, June 14, 2023). • Organisations such as the WRC, DWS, GroundTruth, DUCT and WESSA have played a pivotal role in increasing exposure of the tool to many South African communities.
Changes required for online learning:	• The simplification of the manuals. • The addition of instructional video content. • Translation into other South African languages to increase accessibility and use.
Updates undertaken through this project:	• The addition of instructional video content and picture-based notes. • A one-pager summary was translated isiZulu, Afrikaans, and Sesotho. • Self-assessment tasks were created for online participants to engage with.
Proposed changes for future use:	• The training material (manuals, video content and one pagers) can be translated into a range of other South African languages.

A review of this tool was conducted through an in-person unstructured interview[20] (**APPENDIX B – INTERVIEW TRANSCRIPTS**) with one of the developers of the citizen science Toolbox. Participant 4 provided valuable insight and further technical understanding on how the tool could be adapted to increase functionality. It has been proposed by Participant 4 and other users of the tool that the material that the tool is made from is changed to a more robust material, as the Perspex tube is easily damaged. A current solution proposed by a frequent user of the tool would be to have a warning printed on the clarity tube bag, that the tube is "fragile".

Participant 4 further suggested how to adapt the instructional manual for online learning:

"*You need a paragraph describing it. You need to be able to say, clarity tube for turbidity and suspended solids. You must use that term, then you need to have a paragraph explaining it and then you click on that, and it links to the diagram, then click on that to see how people are using it. Then you click on that, then it takes you to a YouTube video.*" (Personal communication, June 14, 2023).

[20] Unstructured interviews are a qualitative research method, that use open ended questions in an interview process often taking place in a conversation-like manner, to acquire information on a specific topic (Chauhan, 2019).

Participant 4 has championed the need for an interactive website to use to learn about the tools, and for uploading the data collected by a user. These ideas have been added to the directives for the team that are redesigning the miniSASS website (through a project outside of this study), and it is hoped that with additional funding they can be incorporated into the design. The interview highlights how the learning about the tool and the use of the tool are intertwined and take place concurrently for a user. This reiterates the value of this type of citizen science for bringing about social change, as it increases both the individual and social agency of the people using the tool (Vallabh *et al*., 2016).

4.2.4 The Transparent Velocity Head Rod (Velocity Plank)

The Transparent Velocity Head Rod (Velocity Plank) allows a user to apply the specialised process of calculating the velocity, or discharge of a stream or river through seeing how far water pushes up the plank when held in the course of a river or stream (Graham and Taylor, 2018). The current manual is technically written but explains the steps needed to use the plank to collect the data needed to calculate both the volume and speed of the water moving through a water course. The updates to this tool are outlined in (**Table 4-6**) below.

Table 4-6: Summary review of the Velocity Plank.

Name of tool:	**The Velocity Plank**
Current range of use:	• Used across South Africa but applied extensively within the uMngeni Catchment and in the Tugela Catchment. • The tool was used during the AEN programme, piloted in 2020.
Changes required for online learning:	• The simplification of the manuals. • The addition of instructional video content. • Translation into other South African languages to increase accessibility and use.
Updates undertaken through this project:	• The addition of instructional video content and picture-based notes. • A one-pager summary was translated isiZulu, Afrikaans, and Sesotho. • Self-assessment tasks were created for online participants to engage with.
Proposed changes for future use:	• The calculations and velocity table should embedded into a mobile app. This would remove the technical and mathematical aptitude from the application of this tool and would enable more people to use it.

This tool has been used extensively in KwaZulu-Natal, through research projects initiated by DUCT, SAEON and the Expanded Freshwater and Terrestrial Environmental Observation Network (EFTEON) in the Tugela, uMngeni Catchments and near Lake Sibayi. The general feedback from participants was that this process was complicated, and most did not fully understand the value of collecting this form of data. Even the university graduates employed as “River Rovers” and “Data Detectives” for AEN struggled with the use of this tool (they also used miniSASS, clarity tube, and the *E. coli* test), as shared from Participant 14 (**APPENDIX B – INTERVIEW TRANSCRIPTS**) below, in their email interview:

“*Their work focused on the clarity tube, the velocity plank, and miniSASS. They took quickly to using the clarity tube, it’s quite straight forward to understand, and with some practice, were able to understand miniSASS, but they all struggled with the velocity plank*”.

Based on the feedback collected about this tool, the one-page summary and instructional videos have been designed to break down the steps carefully. The one-page summary focuses efforts on how to collect data to calculate velocity, with an additional explanation of how to calculate discharge added as an optional activity on the online learning system. The complexity of the calculations could easily be removed from the user if they were embedded into mobile app which would simplify the application of this tool immensely, as was stated by Participant 14:

"*I think [the difficulty] is mostly the calculations involved, and perhaps that they did not really understand why the tool is important, what kind of data it gives? With clarity tube and miniSASS it's so much more tangible – you can see immediately what the tool is trying to tell you*" (personal communication, June 29, 2023).

The updates to the tool would also benefit from additional video content explaining the context of how the tool could be used in a reality-based situation. Providing a context to the user about how the data could potentially be used, could increase the understanding of the application of this tool. This type of video content has not yet been created; but is listed as a necessary addition to the current set of updates to this tool to increase its functionality for an online learning system.

4.2.5 The Riparian Health Audit (RHA)

The Riparian Health Audit (RHA) is an under-used tool with great potential. The tool does require some level of training to enable it to be used effectively. Thus, simplification of the tool is required to suit citizen and online learning use, which could potentially enhance and extend the use of this tool. The updates undertaken for RHA and associated recommended updates for online learning are summarised in (**Table 4-7**) below.

Table 4-7: Summary review of the Riparian Health Audit (RHA)

Name of tool:	**The Riparian Health Audit (RHA)**
Current range of use:	• The tool was extensively used in 2015 and 2016 during its pilot phase by GroundTruth and EnviroChamps in the uMngeni Catchment. • More recent use has been limited
Changes required for online learning:	• Simplification of the instructional manuals and addition of short instructional video content and images.
Updates undertaken through this project:	• A one-page summary of the step-by-step process was created.
Proposed changes for future use:	• Simplification of the background document of the tool. • The addition of short instructional video content. • Adaption of the tool for use with the ODK app[21]

The RHA tool guides the user through a series of directed questions and assists the user to identify potential impacts within the riparian zone (Graham and Taylor, 2018). The manual provides a range of guidelines that should be considered by a citizen scientist before going in field to collect data including how to obtain landowner permission, and when and where this is required. The citizen scientist needs to have background understanding of basic riparian ecology in order to use this tool and, as such, needs to have attended a course in basic aquatic ecology. This requirement lends rigour to the application of the tool but reduces the extent to which it can be applied readily. It does, however, bring to light the potential impact the development of online

[21] Open Data Kit (ODK) application is a globally recognised and flexible data collection and management tool which ODK offers ODK Collect. ODK Collect allows for the collection of all types of geo-referenced, photographic or text data typically collected by citizen scientists.

training could have for this tool. A review of the tool was conducted (**APPENDIX B – INTERVIEW TRANSCRIPTS**) through an email interview with a wetland technician (Participant 16) who provided insight on the current challenges to a new user of the tool.

Participant 16 commented; "*the one limitation on the RHA is that whoever uses it needs to read the manual which can be found online on a report by Braid (2014); this helps with background info and to clearly understand the tool, but this document is not easily accessible to everyone*."

It is evident that while the RHA tool has a range of resources aimed at helping users learn how to use the tool, limited access to these resources (potentially linked to lack of internet access) have led to the limited use of this tool. Other barriers attributing to the limited use of the tool is the technical terminology used in the background document of the RHA tool. Another user of the tool commented:

"'Vegetation removal' should refer specifically to 'Indigenous vegetation removal/displacement' and in addition it should be clarified that this includes impacts such as the physical removal of the indigenous vegetation in order to grow crops as well as the displacement of the indigenous vegetation, for example, as may occur dramatically to indigenous grassland when invaded by black wattle which establishes a dense canopy".

This user also noted that the RHA has been designed with urban systems in mind, and that it takes a little adaptation and specialist knowledge to apply the tool within a rural landscape

While the RHA manual is intended to provide a contextual understanding of the tool to the user, the technicality of the document could exclude a citizen scientist. Further efforts need to be applied into creating materials that break down the process and the information that needs to be understood in order to apply the tool. Video content, such as what has been developed through this research project for the Wetland citizen science tool (miniWET-Health), would assist in this breakdown.

4.2.6 The Wetland Assessment Tool (miniWET-Health)

The Version 2 of the WET-Health Assessment tool was introduced in 2020 (Macfarlane *et al.*, 2020). This revision of the professional assessment tool drew on what had been learnt through developing the citizen science wetland assessment tool through the development of the original citizen science Toolbox. As such, the full assessment tool and the citizen science version are closely related in their background design. The recent advancements of the WET-Health assessment in the development of the Version 2 of the tool required that the citizen science wetland tool be revised and updated to incorporate the recent changes. Dr Donovan Kotze (a co-developer of the citizen science wetland assessment tool) assisted the research team with this. The updates have been made for this report, as outlined in **Table 4-8** below.

Table 4-8: Summary review of the Wetland Assessment tool (miniWET-Health)

Name of tool:	**The Wetland Assessment tool (miniWET-Health)**
Current range of use:	• The tool has been applied by GroundTruth, SANBI, and the DWS
Changes required for online learning:	• The manual and procedures required further simplification of the language to assist a user with limited wetland science knowledge to understand the content-related to applying the tool. • Downloadable instructional video content and images should be translated into other South African languages for online use.
Updates undertaken through this project:	• The scores used in the tool were re-analysed and adapted to incorporate the recent changes to the Wet-Health (Version 2) Assessment tool. • A name change has been proposed from “the wetland assessment tool” or “the wetland citizen science tool” to “miniWET-Health” to better reflect how these two tools are related in their design. • The tool manual was condensed into a 2-page summary. • Instructional video content and picture-based notes were created. • The language on the field sheet was revised and simplified and illustrative photos of different land-use types in a wetland were added. • The Spreadsheet to calculate the PES score was updated to reflect updates to the Version 2 of the WET-Health Assessment and to allow for an automatic determination of the wetland’s Present Ecological State (PES) when using the “Sketch-map” option. • Activities were developed to explore key concepts needed to be understood to apply the tool – these are the concepts of “the wetland’s catchment”, “the wetland area”, and “the wetland’s buffer”
Proposed changes for future use:	• An online glossary specific to wetlands needs to be created. • Additional instructional video content explaining key concepts could be developed. • The development of an app for the user to record the land-cover types in the wetland and its catchment (and their approximate extent class) and which would automatically generate a PES score for the wetland without needing to use the Excel spreadsheet to do so.

Users of the original citizen science tool have highlighted that, like the RHA, the manual for this tool is detailed and technical. The language used may exclude some citizen science users, and training is required so that the tool can be properly applied. With these comments in mind, the updates to the tool have included the creation of a simplified, step-based picture guide to applying the tool, and the production of instructional videos that break down the process and concepts incorporated into the knowledge needed to apply it accurately.

Two workshops (with the Maputuland Coastal Biodiversity Forum; and Nature Connect – see Appendix J for more details) focussed on applying the updated tool have been facilitated. The feedback from participants were used to further refine the tool, and its recommended teaching practice. From this, the following recommendations have been summarised for the further use of this tool:

- Using the “Sketch-map” option is easier for most users than applying the “Detailed-map” option.
- For those that are comfortable using an Excel spreadsheet, filling-in scores on the spreadsheet is easy and the Present Ecological State (PES) score that is generated is a useful outcome of the tool. It was noted that the participants felt that the generation of a PES score could be useful for applications to the Municipalities and local government structures when interventions were needed.

- For those that were not comfortable using Excel, the Sketch-map and field data sheet proved useful to highlight threats to the wetland and helped participants decide where to focus their management efforts.
- The tool showed promise as being very useful for both monitoring of a wetland; and for improving management practices.

A participant from Nature Connect had this to say about the tool:

"This is great, I can see how easily we can use this to highlight where we need to put efforts into to improve our wetlands. I'm definitely going to be using this tool from now on. I now understand how what is happening around the wetland, affects it".

This tool has great potential and when used in collaboration with other tools, like the clarity tube, the *E. coli* water test, and the Dragonfly Biodiversity Index. Combining the data from this suite of tools helps a citizen scientist to form a diverse picture of what is happening in and around their wetland.

4.2.7 The Spring Tool

The Spring tool is a useful when the user would like to assess the impacts on a spring. This tool has been applied in some community contexts within the uMngeni Catchment, and elsewhere. The tool is straightforward in its application but would benefit from adaption for online learning through the creation of online video content. These videos have not been created through this project, as efforts into the more widely applicable tools have taken preference. The reasons for this are outlined in (**Section 4.3**) of this report. **Table 4-9** below outlines the updates that are needed for this tool to be adapted for online learning.

Table 4-9: Summary review of the Spring Tool.

Name of tool:	**The Spring Tool**
Current range of use:	• The tool has had sporadic use since its development.
Changes required for online learning:	• The simplification of language and the condensing of the background document is needed. • The creation of video content explaining the process of applying the tool is needed. • The need to provide guidance for measuring spring discharge.
Updates undertaken through this project:	• A one-page summary was created translated from English into isiZulu, Sesotho, and Afrikaans.
Proposed changes for future use:	• Translation of the user guide of the tool into other South African languages. • The development of an online glossary for the tool that can be translated in several other South African languages. • The creation of instructional video content to explain the steps involved in application of the tool. • The addition of relevant guidance for measuring spring discharge, e.g. using the container fill method/timed volume method (People's Science Institute. Undated. 3.1 Spring discharge measurement in different flow settings. MCLLMP Virtual Training. Spring Initiative Partners, Dehradoon, India).

The Spring tool is a specialised tool that can only be applied to an environment where a spring naturally occurs. A user of the tool (participant 14, **APPENDIX B – INTERVIEW TRANSCRIPTS**) commented that:

"*The tool would work well when using it with an app like ODK, the questions are logical and done in a step-by-step manner, which would be easy to set up on the app*" (personal communication, June 29, 2023).

The systematic application of this tool does lend itself well to the use on an app like ODK. It is recommended that an app of this nature be customised to streamline the use of the tool. Some background knowledge is also beneficial to the user to assist in their correct use of the tool. This is well suited for development for online learning, and the lessons that are learnt from this broader study can guide the creation on online content in the future. Additionally, there is a need to engage the DWS groundwater monitoring team to further develop and refine this tool, based on the DWS groundwater monitoring indicators.

4.2.8 Estuarine Tool

This tool was designed to provide the user with a rapid assessment of the health of an estuary (Graham and Taylor, 2018). Through the review process for this study this tool has been identified as needing further refinements for more widespread application across the various estuarine ecosystems in South Africa. The updates that were identified are outlined in **Table 4-10** below:

Table 4-10: Summary of the review of the Estuary Tool.

Name of tool:	**The Estuary Tool**
Current range of use:	• The tool has been piloted for use in one example estuary in the Eastern Cape.
Changes required for online learning:	• Simplification of manual, • creation of instructional video content and online learning materials including picture-based notes, a one-page summary, and design of self-assessment quizzes.
Updates undertaken through this project:	• None – the updates needed for this tool are extensive and have been viewed as best undertaken outside of this project's scope.
Proposed changes for future use:	• Update the background document to include recent scientific developments in the field. • simplification of manual and procedure, piloting, and testing in a range of contexts, to provide a final refinement of tool.

A review of this tool was conducted through an email interview (**APPENDIX B – INTERVIEW TRANSCRIPTS**) with an Estuarine specialist (Participant 17). The email interview allowed the interviewee to provide reflections and recommend suggestions on how the tool could be further developed for future application. From the review conducted of the tool, it is evident that the Estuary tool still requires development and refinement.

The Estuary background document should be reviewed and updated: there have been various new additions and developments made in estuarine science since it was developed in 2015 by Dr Taylor, these need to be included in the tool. Participant 17 explained that:
"*Instead of five estuarine types, we now have nine, with a further three categories for micro-estuaries. Also, the key buzz word today in the current legislation is the estuarine functional zone, which is critical and is not in the document*.'' (Personal communication, April 20, 2023).

Some aspects of the Estuary toolkit provide challenges for a citizen scientist. The language and concepts used to explain some of the processes are very technical and require specialist knowledge. Use of the tool would require extensive training of a citizen scientist. Participant 17 alluded to this by noting that:

"*The toolkit is quite advanced – speaking about measuring volume of the estuary, volume exchanged and even slope of the beach. I think this is something we touched on a university*" (personal communication, April 20, 2023).

The toolkit includes complex steps but omits important faunal aspects. These include engaging activities that citizen scientists could easily apply when using the tool. Participant 17 noted:

"*I feel that the toolkit is perhaps a bit thin on the faunal aspects. These are things that people can see, and it would be good to help them to do this activity. Yet this would be something quite difficult to narrow down because there is such a diversity of faunal groups and diversity of habitats. The toolkit does not even mention the possible ways of sampling different animals, e.g. a prawn pump, or netting of fish, or bird watching on exposed banks. I think this could be improved/added to*" (personal communication, April 20, 2023).

Citizen science tools need to reflect current knowledge, and as such, require regular review and updating to remain relevant, accurate, and applicable. The updates required by this tool are extensive and are likely to take time and human capacity. This focused effort may call for a research project with this sole endeavour.

4.2.9 Weather Monitoring Tool

This set of tools were designed to allow the user to be able to construct their own implements to capture weather data. It includes instructions on how to make your own rain gauge (Graham and Taylor, 2018). These tools were not selected for focused updates for the piloted online learning study, the reasons for this are outlined in **Section 4.3** of this report. The tool was however reviewed, and a one-page summary was created (see **Table 4-11** below).

Table 4-11: Summary review of the Weather monitoring Tools.

Name of tool:	**The Weather monitoring Tool**
Current range of use:	• Currently not being undertaken in Maputaland and the Zululand coastal plain, but with high potential for implementation.
Changes required for online learning:	• Simplification of the user manual. • Creation of instructional video content and online learning; materials including picture-based notes, a one-page summary. • Design of self-assessment quizzes. • Additionally, translation of manuals into other South African languages will be a benefit.
Updates undertaken through this project:	• A one-page summary of the tool has been created.
Proposed changes for future use:	• Creation of video content to explain how to build and make the weather monitoring tools will assist in increasing its use. • Linking the use of these monitoring tools to curriculum-based projects and sharing of these lesson plans will also help increase the scope of the tool.

The tool has potential for application in schools, as the design, building, and use of the weather monitoring tools has many links across subjects, as outlined in the Curriculum and Assessment Policy Statements (CAPS) for South African schools. In addition to this, these tools could assist communities to begin recording changes in weather systems and help with climate change reporting, this is important and relevant to the SDGs. The manuals for this set of tools are not complicated but could benefit from video content that can easily be shared on social media platforms to assist the user in understanding the “how-to” aspects of these tools. This type of content would help to popularise the tool and would increase the range of its use.

4.2.10 School Lesson Plans

This tool was designed to connect the citizen science tools to the national curriculum, with the explicit aim of supporting teachers and learners to incorporate the tools into their learning (Graham and Taylor, 2018). The lesson plans are in need of a more detailed review by a teacher to comment on their current relevance to what teachers need to achieve in the school year. **Table 4-12** below outlines the current review that was undertaken for this study.

Table 4-12: Summary review of the school lesson plans.

Name of tool:	**School lesson plans**
Current range of use:	• The school lesson plans are aligned with the current national curriculum statements. • Organisations such as GroundTruth, SAEON, WRC, DWS and DUCT, have played a pivotal role in integrating these lesson plans into school support programmes and through projects that promote Eco-clubs and extra-curricular citizen science.
Changes required for online learning:	• Development of "bite size" and data friendly activity-based material (video content and images) on online platforms to support the citizen science learning of students. • Development of a learner-friendly website which provides extensive information on citizen science tools to support the fieldwork experiences of learners.
Updates undertaken through this project:	• Creation of a step-by-step guide to how the citizen science tools could be used in a school system.
Proposed changes for future use:	• Translation of material of the tool to other South African languages to facilitate its use across the country. • The addition of video content created to briefly explain the activity ideas to teachers and users across the country, could lead to a larger uptake of its use. • Housing of the lesson plans on multiple websites, hosted by partners of the WRC and GroundTruth (e.g. on SAEON's educational resources page, Fundisa for Change, etc.).

The school lesson plans are well designed and thought through but, as with any resource material, the resource's application is limited by the user's knowledge of its existence and of how to apply it in the classroom. To extend the use of this tool, video content could be designed, in a fun and user-friendly manner, aimed at sharing the activity ideas with teachers and learners.

4.3 TOOLS SELECTED FOR THE ONLINE LEARNING PILOT

The selected community resides in a region of South Africa that is unique in its hydrology. The use of the current suite of citizen science tools have been well documented in a typical river catchment where the topography and geomorphology are aligned with what is expected in a South African river that drains eastwards off the escarpment. This is not the case in the region where these tools will be piloted. The selected community is situated in a region that is dominated by a groundwater-fed lake system and has very few streams. Although not originally the intentional aim of this study, the location of this community brings the opportunity to test the relevance of the citizen science tools in this unusual geomorphological context[22]. Hence, this allows the researchers to test if these citizen science tools are applicable in a broader South African context, in regions that don't fit the expected geomorphology.

With this unique landscape in mind, the following tools were selected from the toolbox to focus efforts on when designing the online learning system as the length of time available for the pilot was limited:

- The Enviro Picture-building
- Clarity tube
- miniSASS
- Velocity plank
- The wetland assessment tool (miniWET-Health)

Two new tools have emerged since the toolbox was developed in 2018. These tools are becoming increasingly popular and add value to the data collected as they are able to add to the narrative that the data builds about the system. These two tools are:

- The *E. coli* water test[23]
- The Dragonfly Biodiversity Index (DBI)

These six tools were selected for development and use within the online learning system as they are relevant to the region where the community is located. Research and biological monitoring in the area has been conducted by SAEON field technicians over the past few years. The data that is collected includes use of miniSASS, the clarity tube, and the velocity plank; so, these tools were included based on their existing use in the region. The region is rich in wetland ecosystems, which lends itself well to the application of the miniWET-Health tool. To compliment the miniWET-Health tool the DBI method was proposed as it gives an indication of ecosystem diversity through the species richness of dragonflies and damselflies. The *E. coli* water test is a valuable tool as it provides an indication of the level of *E. coli* and Coliform bacteria in the water, a factor which is not measured by any of the other tools. The Enviro Picture-building tool was included as it has great potential as a teaching and learning tool. The picture was updated to represent the landscape of the region.

Efforts were focussed on adapting these six tools for online learning, with the view that what was learnt through the pilot case study, could be taken, and applied to the other tools in the toolbox at a later stage as funding allowed. However, updates were made to the four other tools (not included on the remote learning system), as reflected in Section **4.3**, which encompassed, the simplification of the language and translation of the instructional manuals to Sesotho, isiZulu and Afrikaans.

[22] This study was commissioned to update the citizen science tools in the "virtual toolbox" designed by Graham and Taylor (2018) for the monitoring of aquatic systems. Subsequent to the development of these tools for the monitoring of river, stream, wetland, and estuarine systems; a set of groundwater citizen science tools has been developed (Goldin et al., 2021). The groundwater tools would add value to the suite of citizen science data that could be collected in the region of the selected community, but their use falls outside of the scope of this study.

[23] The *E Coli* water test is a citizen science tool, which can be used to check the presence of coliform bacteria (*E. Coli*) if freshwater samples. Coliform bacteria are a commonly used indicator of the sanitary quality of water. Some examples of coliform bacteria include *E. coli*, Serratia, Enterobacter, Citrobacter, Hafnia, Yersinia and Klebsiella.

4.4 EXAMPLE OF A MODULE ON THE ONLINE LEARNING COURSE

Pictured below (**Figure 4-1**) is an example of the layout of the miniSASS module on the Pluto platform (Online Learning Tools), with re-presented text and video content. The major updates undertaken to adapt the tool for online citizen science learning included the simplification of the instructional manual to 'bite-size' one-page summaries and images and the addition of data-friendly instructional video content. Interactive platforms for participants to engage and gauge their growth in understanding were also added to the module, in the form of forums [24]and quizzes.

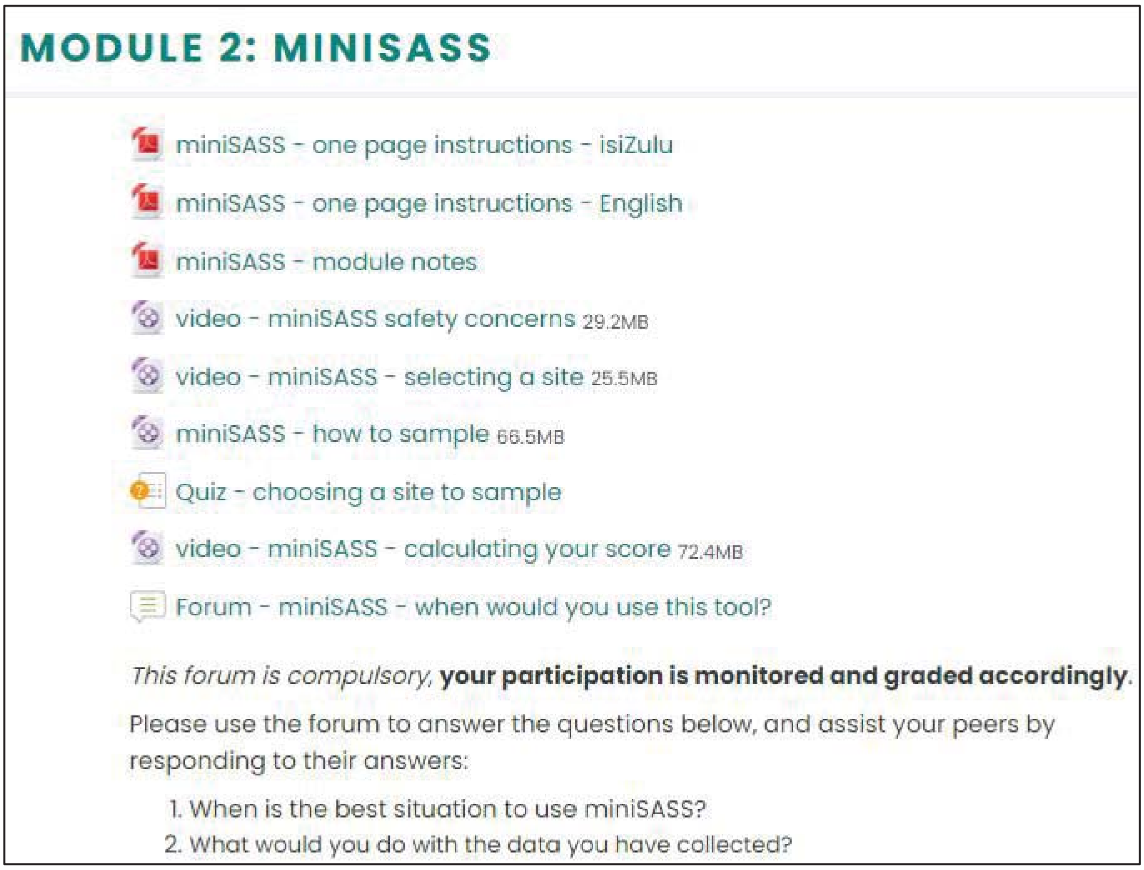

Figure 4-1: Example of the miniSASS module on The Tools for Citizen Science course

[24] An online forum was created on the Pluto LMS, which allowed for discussions to take place amongst the participants and facilitators.

CHAPTER 5: CASE STUDY – CITIZEN SCIENCE REMOTE LEARNING IN THE LAKE SIBAYI COMMUNITY

5.1 PARTICIPANT SELECTION PROCESS

5.1.1 Engagement Process with Selected Communities

Traditional tribal council meetings were scheduled with the selected community (Tembe, Mabasa and Zikhali TAs) with the intention of introducing the project to the tribal council and request permission to pilot the learning programme with participants in their respective TA's. The area around Lake Sibayi is represented by three TAs, Mabasa, Zikhali, and Tembe. **Table 5-1** provides a snapshot summary of when the tribal council meetings took place and the outcomes of each meeting. It is worth noting that SAEON played a pivotal role of introducing GroundTruth to the Lake Sibayi community, in particular the Zikhali and Mabasa tribal councils. The project leveraged on the extensive work that SAEON has already done with the community for their research (WRC project: C2020/2021-00430). This made the process of introducing this project to the Lake Sibayi community less complicated.

Table 5-1: Outcomes of the tribal council meetings with TA's.

Tribal Authority	When the meeting took place	Outcome of the meeting
Zikhali and Mabasa	8th and 13th of February 2023, respectively	Both the Mabasa and Zikhali tribal council granted GroundTruth permission to pilot the training with participants from the community. This permission was granted contingent on GroundTruth following the traditional recruitment procedures agreed upon with the council.
Tembe	14th February 2023	The Tembe tribal council raised two primary concerns at the meeting. The first being that the participants would not be compensated for participating in the project. The tribal council also requested a follow-on meeting in which GroundTruth would provide sustainable solutions to the water quality issues already existing in the Tembe TA.

Subsequent to the tribal council meetings, a permission letter, was drafted and sent to the secretaries in each TA (**aAPPENDIX H – LETTER OF PERMISSION FROM THE MABASA TRIBAL COUNCIL**). This letter was intended to get written permission, to conduct the recruitment process in the respective TAs that GroundTruth would be piloting the citizens science remote learning system with. The Mabasa and Zikhali TAs signed off the permission letters, after which GroundTruth commenced with the participant selection and recruitment process. However, the Tembe TA, did not sign off the permission letters, despite countless meeting requests made by GroundTruth to follow up on the concerns raised in Tembe tribal council meeting. After 2 weeks of following up with the Tembe secretary and getting no response, GroundTruth decided to commence with the participant selection process with the Zikhali and Mabasa TAs only.

5.1.2 Participant Selection

To initiate the participant selection process, an advertisement was created and was posted at the office of the Tribal Authority, the document was also circulated digitally via WhatsApp (**APPENDIX I – COURSE**

ADVERTISEMENT). The notice specified the requirements the participants needed to have, and the outline of the course. The minimum requirements for each participant were as follows:

- Must have a Matric (Grade 12) certificate,
- Must be able to read and write (isiZulu and/or English),
- Must be able to operate and have access to a smartphone (you do not have to have one of your own),
- and be willing to learn.

Ideal attributes:

- lives within walking distance of a wetland or stream,
- an interest in the environment.

Interested potential participants left their documents with the secretary of the Mabasa and Zikhali Tribal Authorities. Applications extended through the month of April; the timeframe of the recruitment process had to be extended due to there being a limited number of participants expressing initial interest. A second call of recruitment was therefore made which resulted in Mabasa having more participants (18) than the Zikhali group (13). The intended total number of participants was 30, so once the applications reached 31, the call for participants was closed. All those that applied were included in the study, as they all met the requirements outlined in the advertisement.

5.2 THE REMOTE LEARNING PROCESS

The piloting of the citizen science remote learning system followed a phased training that comprised a mix of interactive, online and in-person learning sessions over a 3-month period. The sessions were run by two facilitators from GroundTruth, supported by an intern from SAEON (who had acute knowledge of the region as she had been involved in data collection for the SAEON WRC project C2020/2021-00430), and two master's students (funded by the WRC) who attended the in-person sessions on a rotational basis. All the facilitators completed a short course on facilitating social learning through citizen science, run internally at GroundTruth. The aim of this training was to ensure that all the facilitators participating in this research applied the same pedagogy when giving support to the participants.

5.2.1 Educational Design

The remote learning system was designed to encourage social learning through learner engagement with the facilitator, fellow participants, the learning content, and the participant's environment. The pedagogy and approach to learning was influenced by the following educational frameworks:

- The learning framework devised in phase one of this project (Box 2),
- Bloom's Taxonomy theory (Hyder and Bhamani, 2016),
- Transformative Social Learning (Wals, 2022),
- and Vygotsky's Sociocultural theory, specifically the concept of scaffolding learning (Van de Pol and Elbers, 2013).

The learning framework developed in Phase one of this study (GroundTruth, 2022) is based on an evaluation of citizen science learning in South Africa. From the evaluation, eight guiding principles emerged, which have been incorporated into the design of the remote learning system. These informed how the training rounds would be facilitated, and the pedagogy applied in the course. The scaffolding approach, which is linked to Vygotsky's socio-cultural theory, particularly the concept of working in the Zone of Proximal Development (ZPD) (Van de Pol and Elbers, 2013) also influenced the facilitation of the in-person training and design of the course. Scaffolding can be described as a method of teaching in which a student gradually builds new knowledge at different levels with the teachers' level of support adapted or determined by the students' level of understanding (Van de Pol and Elbers, 2013). The teacher first demonstrates or teaches a concept to the students, thereafter the student and teacher work together to co-develop or deepen the understanding of the new knowledge whilst 'adding' or learning new knowledge. This can be through contextual based activities or discourse between students or between the student and teacher. The third phase of this technique sees the student learning more independently, with minimal support from the teacher depending on the students' response to the challenge presented. Ultimately, the teacher support offered within the scaffolding technique is characterized by three main factors, namely, contingency[25] , short termism[26] and transference of responsibility to the student (Van de Pol and Elbers, 2013).

5.2.2 The Structure of the Learning Process

Bloom's Taxonomy assumes that learning must occur in consecutive stages (**Figure 5-1**), ranging from initially acquiring new knowledge to translation and application of that knowledge by the student into a new context. Bloom's learning theory explores the concept that learning is not merely about recalling information, but a transformational process that allows students to access higher levels of thinking (Hyder and Bhamani, 2016) such as critical analysis, valuation, and the creation of new concepts. The first (remember) and second (understand) stages of the Bloom's taxonomy are focused on the transference of knowledge to the student by unpacking concepts and ensuring that they can recall the information. The third stage (apply) involves the student employing the new knowledge they have acquired into their situational context. The following stage (analyse) is to integrate this new knowledge with other forms of knowledge to make connections and compare it to what has been understood previously. The fifth stage (evaluate) is about the student assessing the new information and the suitability of the knowledge to the applied context and allocating a value it. The final stage (create) is considered the highest level of thinking for the student, in which new information is constructed through the re-interpretation of the initially acquired knowledge in a new situation (Hyder and Bhamani, 2016). These concepts were incorporated into the design of the remote learning system that the Lake Sibaya groups participated in.

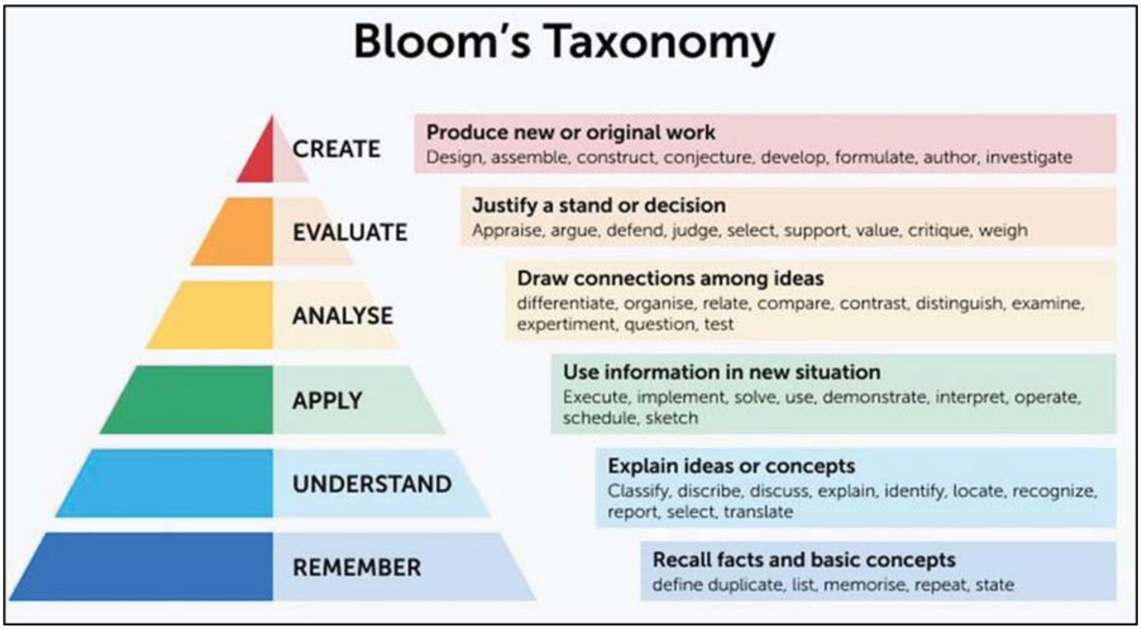

Figure 5-1: Bloom's taxonomy, structure, and related concepts; adaptation from Hyder and Bhamani, 2016.

[25] 'Contingency' implies that the teachers' support is dependent on the students' response to a task/challenge presented. If the student demonstrates that they require more support within the learning process, the teacher is able to provide this.
[26] 'Short termism' refers to the teachers' support not being a long-term factor but being dependent on the level of growth in understanding of the student, which should ultimately result in independent learning.

Some of the elements of the remote learning system are explained in **Table 5-2**, and the main learning theories that shaped their construction are listed below.

Table 5-2: Some elements of the remote learning system and the related learning theories.

Learning element	Description	Related educational theory
Pre-course task 2	Participants identified an environmental concern in their place of work or residence, took a photo, and wrote a short description of it.	"Tuning-in" from the 5Ts of the Action Learning Framework. This comes from the guiding principles identified in the evaluation of current citizen science learning completed in Phase one of this study.
		"Scaffolding" – and the Zone of Proximal Development, starting from a "place of knowing" for the participant.
The 'Place of the Waterfall' video	The story of citizen science in the township of Mpophomeni – a 5 min video sharing the journey of the EnviroChamps and how the data they collected led to the restoration of an important wetland (Box 1).	"Scaffolding" – and the Zone of Proximal Development, gently stretching the concept of what is possible through the sharing of a 'real-life' story from another community.
		Transformative Social Learning – feeling inspired by what has been achieved by others.
Online instructive videos and written content, followed by a quiz.	Each online module, for each of the citizen science tools, contained videos that explained how the tools are used, with written image-based notes summarising what was covered. The participant needed to complete a quiz on this material, when they felt ready to do so.	This applies the "remember" and "understand" stages of Bloom's Taxonomy.
		Demonstration of a skill is a valuable part of social learning and can be facilitated through video media
Online forums	Participants were required to participate in the forum discussions, where they uploaded their pictures of environmental concerns; and discussed how they would use the tools that they had learnt about to monitor those environmental concerns. The discussions were facilitated by the trainer, through prompting of questions.	Transformative Social Learning – the aim of this activity was to generate discussion between participants to listen to and reflect on the views of others.
		"Talk" from the 5Ts of Action Learning. This comes from the guiding principles identified in the evaluation of current citizen science learning completed in Phase one of this study.
Break away task	Participants practiced using the citizen science tools. They selected one tool that applied to their environmental concern and made a video to teach others how to use that tool.	This incorporates the "apply" stage of Bloom's Taxonomy.
		"Touch" from the 5Ts of Action Learning. This comes from the guiding principles identified in the evaluation of current citizen science learning completed in Phase one of this study.
Change project	Participants needed to reflect on the environmental concern that they highlighted in the pre-course task, and then decide what citizen science tools would be best to use to monitor that concern, devise a monitoring plan using those tools, put it into action, collect data and report on their findings.	"Think" and "Take Action" from the 5Ts of Action Learning. This comes from the guiding principles identified in the evaluation of current citizen science learning completed in Phase one of this study.
		This incorporates the "analyse", "evaluate", and "create" stages of Bloom's Taxonomy.
Group work	For the "break away task" and the "change project", the participants were encouraged to work together in groups, and present their work together to the rest of the participants.	Transformative Social Learning – the aim of this activity was to generate discussion between participants to listen to and reflect on the views of others and to come to consensus as a team.

5.2.3 The Adaptations to the Learning System

The piloting of the remote citizen science learning platform presented a range of challenges and opportunities. Throughout the duration of the course, the course was adapted to suit the needs of the participants and increase ease of use. The aim being to improve the structure of the remote learning system through trail and adaptation; and to research the process. The adaptations were applied on the learning platform and during the in-person training. **Table 5-3** below provides a summary of the challenges that the participants raised at different phases of the course and the associated changes that were made.

Table 5-3: Most significant changes made to the online learning system.

Online course version	Most significant changes made
1. With videos loaded as high-res YouTube links	• Videos sent via WhatsApp. • Videos loaded as low-Res versions and embedded into the Learner Management System (LMS). • Instructions on how to make a DBI net and how to tell the difference between a dragonfly and damsel fly added.
2. With videos loaded as low-res versions embedded into the LMS	• Added the step-by-step instructions for each tool.
3. With videos loaded as low-res versions embedded into the LMS	• Remade the miniWET-Health tool video and added annotations and diagrams to the video.
4. With videos loaded as low-res versions embedded into the LMS	• Re-configured some of the quizzes and added another miniSASS quiz as participants had commented that they were not challenging enough.

Other challenges and opportunities arose for the adaptation of pedagogy and learning design of the course, these are more fully outlined in **SYSTEM. The** Action-orientated Research approach to this study meant that as challenges or opportunities emerged, the research team was able to reflect upon the needs of the participants; and co-create a new process to meet their needs.

5.3 REVIEW OF THE REMOTE LEARNING PROCESS

5.3.1 Methodology

The methodology for this research project applied an Action-Orientated Research approach in which each phase was evaluated, and the results were used to inform the steps taken in the next phase of the research. The following section provides a detailed account of the data collection methods applied in the study aimed at evaluating the progress and development (learning experience) of the participants on the remote learning system. The data collection methods applied in this study, were attempted to answer the following research questions:

I. How are the participants learning to conduct citizen science?
II. What pedagogies and technologies are most effective?
III. How can the remote learning system be adapted and improved?

5.3.2 Data Collection Methods

The participants' learning journey throughout the study was captured through a formative evaluation using a mixed method approach. Data collection methods for undertaking this evaluation included semi-structured interviews, focus groups discussions, direct observation, and reflection on citizen science learning engagements, as well as an appraisal of a case study. The data was generated through qualitative and quantitative data collection methods which included the following:

- An initial appraisal to rate each participant's current knowledge, values, and water related practices.
- Periodic surveys, interviews, and focus groups following learning engagements.
- Observations from reflective journals from the participants and the facilitators.
- Document analysis from written records of discussions on social media platforms such as WhatsApp.
- A final appraisal, using the same format as the initial assessment, to rate each participant's knowledge development, change in values, and use of sustainable practices related to water.

Table 5-4 below provides a detailed description of the data collection methods used and the reasoning for them.

Table 5-4: Data sources used in the study.

Data set	Data source	Purpose of the data source	Recording method	Analyse/Use
1	WhatsApp	To capture the online interaction and effectiveness of WhatsApp as an online support platform for citizen science training.	Text, images, and voice notes from the WhatsApp conversations of both groups	Textual information (recordings were transcribed) and images were analysed and coded for emergent themes.
2	Periodic surveys	This data collection tool was used to capture the level of understanding and learning journey of the participants at different stages of the online course.	The online forum, quizzes, and post learning survey.	The responses were analysed and coded for emergent themes
3	Reflective Observa tions	To capture the reflections of the facilitators of the learning journey of the participants and the facilitation of the online and in person training.	Recordings that were transcribed.	Transcripts were analysed and coded for emergent themes.
4	Reflective journal entries by participants	To gain an understanding of the participants' perceived learning journey throughout the training.	Transcribing of reflections into journals by participants. These reflections were shared as pictures.	Transcripts were analysed and coded for emergent themes.
5	Focus group discussions	To gain an in depth understanding of the participants learning journey and the challenges they faced.	Recordings and transcripts	Transcripts were coded for emergent themes and analysed.
6	Semi-structured Interviews	To capture the individual learning experience of participants in the Zikhali and Mabasa groups. Each participant provided a different perspective of their learning experience, due to the difference in age, background, internet access and digital literacy levels.	Recordings and transcripts	Transcripts were analysed and coded for emergent themes.

Data set	Data source	Purpose of the data source	Recording method	Analyse/Use
7	Tying together activity	To capture the level of understanding of the participants of different concepts in the course.	Textual and drawing transcripts	Text was translated and coded and drawings were interpreted.
8	Pre- and post- course appraisals (drawings and writings)	To understand the change in depth of each participant's knowledge, values and use of the sustainable practices related to water.	Transcripts (textual and drawings)	The element depicted in each of the drawings and text were counted, scores were allocated on a sliding scale, and an average for each group calculated. The submissions were also described, and these narratives were coded for emergent themes.

The various data sets and their sources are outlined in **Table 5-4** are further described below.

Data set 1: WhatsApp

WhatsApp groups were created for the Mabasa and Zikhali participants respectively. These groups were intended to provide online support to the participants and a platform for engagement throughout the duration of the course. WhatsApp was also primarily useful as a communication platform for participants relating to their change projects, in which they were able to raise their concerns and address issues. WhatsApp is the most familiar and easily accessible communication platform amongst the participants which allows data to be stored. The ease of use and storage function of WhatsApp was identified as a useful online support tool for the course.

Data set 2: Periodic surveys

Periodic surveys were incorporated on the Pluto remote learning platform in the form of quizzes, forums, and a post-training online training evaluation survey. These collaborative online platforms provide an understanding of the level of knowledge gained by the participants at different stages of the course. The data collection method (forums and the survey) was useful in gaining a current and progressive indication of the participants' learning journey at various stages of the course duration.

- The quizzes were intended to gauge the level of understanding gained by the participants for each module. This data was also a useful indication of whether the participants' knowledge of the citizen science tools was growing or remaining the same.
- The forums provided participants with an opportunity to engage online, through answering questions and engaging with their peers by answering course related questions. This dataset also provided insight into the level of understanding gained by the participants at different phases of the course. It also provides opportunity for the participants to learn from each other.
- A post-training online training evaluation survey was added at the end of the online course to capture the online learning experience of the participants. This data source is intended to further improve the online learning platform.

Data set 3: Reflective Observations

Facilitators reflected on the in-person training after each training round. The reflective process was captured via recordings and thereafter transcribed. The intention of this data source was to capture the facilitator's observations of how the in-person training was taking place, how the participants were learning and the effectiveness of the applied teaching styles. These reflective observations were useful in refining and adapting the facilitation of the next training round.

Data set 4: Reflective journal entries by participants.
Each participant was given an A5 notebook to personally reflect on their learning process throughout the course. In each training session, participants were encouraged to voluntarily share some of their reflections to their peers or over WhatsApp as images. This data collection method provided participants with the opportunity to record reflections of their learning journey in their own pace and space. Reflective journaling allowed the participants an opportunity to deeply reflect on their learning experience daily. This data collection tool was assumed to provide a richer account of the personal learning experience of the participants.

Data set 5: Focus group discussions.
Focus group discussions were conducted with the Mabasa and Zikhali groups in their respective wrap-up workshops. The focus group discussions were aimed at gaining an in depth understanding of the learning experiences and the potential challenges faced by the participants with the in person and online training. This data source will contribute to further refining and adapting the citizen science remote learning platform.

Data set 6: Semi-structured interviews.
Individual semi-structured interviews were conducted with selected participants from the Zikhali and Mabasa groups. The interviews were intended to provide an in-depth account of the learning experience of each of the four selected participants. These participants were selected to be interviewed because they represented the different modes of access to the internet, and the varying degrees of experience with digital learning. Each participant interviewed provided a different perspective of their learning experience, dependent on their level of internet access and connectivity and their level of digital literacy. This data collection method is intended to inform how the remote citizen science learning platform and in person facilitation can be improved. Appendix 10 – C provides contextual background and demographic data of the interviewees to provide reasoning for being interviewed.

Data set 7: Tying together activity.
Participants were tasked with linking topics covered in the course using a piece of ribbon, to demonstrate the interconnectedness of the various topics covered throughout the course. The topics included aquatic ecology, indigenous knowledge practices, citizen science tools and change projects. The activity prompted participants to share their understanding of each topic through reflecting and responding on a range of questions and “consolidating” their understanding of the environmental topics with a ribbon. This activity demonstrated the level of understanding and learning of the participants of the overall course. Reflections and observations from during this process were recorded, and these were included as a data set.

Data set 8: Pre and post course appraisals.
Participants were tasked with writing or drawing up their own interpretation of a healthy water ecosystem. This task was intended to gauge the initial understanding of the participants of a healthy water ecosystem and the final assessment was intended to gauge if the depth of the participants’ knowledge, values, and use of sustainable practices related to water had changed after their participation in the course.

5.3.3 Data Analysis

Emergent themes
The data sets 1-7 were coded for common themes using the thematic analysis technique. The common themes identified were then used to re-examine the transcripts and additional evidence was included. The themes identified across the data sources were then grouped, based on their commonality, as emergent themes.

Pre-course and post-course appraisals

Data set 8 consisted of "before" and "after" drawings or writings to express the concept of a "healthy water ecosystem". The pre-course and post-course submissions from each individual participant which were compared side by side, and a simple assessment applied to infer the increase in knowledge. The scoring system is outlined in **Table 5-5** below. The scores for each participant were calculated by finding the difference in number of elements depicted in each participant's pre-course and post course submission, this amount was allocated to a category and given the associated score. The scores for each group were then added together and divided by the total number of participants in the group, thereby giving a mean (average) for each group. This mean value represents the increase in the number of elements that were included in the post-course submission.

Table 5-5: Assessment criteria for the pre and post-course appraisals.

Categories	Scores
The post-course drawing/writing does not show an increase in complexity	0
The post-course drawing/writing contains one to two new elements	2
The post-course drawing/writing contains three to five new elements	5
The post-course drawing/writing contains five to ten new elements	10
The post-course drawing/writing contains more than ten new elements	15

This simple scoring system only rated the increase in components in the submissions from the participants, it did not describe how the content changed in the writing and drawing of the participants. To reflect how the content of what was depicted changed, a narrative of each drawing was written, describing in words both the 'before' and 'after' submissions. The narrative for participants' 'before' and 'after' was assessed side by side and common changes in the depicted content was identified.

5.4 RESULTS OF THE LEARNING JOURNEY OF THE PARTICIPANTS

5.4.1 Emergent Themes

The emergent themes from data sets 1-7 were coded, grouped, and summarised (**Table 5-6**). These themes will be discussed in the following section of this report in relation to the research questions of this study, which aim to understand which pedagogies and related technologies were most effective in supporting remote learning.

Table 5-6: Emergent themes from data sources 1-7 (not in order of importance).

Emergent Themes	Data sources
The learning experience increased the confidence and personal agency of the participants	Dataset 5, 6, 7
Participants found the visual learning (video-based content and image-based notes) as most effective for online learning of citizen science tools.	Dataset 3, 5, 6
In-person demonstration and hands-one use of the tools was a valuable activity to supplement the online learning.	Dataset 3, 4, 5, 6, 7
Facilitator-learner relationships were able to bridge the gap during independent online learning.	Dataset 3, 4, 5, 6
Learning in a group enhanced and deepened the citizen science learning process for the participants.	Dataset 1, 5, 6, 7
Internet charges to view or download the learning content inhibited how freely some of the participants could interact with the course materials.	Dataset 3, 4, 6
Participants were able to overcome the challenge of access to the internet through creativity and working together.	Dataset 3, 4, 6

5.4.2 Pre-course and Post-course Appraisals

The mean scores for the Mabasa and Zikhali groups were 4,3 and 4 respectively. This indicates that on average the participants depicted an increase of approximately four (4) elements in their drawing and/or writing when describing a health water ecosystem. **Figure 5-2** and **Figure 5-3** are two examples of the drawings from participants, showing how the elements increased and how the content of what they depicted changed. The themes that emerged from the narrative descriptions that were written for each submission, were as follows:

- All participants demonstrated an increase in the complexity of their understanding, the number of elements increased, and the content changed,
- Most participants included aquatic invertebrates in their final drawings, some were labelled with the group names from the miniSASS assessment,
- The language used by the participants changed from the pre-course to post-course submissions. More labels were used, and more technical terms were used, including references to the citizen science tools, and ecosystem related terms.

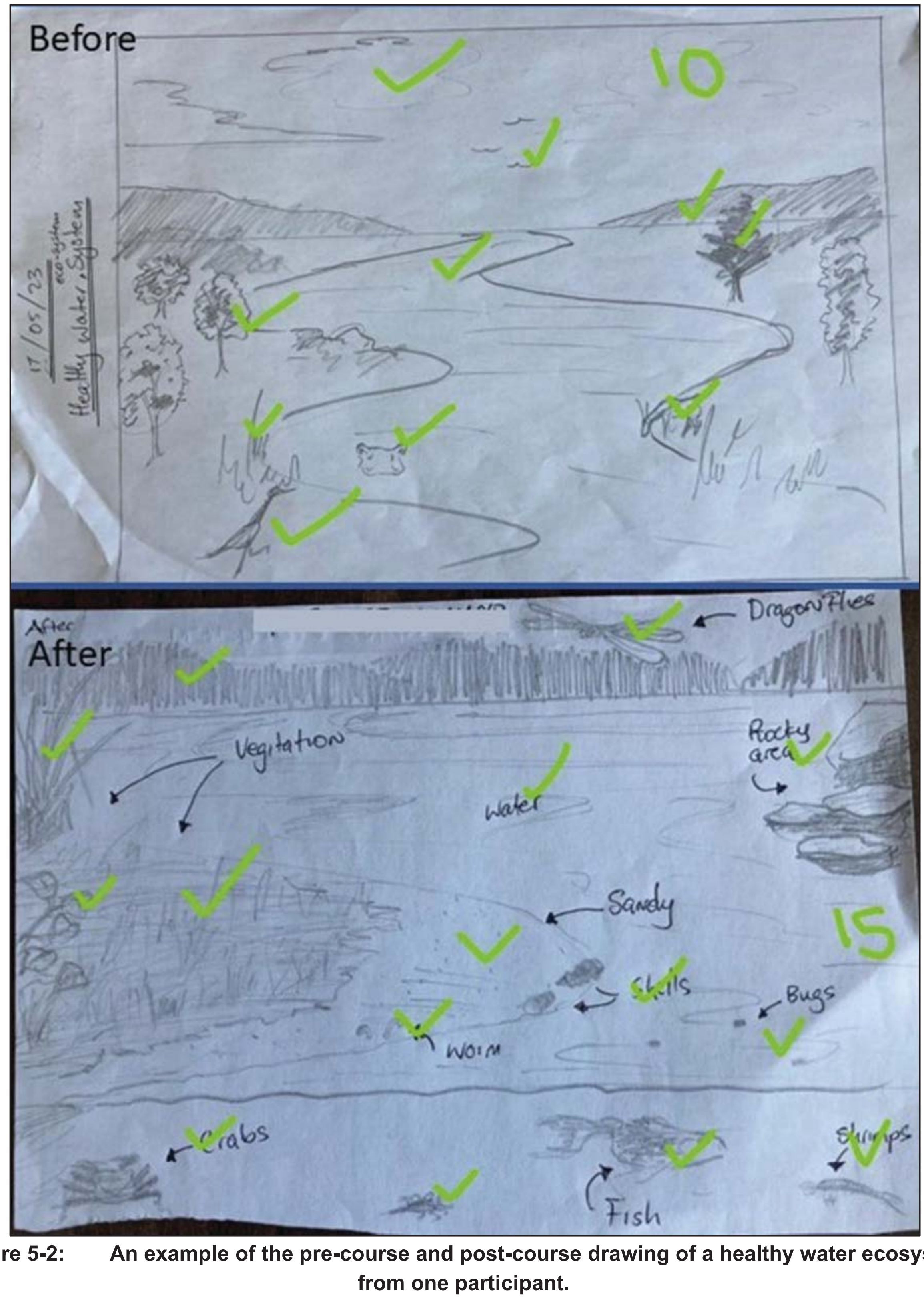

Figure 5-2: **An example of the pre-course and post-course drawing of a healthy water ecosystem from one participant.**

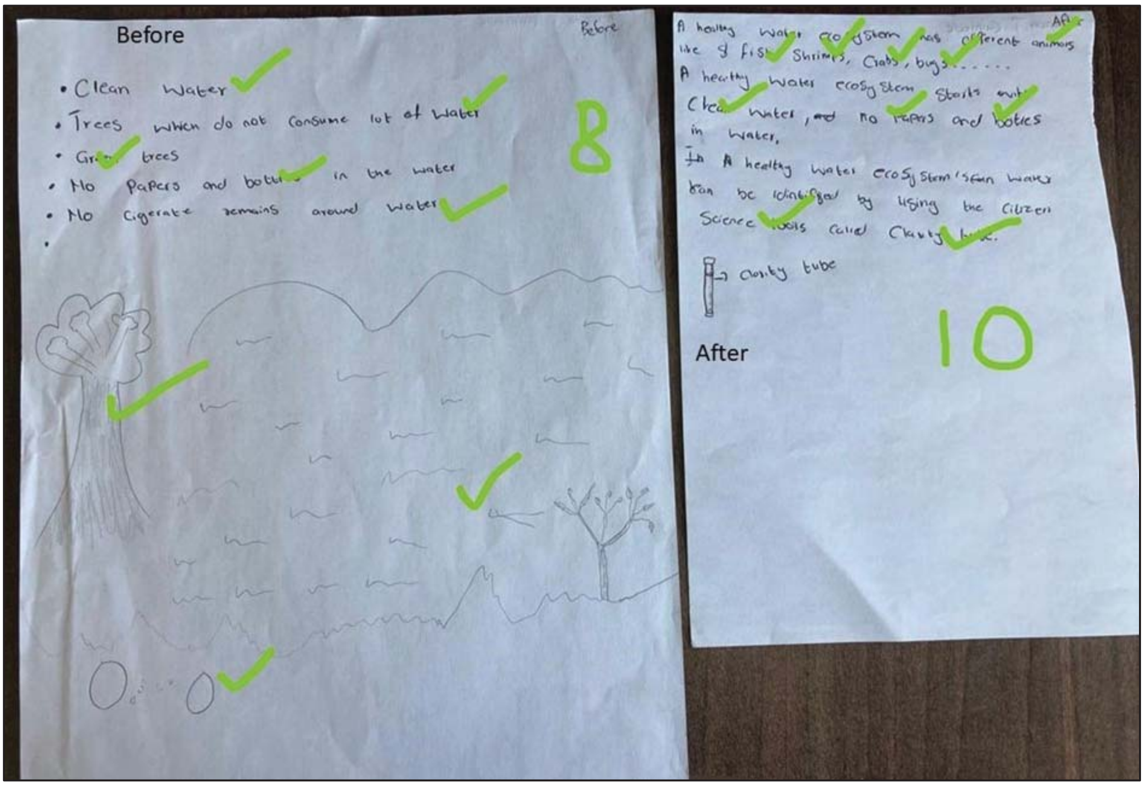

Figure 5-3: Another example of a pre-course and post-course drawing/writing depicting a healthy water ecosystem, from another participant.

5.5 FINDINGS AND DISCUSSION

This section addresses the original questions posed by the pilot of the remote citizen science learning platform in light of the themes that emerged during the data collection and analysis.

5.5.1 The participants demonstrated that they were able to learn about citizen science through their engagement with the remote learning system.

The evidence from the pre-course and post-course appraisals, and the emergent themes from data sets 1-7, reflect that all participants were able to learn about the citizen science tools using the remote learning system. All participants demonstrated an increase in the complexity of their knowledge; and were able to correctly use the tools to monitor a stream or wetland, collect data, and raw conclusions from that data to infer the health of that ecosystem, and the possible follow-on actions that could be taken. This was demonstrated by participants during their change project presentations (**Figure 5-4**), and the transcript form the tying-together activity (Data set 7). The ability to make these links to new knowledge, apply, plan, and generate new ideas is congruent with Bloom's Taxonomy and implies that high order learning has taken place.

Figure 5-4: Participants from the Zikhali group presenting their change project. This group included graphs to show how their data had changed over the three weeks that they have been using the citizen science tools.

5.5.2 The learning experience increased the confidence and personal agency of the participants.

Most participants noted that partaking in the remote citizen science learning course helped them gain confidence and realise their personal agency in contributing to the protection of the environment. Participants from data set 5 also shared that through partaking in the course they were able to gain 'soft skills' such as presentation, communication, and research skills, and knowledge of how to use the citizen science tools. These findings revealed that the practice of citizen science, and the learning that happens around these practices, play a fundamental role in empowering communities through the direct and indirect skills and knowledge gained in the process.

To support this, Participant 19 commented:

"Yes, it has helped me a lot because now I have gained a skill and I have grown in confidence with regards to public speaking, {even though] it was difficult to engage in group work. Also, if I would relocate to another place and come across these environmental concerns, I would be able to introduce these tools to help mitigate the problems".

It is evident that participants partaking in the remote citizen science learning programme felt confident to teach others about the tools as shared in the viewpoint above. With global change potentially limiting the travel to remote areas to provide in-person training of citizen science tools, remote citizen science learning has the potential to play a fundamental role in empowering citizens, particularly marginalised communities to affect change in their regions whilst gaining competency in application of citizen science.

5.5.3 Participants found the visual learning (video-based content and image-based notes) as most effective for online learning of citizen science tools.

Most of the participants commented that the YouTube-style videos were most effective in learning about the citizen science tools online. The demonstration of the tools through the videos helped the participants learn about the tools independently. Participants also commented that the option of the learning material being in isiZulu or English supported their learning experience, especially if they did not understand the learning material in one of the two languages. 5 participants from dataset 5 revealed that the image-based notes in PDF-from where most data friendly and easy to understand when learning about the citizen science tools.

A participant from dataset 5 commented that:

"I like learning through visual learning and seeing something being done practically, I understand better."

This provides evidence that the video-based content was found as most effective for online learning of the tools for the participants. In support of this, participant B stated:

"*The videos on Pluto helped me learn more and learn about the tools independently*."

This comment reinforces the evidence of the effectiveness of the YouTube style videos in learning about the citizen science tools for the participants. Further to that, the scaffolding theory (Van de Pol and Elbers, 2013) alludes to learning being a process which involves the teacher gradually decreasing the support to allow the participant to assume an independent role when learning. The design of the remote learning platform was informed by the scaffolding theory, which meant that the facilitators provided decreasing levels of support to the participants, which allowed them to learn independently online. It can therefore be assumed that effective learning material can support independent learning in students, which results in a decrease on the reliance of teacher support.

5.5.4 Internet charges to view or download the learning content inhibited how freely the participants could interact with the course materials.

An important theme emerged from the data which emphasized the need to reduce or remove the internet charges for educational material. Most of the participants would not have been able to access the learning materials without the initial internet provision made through the project, which enabled them to download the Pluto LMS app, and the course materials. Eight (8) participants from dataset 5 shared that they had to use their personal data to access Pluto, which made it challenging for them to access the online learning material. Some recommendations that came from the focus group discussions (dataset 5) included, making the citizen science learning platform free, with no charge for internet usage. Another participant suggested that GroundTruth or the institution providing the training should also provide data for the participants to partake in the online training. However, this challenge also promoted greater inter-reliance on the relationships between participants, as they were pushed to work together to overcome the challenge of limited internet access. This brought about the next emergent theme from across the datasets, described below.

5.5.5 Participants were able to overcome the challenge of access to the internet through creativity and working together.

The project researchers had made provision for the initial internet connection which allowed the participants to download the initial course materials on the Pluto LMS app. However, no additional provision was made after this point, which meant that the participants had to find means to complete the course, as parts of it (the quizzes, and forums, and in the instance of the Mabasa group, the videos) needed a live internet connection to run. The participants surprised the researchers with the creative solutions they found to overcome this challenge. Several participants in dataset 5, shared that they had to use their local library Wi-Fi to access the learning material on Pluto, and to engage on collaborative platforms on Pluto, such as forums. Two participants from dataset 5 noted that they used data they got from school to access the learning platform, which meant that they did not incur costs.

One of the participants form dataset 5, in the Mabasa group commented:

"I didn't have data issues because I received data from UNISA where I am currently studying, and I was able to complete my modules."

Other creative ways in which the participants approached this challenge included downloading the videos directly from YouTube and storing them on a personal computer. Participants noted that they needed to communicate more with each other to ensure that they had covered the materials that were needed, and some formed their own study groups to assist with this.

5.5.6 In-person demonstration and hands-on use of the tools was a valuable activity to supplement the online learning

The findings revealed that participants were able to learn most effectively about citizen science through a mix of online and in-person training. This finding is further supported by Graham and Taylor (2018) who noted the importance of incorporating the 5Ts of Action Learning model in citizen science learning[27], which enables and enhances the learning process. This is because the participants were able to practically apply the citizen science tools during in-person trainings and engage with fellow participants and facilitators through discourse to understand the practice of citizen science and the tools better.

Participant 19 commented:

"*I think in-person sessions helped a lot; I don't think I would have understood as much as I do now. " For example, I understood the water clarity tube better but if there were no in-person trainings I wouldn't have understood the E-coli test because there are so many things to consider like water measurements. Another example is the miniWET health had more videos than notes it would have been much better*."

This finding emphasizes the importance of including in-person trainings into remote learning, as this strengthens and enhances citizen science learning. Participants shared that in-person trainings were most beneficial to the learning experience of the participants when there was 'hands-on' practical demonstration of the citizen science tools by a facilitator, when the tools were practically applied by the participants, and when the participants were teaching each other. Graham and Taylor (2018) support this by noting that, "touch" is a fundamental aspect of citizen science learning as it deepens the learning experience of an individual.

To support this, a participant form dataset 5 noted:

"*I learned the best when I applied the work practically. When I held the tools and applied the information that I got from Pluto, I understood the tools better*".

Another participant from dataset 5 reinforced the findings by sharing:

"*Talking and explaining to other participants about tools helped me to understand the tools better*".

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[27] The 5Ts model of Action learning includes the components – 'touch', 'talk', 'think', 'tune-in' and 'take-action'. This model is explained in more depth in previous reports.

Figure 5-5: A participant teaching others how to correctly identify aquatic macroinvertebrates when undertaking a miniSASS.

This strongly supports Bloom's learning theory which emphasises that learning should be a transformational process, that enables learners to access a higher level of thinking (Hyder and Bhamani, 2016). Through the hands-on learning experience and use of the citizen science tools participants are able to build on the existing new knowledge gained from the online learning experience of the tools in their own context. This finding reinforces Bloom's learning theory which emphasises that learning must occur in consecutive stages, which ranges from learning and recalling new knowledge to practical application and translation of the knowledge by the student into their context (Hyder and Bhamani, 2016).

5.5.7 Learning in a group enhanced and deepened the citizen science learning process for the participants.

The data revealed that participants felt that the learning was most beneficial when it occurred in a group (both in-person and online). One of the group activities that the participants noted was when the most citizen science learning took place was during the change projects. The challenge of designing their own monitoring plan provided an opportunity for the participants to apply what they had learnt into their own context. The diversity of the groups helped the participants learn from each other about the tools, as some participants were more knowledgeable about some tools than others.

Participant 20 supported this by commenting:

"*For example, I did not understand the miniSASS scoresheet but when I was working with my group, I learnt that I must follow arrows to identify which invertebrate we found*."

Participant 21 also reinforced the finding revealed by the data by commenting:

"*When working as a group there are different opinions being shared and we can remind each other of what was said during the training. I would say it helped me that way, being able to get assistance from my group members and especially because we had a change project which required us to rely more on each other as compared to the facilitators. Although group work is challenging, there are benefits of being in a group. There was a learning happening within the group especially in the change project*."

Figure 5-6: Participants working as a group.

5.5.8 Comparative Case Study – the same remote learning system applied within an urban context.

Concurrently to the duration of this project, a parallel study has been run by a Master's student (funded by the WRC, through this project) using the 'Tools for Citizen Science' course but within a community that was situated in an urban context that had access to the internet. The outcomes from the learning engagement of that study have been summarised (**Box 3**), and some of the findings overlap with the experience of the rural Lake Sibayi groups. In particular:

"*Participants preferred a mix of online and in-person support",*
and
"The demonstration of the tools in-person was a great learning opportunity as questions were asked and explained while demonstrating the tool".

The value of the in-person component was a common theme that emerged from the data sources from both projects. This is important to note as there is a global shift in moving away from in-person training and a greater reliance on online learning. In spite of this shift, people are socially orientated and value interactions with other people. There is a great value placed on learning together, as the differing viewpoints bring a richness and depth to the knowledge that is built in a co-constructive manner (Wals, Van der Hooven, and Blanken; 2009). These form some of the principles of the social learning processes that Wals outlines for transformative change (2022). He notes that for a shift towards sustainability to take place, conversations need to take place between diverse groups of people, that we need to be confronted by truths that make us uncomfortable, and thus open the space for visiting or re-visiting sustainable practices that may be unknown or have been forgotten. This level of human interaction is usually best done in-person, as people are kinder to each other face-to-face. Discourse that occurs in this manner can bring about huge positive change (Wals, 2022). It is this level of engagement that needs to be facilitated by the online learning system, which is why some provision needs to be made to retain some in-person support elements, if possible.

Figure 5-7: Participants from an urban area practicing using the citizen science tools, an example from the comparison case study.

Figure 5-8: Participants from an urban area working in groups, an example from the comparison case study.

Box 3: Case Study of Master's Research Study by Nondumiso Mahlanze

Rationale for choosing the case.

The Masters Research study explores the perceptions of peri-urban communities on river health and the adoption of a remote learning approach for citizen science. Participants were selected in Sobantu Township, Pietermaritzburg and divided into two groups, online based training was undertaken by group one and contact training was undertaken by group two. The participants were divided with an aim to identify learning opportunities and challenges between traditional learning methods for citizen science and advanced learning methods using the Pluto platform to learn about citizen science tools. This case study is relevant to this research project as it uses the same remote learning system for citizen science, but the study was done with a township community. Therefore, this case study is valuable as it investigates the piloting of the remote learning system in a different community and will assist in identifying how communities with different socio-economic issues respond to advanced learning methods.

Findings of the training evaluation:

What challenges do local communities in engaging in citizen science monitoring face?

- Lack of knowledge about citizen science, river health, basic environmental management, types of pollution and impacts of pollution on communities.

The successes of the online learning system in teaching the tools for citizen science course:

- The participants did not have network challenges, data challenges and app use challenges.
- Little supervision was required with using the app at the workshop venue and no assistance was required with using the app at home.
- Undertaking the course on a digital platform allowed for further independent research by participants as some utilised the internet for further research interests, such as what kind of jobs a person who has learnt about citizen science in South Africa can do.

The challenges and successes of teaching citizen science in-person:

- The participants preferred online training coupled with some guidance in-person.
- The participants preferred to work in groups and not independently.
- The demonstration of the tools in-person was a great learning opportunity as questions were asked and explained while demonstrating the tool.

Recommendations for addressing the challenges:

- Some in-person training should be incorporated to the online learning course.
- In the introductory workshop, expand on related concepts such as citizen science and aquatic ecology, to help situate the participants in the broader context of environmental management and ecological infrastructure.
- Participants to be selected based on their interest in the environment as this plays a role in how they participate.

CHAPTER 6: LESSONS LEARNT AND RECOMMENDATIONS

A valuable outcome of this research is what the research team has learnt about interacting with communities within rural contexts, about facilitating remote learning, and designing online courses. These lessons have been summarised below:

Lessons learnt from project implementation within a community setting:

- The importance of "closing the loop" when conducting research in rural communities – having a feedback loop and reporting back to the participants and their community is highly valued by the people involved in the study. This feedback should reflect on the impact and contribution the project has made to the socio-ecological state of the community. Further, the project feedback should be shared jointly by the participants and facilitators. This is to ensure that participants benefit from the potential outcomes or impact of a project, despite the scale of impact.t.
- The importance of understanding the "unspoken" manner in which to approach and address leaders, or tribal councils in rural areas. There are protocols governing how introductions are made, and how communication happens, and it is best to seek help in understanding the correct manner to undertake these tasks, if needed.
- The value of having a community liaison person to help navigate socio political dynamics and tensions. Our partner organisation, SAEON (through WRC project: C2020/2021-00430) was a great asset for us in that regard, as they had an established relationship with the community, and we levered off that to accelerate the introductory processes with the Tribal Authorities.

Lessons learnt about facilitating remote learning in a rural community:

- Support from a facilitator via an alternative medium to in-person facilitation (e.g. email, WhatsApp messaging, SMS, phone call) is needed. Participants need to feel supported and that they have a "real-live" human to communicate with. Building the relationship between the facilitator and the participant is crucial.
- Course content that incurs an internet charge for "streaming", "downloading", or "viewing" will not be interacted with as readily as content that does not incur a charge. Provision needs to be made to provide the services at no cost, or the organisation facilitating the learning needs to incur the cost for the participants. The high cost of internet usage in South Africa is a limiting factor for the ease with which knowledge and skills can be developed nationally.
- Although the course that was designed was an "online" course, the participants required some in-person support. This was most valued during hands-on group sessions demonstrating and practicing the application of the tools in the field. This needs to be kept in mind for future applications of remote learning in similar regions, provision should be made for an in-person support visit, if possible.
- A diverse group of participants was able to deepen the learning experience for all. The diversity between the participants in the group meant that they brought creativity to their approach to learning challenges; and added a variety of strengths to the group learning. The groups had participants from a range of ages and education levels.

Lessons learnt about designing online learning for citizen science:

- Video content needs to be short (1-3 min per video is ideal), saved in low-resolution, and embedded into the course structure (Pluto LMS in this case) so that participants can download it once and have it saved on their device.
- An "introduction to the facilitators" video is a good way to establish a relationship with the course facilitator.
- Language needs to be light, simple, and clear. Technical terms need to be explained. For this group they enjoyed working in a mix of isiZulu and English, more than in just one language or the other. The combination of languages aided their understanding.

- Where at all possible, the course needs to draw on the prior knowledge and understanding of the participant and give them a chance to express their understanding to others. The course should start from the point of view of the participant – asking them to identify an environmental concern in their place is a way to do this. However, links should be made back to this activity throughout the training process, or it will not add value to the learning experience of the group.
- Self-assessment in the form of automated quizzes give the learners the opportunity to gauge their understanding and progress. These need to be designed carefully: the language needs to be simple, and unambiguous. Autogenerated feedback from the quiz should help the participant come to the correct conclusion, without giving them the answer.
- The activity of planning and implementing a change project allowed the participants to “pull the threads of the course together”; and make sense of what they had learnt though applying it in a new context. It is a valuable part of the learning process and should always be include in citizen science training.

CHAPTER 7: RECOMMENDATIONS FOR THE FUTURE

This research has documented the process of designing and facilitating online learning about citizen science. This was done in a very specific context, that of a rural community with little access to the internet. The challenge of overcoming the lack of internet connectivity was realised through how the participants were able to work together to co-create solutions. In isolation some of the participants may not have been able to overcome these challenges. This highlights the importance of facilitating opportunities for social learning processes, many of which have overlaps with the Action Learning framework. Future applications of the remote learning system, devised through this research, need to take heed of the following aspects which have been shown foster social learning processes:

- **The introduction of facilitators via the online learning platform**. This gave a face to each facilitator, and allowed the participant to identify with their facilitators, and facilitated the building of trust between the participant and the facilitator. This enriched the learning experience.

- **The provision of in-person contact sessions where the participants were able to meet each other, form bonds and friendships, and interact with their facilitators.** In-person training sessions provided a conducive environment for social learning to occur within the group, and thus enhanced the learning experience of the participants. Evidence showed that even though the bulk of the learning took place in an online setting, the participants valued the time when they were brought together to do activities with their group and facilitators. This human connection is still an important component of learning and should still be incorporated into a remote learning process. The value of online learning is that the time allocated for these in-person contact sessions can be reduced substantially when compared to traditional learning. This can save costs, travel, and the expenditure of Carbon. In instances when in-person contact is not possible, more effort needs to be allocated to providing opportunities for connection through online platforms. This can be done through live online meetings; through the creation of video content by facilitators and by the participants themselves; and through the facilitated interaction during group-tasks and on communication media, as explained below.

- **The setting of group-work tasks**. Providing opportunities for and encouraging group-work opened space for social learning. These tasks fell outside of in-person sessions and encouraged the participants to connect and communicate with each other (either on WhatsApp or in-person) to complete assignments. The challenge of having to complete a task within a group facilitates deliberation, drives active participation, and the need to reach consensus to produce a submission for an assignment. These are important components of the social learning process.

- **Using a WhatsApp group for communication within each group**. This type of communication media provided opportunity for easy discussion within a remote setting. The WhatsApp group also served as an alternative platform to share learning material and for participants to support each other's learning journey. In lieu of face-to-face interactions, the familiarity of the participants with the use of WhatsApp meant that it was their preferred mode of communication. The other mediums communication (the online forums, email, and built-in message system) were not well used

The remote learning system that was devised through this research does require a high degree of input from the facilitators. In this instance, the facilitators all received training (in the form of the 'Training-the-Trainers' course that was developed for this purpose), which explored the concepts of social learning and the 5Ts of the Action Learning Framework. The facilitators managed WhatsApp groups outside of the course contact time, in which they initiated and responded to discussion about the citizen science tools, assignments, and learning content. The facilitators generally had experience of most of the citizen science tools, though some tools were new to them, and some of the tools they had only applied once. The participants benefitted from the knowledge that facilitators added to their discussions, however in converse, the facilitators themselves documented that they personally gained a greater understanding of the tools and how they could be applied in different contexts through their participation in these discussions. This highlights the value of a person taking the role of 'facilitator'. This person may not be an expert user of the citizen science tools, but if they have a little more experience than the other participants, they can enhance the learning of others, and add to their own understanding. In the absence of a designated facilitator, who has received appropriate training for the role, it is important to form working groups that consist of a people with a range of experiences with the citizen science tools, so that those with more knowledge can share what they know, bringing benefit to others and consolidating their understanding concurrently. There was evidence of this taking place in the case study of the Lake Sibayi groups when they were working in groups on their ‘change projects’. For participants that had had no experience in the collecting and processing of data, the ‘change project’ task was challenging as they needed to use appropriate citizen science tools to collect data on the health of their stream or wetland, summarise that data, and present it back to the group. During this task those with more experience in data collecting, and summarising data assisted those who were struggling; and in doing so took the role of ‘facilitator’. This can be summarised in the following two recommendations:

- **Create working groups that consist of participants with a range of experience levels; and provide opportunities that allow participants to take the role of ‘the facilitator’**. It is important to make provision for this both in absence of a facilitator and when there is one available.

- **Facilitators need to be actively involved in the learning process and it is recommended that they attend extra training, such as the ‘Training the Trainers’ Course**, or any similar course that covers the concepts of social learning. This ‘Training-the-Trainers’ course is available through GroundTruth, and investigation is being made into developing online learning content for it, so that it can be used in conjunction with what has been developed for the citizen science tools.

Given that the remote learning system for citizen science was facilitated within a group of people from the context of rural community, it would be prudent to assess how well the online materials could be used with people from other contexts. A brief comparison has already been made with another case-study that applies this system within a group from an urban setting. What was applied with the urban group of learners was facilitated in an almost identical manner to what was done with the group form Lake Sibayi (the facilitator attended the same ‘Training the Trainers’ course; and assisted during the in-person sessions with the Lake Sibayi community). What has yet to be tested though is the application of this remote learning system by a facilitator who has not been prepared in such a manner. It would be beneficial to document how someone could take and use the online materials with only the direction of the guiding document that accompanies the materials. This brings to light the following recommendation:

- **Further research is needed into how the remote learning system is used within different contexts from other regions around South Africa**, and even beyond its borders. Different groups of people from other parts of South Africa may experience diverse challenges when using the online materials. The materials could also be developed in more languages, currently there is written material in English, isiZulu, Sesotho, and Afrikaans, and video material in English and isiZulu. These could be expanded to include other South African languages, and even languages like French, Portuguese, and Spanish, among others.

To allow available access to the online materials that have been developed through this study a suitable “home” for these learning materials needs to be found from within the citizen science community of practice. This project has already initiated discussion within the community of practice through the research process, and it is hoped that this discourse will continue through the further efforts of projects that are already building on the progress that has been made (**APPENDIX K – OUTREACH AND DISSEMINATION WITHIN THE COMMUNITY OF PRACTICE**) Favourably, this community of practice is solidifying its bonds into a formal society, which lends promise to the suitable housing to the Toolbox, its remote learning system, and future updates and adaptations of these products. This pursuit can be summarised as:

- **The citizen science toolbox, and the remote learning system designed for the toolbox needs to be situated in an online space that allows easy access; and accommodates effortless updates of the tools**. This digital space could be on a website hosted by an appropriate governmental institution, such as the Department of Water and Sanitation, the South African Environmental Observational Network, or the South African National Biodiversity Institute. Key role players in these organisations have expressed their willingness to host the materials, and further effort needs to be allocated into the realisation of this task.

As alluded to above it is important that both the toolbox and the online learning materials for the toolbox can be easily updated, so that their use can stay relevant and applicable. The tools in the citizen science toolbox were briefly reviewed as part of this study, which highlighted the current aspects in need of revision, further development, and expansion:

- **Further development is needed specifically focused on the following tools: the Estuary tool, the Spring tool, the River Health Audit, and the Weather-monitoring tools.** These tools are the most underutilised tools in the citizen science toolbox. The school lesson plans also require review and updating.

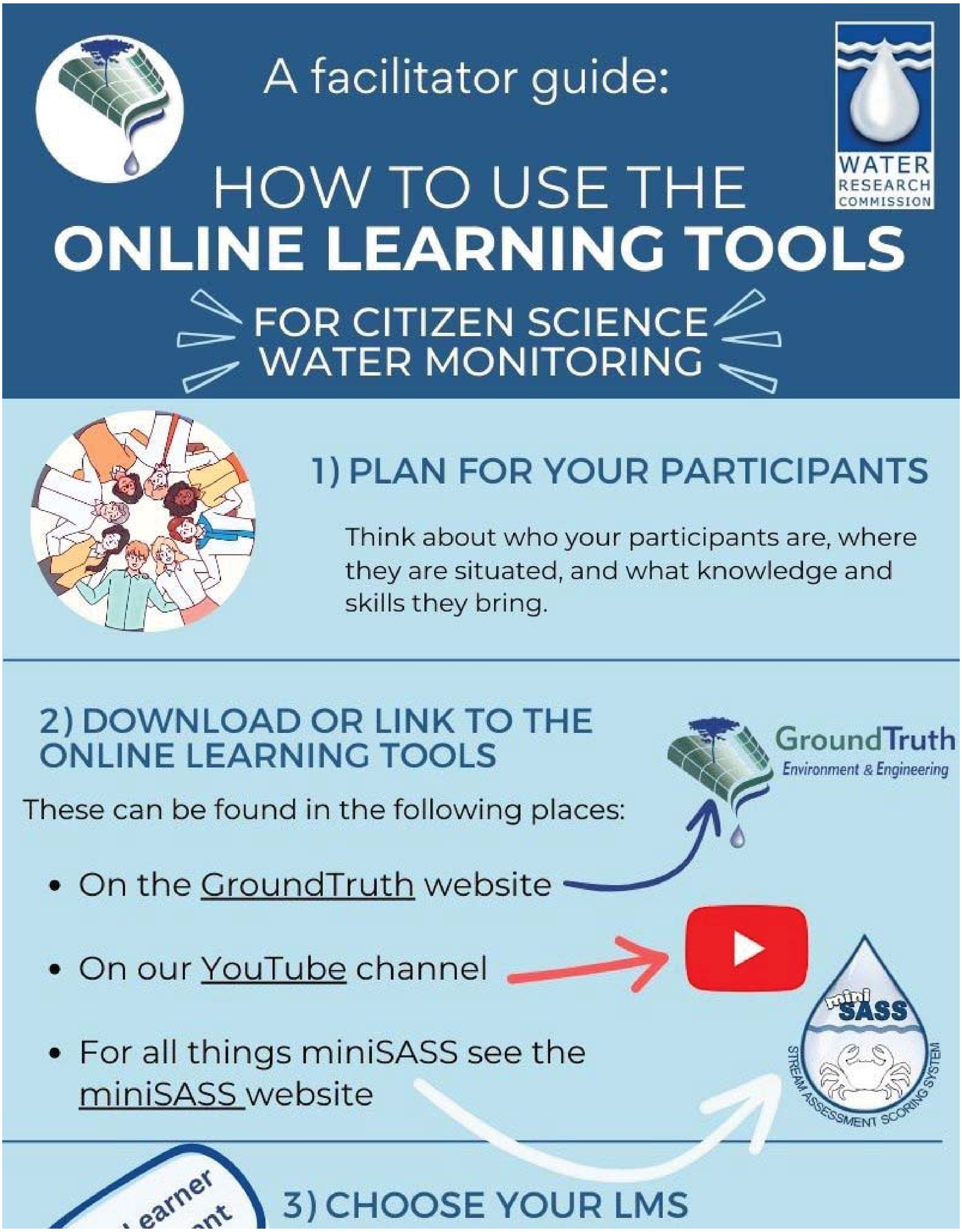
Given that the envisioned aim of the study was to trial the remote learning platform in three of the tribal authorities (Mabasa, Zikhali and Tembe TAs) instead of two (Zikhali and Mabasa TAs) in the Lake Sibayi community, it is recommended that:

- **A community needs assessment be carried out before a project is trialled within a community to determine the challenges, opportunities and needs of that community**. This assessment could potentially inform the project team of the feasibility of the project and prepare them in advance to overcome challenges that could potentially arise, particularly in the initial engagement process. Additionally, the project team can better prepare and tailor the services or products they would be offering with the intention of meeting the needs of the community.

A new research project that is currently funded by the Water Research Commission, though the University of KwaZulu-Natal, will be looking at the use of these citizen science tools to provide information to feed directly into the National 'State of the River Report'. It is hoped that this research, and other research that follows on from this study, will further the review of the citizen science tools available for the biological monitoring of water systems. It is through continued efforts such as these that will result in the realisation of a suite of tools that anyone, in any context within South Africa, could apply to help them understand, monitor, and illicit change for the shared benefit of our water.

CHAPTER 8: HOW TO USE THE ONLINE LEARNING TOOLS – SUMMARY GUIDE AND LINKS

A short infographic has been developed to facilitate the sharing of how to access and use the online learning tools. This infographic contains links to the online learning tools and the Best Practice Guide for facilitators.



LMS = Learner Management System

3) CHOOSE YOUR LMS

There are many free learner management systems available: **Google Classroom, Moodle, EdX,** and **Pluto LMS** are just some of the options you can choose from.

Most offer similar features, but we suggest you look for one that allows you to:

- Design self-assessment quizzes (quizzes that mark themselves)
- Set up forums so the participants can discuss topics with each other
- Work with and view content off-line once it has been downloaded

4) CHOOSE WHICH LEARNING SUPPORT ACTIVITIES YOU WILL USE

- The “picture building” activity
- The make your own “instructional video” task
- The “Change Project” task
- The “tying-it-together” activity

These could be run as either **in-person activities** or online
Descriptions can be found in the “Best Practice” guide

5) SET UP A COMMINICATION NETWORK

Set up a group on WhatsApp or another social communication app that is widely used to allow easy discussion with the facilitators and between the participants.

Share your stories on the **Citizen Science for Rivers** Facebook and Instagram pages by tagging the page or adding the hashtags **#CitizenScienceForRivers #CSFR**

This infographic is best shared as a PDF, and can be accessed in that form from this page: https://www.groundtruth.co.za/olt

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CHAPTER 10: APPENDICES

10.1 APPENDIX A – LIST OF INTERVIEW PARTICIPANTS

Participant	Reason for interviewing participant
Evaluation of Citizen Science Learning – First round of interviews **(Participants were selected/interviewed based on their experience as citizen science user or teacher)**	
Participant 1	A citizen science toolbox co-developer from GroundTruth.
Participant 2	A citizen science tools user from the Duzi uMngeni Conservation Trust (DUCT).
Participant 3	A citizen science tool teacher and user from DUCT.
Participant 4	A citizen science toolbox co-developer and user who has wide experience of applying and teaching the tools.
Participant 5	A citizen science tools teacher and user, a volunteer for DUCT.
Participant 6	A citizen science tools teacher, user, and original developer of the tools from GroundTruth.
Participant 7	A citizen science tool user from WESSA.
Participant 8	A citizen science tools researcher and user from Rhodes University.
Participant 9	A citizen science tools user who has taught the citizen science tools in rural schools.
Second round of interviews	
Participant 10	A teacher and user of citizen science tools such as the Field Survey, clarity tube, velocity plank and miniSASS from DUCT
Participant 11	User of citizen science tools specifically the Field Survey App from DUCT
Participant 12	A user and teacher of citizen science tools from DUCT
Participant 13	A user and teacher of citizen science tools from AEN
Evaluation of the Current citizen science Toolbox (participants were selected based on their use and experience of the current citizen science toolbox)	
Participant 14	Participant 14 is an education and training specialist within GroundTruth who regularly uses the picture building tool when engaging and teaching school children on the environment.
Participant 15	Participant 15 is a research scientist at GroundTruth who is currently responsible for leading the development of the miniSASS mobile application (app) and updating of the miniSASS website.
Participant 16	Participant 16 is a wetland technician who provided insight on the current challenges to a new user of the tool.
Participant 17	Participant 17 is an Estuarine specialist at GroundTruth.
Evaluation of the learning journey of the participants (Participants were selected based on their varying degrees to internet access, level of digital literacy and experience with online learning).	
Participant 18	Had limited internet and network access. The participant was only able to access internet through the local library.
Participant 19	Had access to internet through the local library Wi-Fi. The participant had good connectivity.
Participant 20	The participant had free internet access, as they were a registered UNISA student and did not struggle with connectivity.
Participant 21	Used the local library for internet access, which provided free Wi-Fi. He also did not struggle with network connectivity.

10.2 APPENDIX B – INTERVIEW TRANSCRIPTS

Amanzi Ethu River Rovers – Focus group Discussion

Q: When did you first come across the citizen science tools (CST)?
TN: I first came across it in October 2021 during our training in the Amanzi Ethu Nobuntu phase 2 project.
PN: I first came across CST at Liberty NPO in 2021.
Q: How did you guys first learn about CST?
PN: Through training conducted by GroundTruth.
Q: Was it more like action learning or through theory?
TN and others: Definitely through action learning.
Q: Would you say you are a teacher of CST? Which teaching method did you find to be effective?
PN: We first teach the theory then go do it in the field. I would say it is effective, but it needs regular follow-up.
TN: we teach it through a bit of theory and a lot of practical application. The EnviroChamps and project officers use it too, so it is a trial and error until they get it. The first training done is not effective, so you then need to reinforce the training on citizen science tools.
Q: Is the retraining a result of them not practising CST more than once?
LN: It is to reinforce what they were taught before because we do not have enough time at training to teach the citizen science tools. The programme is too short and has a lot of stuff going on. The CST are not something you can teach someone in one day, even with us it took us a while to be able to understand them. The one day allocated for training is usually not enough, also some teams did not do CST training and went on for months without doing it, they forgot most of the tools.
Q: What has helped you personally to learn, and retain the knowledge of how to use and apply citizen science tools? And what is the best approach to use when teaching others as people who are teachers of it?
NX: I would say it is trying different techniques with different people as people do not understand the same. When you go out to the field have about 3 or more techniques to teach people CST.
PN: Make what you are training the team on more relatable. I have noticed that people struggle with the velocity plank, and they don't even understand what it is for. I think that if they are understanding what each tool represents and what it is used helps them understand it a bit better.
LM: Retraining becomes easier when you already know the teams because after the first training you don't even know the people. But after the first training, we spent time with the groups and we know that this is what this group is struggling with, here are the people who are strong in which tool. You know when you go conduct retraining what it is you would like to focus on based on the team. It becomes easier to come up with a new training method because you have a better understanding of the team and the environment, they work in. In the retraining, it becomes easier to focus on each team rather than working with 40 people from different organisations learning different things at the same time.
PN: The retraining and reinforcements can be done on a more regular basis than waiting months before you go to site as you will find you have a lot of inconsistent data and keep in check more regularly maybe monthly.
RR: I have also noticed that we too as the trainers need retraining on the tools. Sifundo explained the purpose of having 3 people taking clarity tube readings was to get points across the stream by taking one reading at each interval until you reach the end of the stream. You then do not need three people and one individual can take the reading at different points of the stream. This was new information to me as well and I could not comment on what Sifundo had said. So, if we learn regularly, we are able to go out and train people and answer questions asked. When the question was posed back to me, I had to pause and think before answering because I didn't know you could sample in that way. Also with the velocity plank, at first, we took the first reading at the bank now it is taken inside the stream. To a point where when I went back to train my team, they pointed out the confusion of whether to take the reading in the middle of the stream or at the bank of the stream. We end up confusing them because we come up with new information every time, we go back to them. So, we would rather go there with the correct information rather than change it along the way to avoid them soaking in new information.
SB: The best way that I learn is through repetition, so I do the same when teaching others. And I ask them to explain it back to you.
Q: Which of the CST are you the most confident in using and why?
TN: It used to be the clarity tube and miniSASS but now I am also confident in using the velocity plank too.
Q: Of all the CST why do you think we are only teaching the three tools; do you think it is helpful to only focus on those 3?
RR: We were only taught the three tools.
SB: I think the tools used should be context-specific, there is no point in teaching a person downstream about the wetland tool that they are never going to use. Whereas someone upstream in an area like Mpendle or Mpophomeni is based in a wetland, where they would use the wetland tool and for others, it is not applicable. The citizen science tool choice should be unique for each group.

PN: The *E. coli* should be incorporated into the CST used as we have noticed that they tend to only use the clarity tube and MiniSASS score to determine if the water is safe to drink or not. Whereas the *E. coli* score will be able to tell them whether the water has *E. coli* present even if it looks safe to drink.

Individual Interviews: Participant 1
Q: Are you a teacher or user of CST? And why?
AL: I would say I am both a user and teacher of CST. This is because I use the tools and facilitate training to help teach people about CST.
Q: When and how did you come across the CST?
AL: In 2012, I was invited by a group who were using the MiniSASS tool.
Q: How did you learn about the tools?
AL: The tools were demonstrated to me, and I eventually got to use the tools myself.
Q: How do you teach CST and when did you start teaching CST?
AL: I started teaching about CST in 2014, this was more in working with school kids on Saturdays. It was less about me telling the kids how to use them but more about engaging with them by asking questions. And then demonstrating to the kids how to use the tools by collecting samples. And then I would allow the kids to do it by themselves. They made a lot of mistakes in the beginning, and they eventually got the technique right.
Q: Personally, what has helped you learn how to use CST?
AL: I found that there is a difference when you tell someone how to use the tools and when they try it out for themselves. I found that it made a big difference during the time I was learning how to use tools. I found that I was still making some mistakes when I used the miniSASS tool and was trying to identify the invertebrates.
Q: Which of the CST are you the most confident in using and why?
AL: I am confident in using the miniSASS, clarity tube, velocity plank and Riparian Health Audit tools. My work includes the regular use of the CST.
Q: Do you think the constant use of CST is helpful for a person to be able to use them or is it a once-off learning process?
AL: If it is a once-off learning process, a person will not grasp everything, they need to keep using the tool, practice and contact their trainer to see where they are getting things wrong. It does not work if you only go to the training once-off and you come back and think you know everything. One of the challenges is that you find that the people who do CST training are using the tools and not doing it right. At times I found that in a CST training of 20 people you find them not using them correctly. Then they pick up the mistakes done and think that is the correct way of using the tools. And then they will go train other people and then you will have a group of people not using the tools correctly.

Individual interviews: Participant 2
Q: How did you learn about CST?
NS: I learnt by practically applying the tools each time we are taught about them. I find as the best way to learn is through the practical application of the tools than only learning them in theory.
Q: What has helped you learn how to use CST?
NS: I learnt through WhatsApp videos, and re-trainings we had were really helpful when it was re-demonstrated to us, was very helpful to have a good understanding.
Q: Which of the CST are you the most confident in using and why?
NS: The miniSASS, because I have been using it for a very long time. I would use it even when the miniSASS tool kit was not complete, I would sometimes make my own nets while I am teaching people in the field. I know how to use the miniSASS the most because then I learnt about the other tools at a later stage.
Q: Was DUCT the organisation that helped you learn about the CST or did you know about them prior to being part of DUCT? And who trained you about the CST?
NS: I learnt about the CST tools at DUCT. Wendy Ngcobo and Portia Vilakazi trained us.

Individual interview: Participant 3
Q: How have you learnt about CST?
LM: I learnt it practically in the field, the first person who taught me was Wendy Ngcobo. I then later learnt the theory part of it in terms of what they are used for and why. This was to make it easier for citizen scientists to test water quality. So if someone instructs you practically how to do it is very helpful.
Q: what has helped you learn the CS?
LM: The practical learning of CST helped me a lot. Because most of the time I am practically teaching people how to use CST and not in theoretically.
Q: Which of the CST are you the most confident in using and why?
LM: The miniSASS one, I am not that good at the clarity tube and I am still struggling with the velocity plank tool. Because most of the time when I am teaching people, we will use the miniSASS tool because it is something I was taught. And when I am teaching people, I am learning as I do it. I remember in the

GroenSebenza induction we were taught by GroundTruth on how to use CST. I was familiar with miniSass and on the induction day, I learnt about the clarity tube and velocity plank. I am more comfortable teaching people how to use miniSASS.
Q: How do you teach CST as a teacher?
LM: I mostly teach teams on the miniSASS or clarity tube who conduct tests in the streams they are working on. I teach them by taking them to the river and first explain what CST are, miniSASS and why we do them. What are the tools for and tell them how to use them, in terms of minutes, how to stand in terms of river flow? I do the basic things before conducting the training.

Individual interview: Participant 4
Q: Are you a teacher or user of CS?
JT: I am definitely both a user and a teacher.
Q: When did you come across CST and how did it happen?
JT: In the 1980s, I started working for WESSA at Umngeni Valley they introduced me to CST to help people understand nature, ecology, biodiversity, etc.
Q: How did you learn about CST? Was it more experimental or action learning?
JT: There was no specific course on citizen science, people were not using that term then. We were taught fieldwork, and how to do science in the field and that included water and soil studies, cross-sections, tree analysis, etc. So, there were a lot of things going on that you would have called citizen science. And then we were taught so we could teach others including university students and school children.
Q: In the science in the field were you using CST or was it more of to give an idea of what you need?
JT: I would say they were tools, for example, we used a probe with a battery pack, and it could give you data on the environment such as the light intensity, the pH, etc. that was probably the most sophisticated tool we had in the 80s. And we also had booklets and reference guides to help us to key out which organisms or trees we are looking at. It was quite comprehensive, and all linked to theory. so, there was a wonderful theory-practice mix which we called Theory in Action. The learning was about theory understanding and then practically trying it out.
Q: When did you come across CST as you know it now?
JT: Mark Graham and I did a WRC research project that finished up 3-years ago. I think it was published in 2018. In those 3years (2015-2018), our job was to develop CST for South Africa; use them and research them and we developed 10 which are found in the blue book. And some of them you are familiar with like clarity tube, velocity plank and miniSASS. The ones I think are best for rural online learning, I think are the Enviro-Picture building game, especially for things like climate change. There is a resource called ‘puzzling climate change’ which was developed in a very remote rural isiZulu-speaking school in KwaZulu-Natal. They were struggling with the language and the meaning of Citizen Science. The fact that a resource came out of a remote rural area, meant it had a lot of relevance to that area.
Q: Were the 10 CST mentioned earlier developed primarily in partnership with you and GroundTruth or did the public also contribute to their development?
JT: There was public involvement, but GroundTruth was at the centre of it.
Q: What was your role?
JT: In those days, uMngeni Water was very active in Citizen Science, and they developed slide rule which was the tool which pre-dated MiniSASS. It is a piece of cardboard inside another piece of cardboard, and you pull it out, depending on which one you find, it gives you a river health index, and that was developed in partnership between WESSA and uMngeni Water. At uMngeni Water it was led by Chris Dickens and Mark Graham, as they were both working for uMngeni Water at the time.
Q: Is there a reason why the most common CS tools used are the 4 we know? Is it because they are the most applicable in South Africa?
JT: I think the 4 common tools used are the most useful, that is why they are used the most. And they are quite specific to things like turbidity, water pollution< etc. And the strength of miniSASS is that it gives you a river health index, it is quite cost-cutting. If there is a very bad nutrient load, heavy metals or flooding, miniSASS is going to tell you the story. As the little organisms will be affected by those factors. Unlike something like temperature, I think it is useless as it only tells you the temperature of the water, it doesn’t tell you much else. We published the tools in the blue book, where the best thing about it is the little memory stick on the front cover which has comprehensive appendices of all the 10 different tools which are not in the text of the book. People have not picked up on the Enviro-Picture building. And the other recommendation from that research was that the website developed called ‘Capacity4Catchments’. Capacity4Catchments is a registered website which came out of our project, and we were saying how can we help people understand the tools, where they are and what they can be used for. We used a painting my sister did of the river, trees, town, rural huts, and Eskom wires, which is a landscape of South Africa. The website has miniSASS dichotomous key, when you move it to the trees it will tell you how to study the trees. Just by moving your mouse around you can find the tool that you need. And for me, that is a very good interface between people and the tools. The whole thing was duplicated in hard copies, so you didn’t have to be in front of a computer to do it, as all the tools were

linked to different places. So, it is like a conceptual landscape of all the tools. We didn't have the funding to take this forward, which I think will be expensive to do. But it probably is what South Africa needs, if not the world.
Q: Did you learn how to use CST through action learning?
JT: I learnt through action learning.
Q: As a teacher of citizen science, how do you teach the tools, and how has it worked for you?
JT: The most recent example was that I was asked to go to Ethiopia to teach a lot of people about miniSASS and citizen science tools. So, I took the clarity tube, velocity plank< etc. And then we all had a big meeting where I used PowerPoint to explain how it all works and the next day, we went straight into the field to a river to do some testing. And they did it with me, where we also put the data on the website. It was a mixture of action learning, theory and practice.
Q: As someone who has taught CST for a while, what would you say is the most effective way to teach CST?
JT: I would keep using the term action learning, and the 5T model. Every time I find that something is not working, they have neglected one of the 5Ts of Action Learning. Either the people were not tuned in properly, and they were not orientated to the lesson, or there was not enough dialogue before the lesson to interact on what people thought about it, or there was not enough hands-on on the apparatus. Remember when the Data Detectives about 2 months ago were analysing data coming in through a field survey from the field. It was going nowhere, and Charlene realised if they were not doing some studies, they were never going to understand the data they were trying to deal with. So, you need to be more hands-on. If you do not take action from the citizen science, it is also futile, you need to do something out of that learning, I think that is important. Those 5Ts are not dependent on the internet, computers, or phones, they would be worth considering for rural learning. And if people did an online course, they would have a useful framework to build it from. Like in Lesotho where we did the Orange Senqu river basin study, we offered webinars to anyone who could attend them, even on the phone. And they would become very popular, even after the project ended, Lesotho came back to us and asked for more webinars in their remote rural areas. I think that was very important. They found a signal, somewhere near where they were living. Mohale's Hoek was where we did the last one, which is miles from anywhere. I was amazed they found a signal. Someone had a cell phone, and the teachers gathered around, and we did online learning.
Q: What has helped you to learn how to use citizen science tools?
JT: My colleagues, all the people I have worked with have taught me. Without that, no one is an island, that's why we call it social learning because you learn with somebody you don't learn on your own. You can go read the blue book, but it doesn't mean you will understand. But when you have a dialogue with colleagues it deepens the learning. That's why I would say learning with and from others is very critical.

Individual interviews: Participant 5
Q: Are you a teacher or user of CS? How would you describe yourself?
LT: I would describe myself as a teacher because whenever I do use the tools is because I am showing somebody how they work, how they could use them. So, I don't just go to the river by myself and measure and send the information. I always have a group of people around me.
Q: When did you come across CST?
LT: We have always worked very closely with Mark Graham, his always been a friend of ours. So right in the beginning when he was developing miniSASS in the 1980s and 1990s, we heard about miniSASS, and then, I was working with somebody in Shiyabazali to measure the outflow of the wastewater treatment works. And we were using little bottles, and people were saying "oh it's about a 2 or 3". And Mark said look, I have been working on this thing called a clarity tube, and that must have been about 2009 in his GroundTruth company. He developed it, so you could actually measure the suspended solids in a litre of water. And that could convert to exactly parts per million in a litre of water, and you could predict if the Howick wastewater treatment works is releasing this amount of sludge into the Umngeni river. Then it's going to arrive at Albert falls dam, then Albert falls dam only has 18 more years before it goes eutrophic. Because all of this nitrogen and phosphorus is getting into the dam. And he has got the exact measurements. He had them calibrated at proper laboratories where we took samples, you can even ask Nompumelelo. She took sample bottles, she said: "this is a 2 or 3 or 4" and they sent those bottles to the laboratory, and they measured the amount of sediment or sludge in there which was from the sewage. So that we knew, and she would also do the clarity tube reading and say, "this is a 5 or 7 or 20 on a clarity tube". And then that would relate too, so they knew exactly what they were talking about. And then of course the velocity plank I'm very interested in, and all the tools.
Q: Were the rest of the tools from GroundTruth as well? And co-developed with you?
LT: Yes, the tools were developed primarily at GroundTruth. We would try them out in a very relaxed way, with EnviroChamps just to see if they could use them. but we weren't really involved in the development side. We left that up to the scientists, we did the trying out.
Q: So the trying out of the first set of tools, was it through the EnviroChamps?
LT: No, I don't think so, I think Mark probably used his own field staff, like Juan, Gary and all of them would go out and try them out in the field, in an accurate kind of way.

Q: How did you learn how to use the CST?
LT: I think through a little bit of showing by people and then questioning. Because for example the velocity plank, it's very easy to measure the width of a river with it if it is not too wide obviously. It is sort of easy to measure the depth and convert, measure it in four places and take an average. But now the velocity, that's another thing. So, I had to apply my mind to that and keep asking for the table. So, you can't do it without looking at the table. And I had to learn that. And now, I have spoken to a friend of mine who is a maths teacher, and she says if you get the width and depth in metres not centimetres, you have to convert it and multiply it by the velocity that you get off that table. That's m x m x m = m^3 per second. And that's CUMEX, which is what all the water scientists use. Jim uses it in his canoeing "jeez that river is 7 m^3, no, that river is 20 m^3, they know that number. So very simply, the EnviroChamps can go to the river and measure the width, depth, and speed in CUMEX. So, that's something that I have worked out myself with my friend who is a maths teacher. So, it's a little bit of showing me how and working it out myself.
Q: Which part was the best part of learning, where you grasped how to use a tool and which tool was that?
LT: Definitely walking into the field myself, and standing there at the river, then you discover that it is not that easy to hold the velocity plank in the river; oh, it is not that easy to measure the width of the river; oh, sometimes it is wet at the bank. So, you actually need to get into the field, you have too. Unfortunately, with remote learning you need to get people in the field they can't learn it in a class room. Take time to sit at the bank of a stream, and really look around and absorb the magic of the atmosphere, the wind and the trees, the sound of the river, the birds. Nothing can replace the magic of nature. You have got to be there to feel it. I think all of the citizen science tools have its own magic, even the river health riparian zone assessment. But of course miniSASS is so exciting.
Q: Do you think there is a reason why miniSASS is regarded as the citizen science tool, is there a reason why some of the citizen science tools are not as widely used?
LT: I think people don't see the point, you go down to the river and you look and say "oh"; and the clarity tube is a 7, so what does that mean?". So, there is no background information on how you can use it.
Q: How do you teach CST as a teacher?
LT: We go down to the river and depending on the group of people I have got. Because some people you know are university graduates, international people and they know about water resource management then you can go into a little bit more detail. But with some people you know that they are community members who have never looked at the science of rivers before and they have come down to the river to see what is going on. So then I would say that the river has got an exciting story to tell, and also I do also try to start my teaching with saying to people "water is such an important thing, how long can you live for without water, how many days can you survive without drinking something that has water in it?". It is not like your cell phone or your boyfriend, or something nice to have that you quiet like. If you don't get water, you die, end of story. You are dead. This water is very important. It might be nice to have a diamond or gold, but if you don't have it you are not going to die. So I make that point and add that look if this water was really really smelly, you walk to the water and sniff it, look at it and see that its green or brown. Would you take your cup and have a sip? Even if you have got no education, you would not do that. So, people intrinsically know about the health of the water. Yes, you got to get water, but you would not get dirty water because it's like drinking poison. You wouldn't take a bottle which says RATEX – poison and drink it. The same as dirty water, you wouldn't even if you were very thirsty, you will know that it makes you sick. So, you got to have water, but not dirty water. How do we know if some of the water is dirty or not? Sometimes you can't tell because it can look clean, but it is not. And then we need the citizen science tools to look at the water. These little organisms are so sensitive, if a bit of pollution touches them, they die. And a stonefly is like that, so if you find a stonefly you know that the water is clean. If you don't find a stonefly, then you can find out what is going on. So, a river tells a story of how clean it is and makes it interesting like that. But I love taking groups to the river, and feeling the magic of the river, especially if it is a beautiful river that is clean and fresh. And if people do work a lot on dirty rivers, like the Baynespruit, Slangspruit, and in their townships, the rivers are all filthy. I think it is very important to take them to a beautiful area, like up in the Drakensberg where you can drink the water. And say that this is how God intended us to be, to have fresh water to drink. This is how it was before we started polluting the water, the water was drinkable. So, we can drink it and show people. I have taken the Enviro-champs up into the mountain, and they would say "this is the first time that I have seen this with my own eyes".
NS comment: when we went to Cumberland as DUCT and we got to drink water, that was my first-time drinking water from the river, it was such a nice experience.

Individual interview: Participant 6
Q: How did you get involved in CS?
MG: In the 1990s, I was working at uMngeni Water doing biomonitoring, using SASS, etc. WESSA approached us to say can we adapt some of the tools that we were using there to develop some things that might be helpful for environmental education. So, we took the SASS5 method, and looked to see what was possible with that to make it more accessible for environmental education purposes; make it less technical but still give you something useful. So, from that, we developed the miniSASS tool by simplifying the SASS into miniSASS. So

that started it, subsequent to that, we have had some research projects with the Water Research Commission. The product of such is the blue book, where we researched a whole range of tools and possibilities and different systems. We took miniSASS and refined it; water clarity tube developed that; velocity meter we developed that as well.
Q: Did someone teach you how to use CS tools or was it more of developing and training others?
MG: we developed the citizen science and made it available.

Individual interview: Participant 7
SS: I'm both the teacher and the user. So, you know, WESSA, we run school programs, ranging from primary schools, up to university groups, and we also do teacher's training. So that's when we get to use these tools with the people. And I'm also a user, because I'm also a researcher. So I use these tools when I'm doing my own research.
Q: And then when did you first learn about citizen science tools and when did you first come across them?
SS: In 2018.
Q: How did you come across them? Was that a matter of being taught or applying them?
SS: Applying them. I was already an educator. So, once I decided to start using citizen science tools and that's when I started using them. So, all I did is to read the manuals and understand how they work and from the people that are already using them. And then from there, started teaching learners about them.
Q: And so how did you learn about them? Just as you mentioned that you learnt through manuals and applied them. Did you get help? Was there someone who maybe had more experience that taught you?
SS: Yeah, my manager already knew how to use them. And Dr. Taylor was still my mentor back then. So I was still working with Dr Taylor. He actually showed me a few things like using that app; the one you use after you've collected your data and showed me how do you put data on the cloud.
Q: And then how do you teach citizen science tools as a teacher, and how has it worked for you?
SS: Basically, how we do it when the learners get here. We introduce the topic of what we are going to do, and then we introduce the tools. So, each tool is explained in detail on how it works. So, the learner will know exactly what should be done and what shouldn't be done. We teach them how you hold it; and how many people do need to support you if using a clarity tube; how many people should check for clarity; so you can have three readings; if you're alone, how do you do it, because sometimes you might be traveling or sampling alone, it doesn't mean that if you're alone, you can't use a clarity tool, but you can still get readings, even if you're alone. So, there is a way of doing that so you know how you collect the data and recorded. So, all that is explained in detail, so the learner will know exactly what should be done. Because in any scientific research if there is no standard operational procedure presented to a person who is going to use the tool, or the results might be bias or there might be standard error. So, you know what a standard error is?
NS: Kind of please, please explain.
SS: So when you're collecting data, there is standard operational procedure on how things should be done and how you carry out the survey. And if that is not done properly, your standard deviation will be huge. So there is a deviation from a standard operational procedure. If a person samples and let's say you get water, and then you check your clarity, you get maybe 10 and then you do it again, get 50 then you do it again in the same place and get 30, so that tells you that there is a problem with sampling. You cannot have such huge numbers in between. So, there could be a problem with your sampling technique. So that's very important. So that's what we teach the learners and we teach the people that love to learn about using the citizen science tools. So that's how we run it.
Q: Which method has been effective in how you teach citizen science tools?
SS: It is when you tell someone, and then actually demonstrate how things are done instead of just explaining. And then you ask learners to actually do it, before they start collecting data. So, when you tell someone, they might forget it, but when they get to do it themselves, they will never forget.
Q: Which of the citizen science tools are you most confident in using and why?
SS: Right now, I'm using something called a digital scope. I'm not sure if you know it.
NS: No.
SS: Okay. So, what you do is, you collect, let's say, you're doing miniSASS and you capturing creatures, I think that's the best way. And some creatures you can't really identify properly. Then you have this thing called a Digiscope, which is a microscope that doesn't need electricity. So, you charge it and you take it to the field. Then you put your creature in the scope, and then you look at it and identify all the characteristics. So you can identify the creature as it could be this or it could be a bug, it could be a bettle, or whatever. But if you're using a DigiScope, you will be able to actually see the characteristics and correct ID. And of course, a clarity tube is one of them as it is the easiest tools to use.
Q: Okay, for the DigiScope, do you use it alongside miniSASS? Like what is the purpose of the tool?
SS: you use it alongside miniSASS and any other scientific tool. As it helps you identify, species correctly, because the purpose of a microscope is to see the characteristics you couldn't with your naked eye. But when you put it under the microscope, you're able to see.
Q: What is the impact in your opinion of COVID-19 on citizen science learning and application?

SS: What COVID did actually separate people, from both negative and positive impact. The negative impact is it stopped people from coming to our learning centres, so they can learn. So if we were to train people, we would do a little bit of training here, but some people couldn't, because of lockdown. But at some point, it also opened an opportunity for us to adapt our programs and design online learning. It actually opened a lot of avenues, it actually proved to us, you can do things online. You know, before COVID, a lot of people were not using Zoom. Even my teams, a lot of people were not using that. But with covid we started finding out that we can actually save a lot of money, we can actually protect the environment because you don't have to travel. So that was the positive impact. So the negative part is people couldn't come to us and experience things first-hand. The positive part of it so that we could then adapt our way of teaching and now we can have like an integrated way of teaching where you can run things over zoom, and then just go to them to do practicals instead of going up and down. wasting petrol and polluting the environment.
Q: Okay, and how did you guys adapt your way of teaching at WESSA when it comes to trainings?
SS: So, what I was doing was recording my presentation. So, I would sit in my office and present as if I'm presenting to people while recording my presentation. And I'll just share with the people that should be attending. So, it wasn't a live presentation like what I did at UKZN was training teachers which was meant to be a field excursion. But had had a virtual one, where I went to the field, captured everything on video. Then I came to the office, put all that together, made a PowerPoint presentation explaining what was happening in the video. It felt so good knowing that they could Visit any venue in the comfort of their home.
NN: Interesting, how are the tools use following the training? Like after you've trained that group? Do they take away the tools with them? Or how are they used after?
SS: So they don't take away the tools. So we have different types of clients, for instance, we have some who come to our centre as they are just learning. We are we creating environmental awareness. So they don't really need to take tools, when they get to the schools they take back is knowledge. And then you have people that, for example, were from the Drakensberg. They came here to learn, so they could teach people in the in the respective areas. So they didn't take all the tools but information. Like they collect all the names of the tools so that when they get back, they can actually buy and start using them.

Individual interview: Participant 8
Q: Are you user or teacher of citizen science?
PV: A Teacher.
Q: When did you come across citizen science tools?
PV: Gee. I mean, I've been using miniSASS for maybe 20 years, how long has miniSASS been around?
NN: For a very long time.
PV: I have been using miniSASS for a long time, but I've been aware of and focusing on other citizen science for the last maybe 12 years, in much more detail. And then of course, I've done my doctoral thesis on this work.
Q: And then, where did you come across it was it through an organization or?
PV: so for miniSASS I learnt through WESSA, when I started working there. And then the rest of it, I went looking. It was just very interesting to me, so I started to look for different tools and so forth.
Q: And which of the tools do you use, and are confident in using?
PV: I can use miniSASS. And that little bench of, of tools, although I haven't used them in a few years, but I'm familiar with a lot of the digital platforms, including the ones that aren't around anymore. So, I used to be quite familiar with iSpot, and help other people to use; project Noah, iNaturalist, a lot of those kinds of projects. But although I haven't used a lot of tools myself, I've worked with more than 50 citizen science projects in the country to learn about how they use their tools.
Q: How did you learn about the tools themselves? But it wasn't practical or more theory based?
PV: A mixture of the two, but probably more theory-based.
Q: Which did you find most effective as a teacher and also as a user?
PV: I think the important thing to note is that the citizen science work I do isn't limited to the water sector. So, I can't really give you a comparison because the tools do different things in different types of projects, right. So, yeah, but maybe I can say that what I've seen across all the projects is that the learning and the usefulness of the tools increases, if the citizen scientists understand the science, even at a basic level, and if they are able to interpret results, even at a basic level. So, the more that tools, invite participation and understanding, the better the tools do in the field for creating change. So, a lot of the university-based projects just want the citizen scientists to collect data. They don't really teach them how the science works, or how the understanding works, how the analysis works, they just focus on teaching them how to read, to collect data, and that that is a lot less effective, profoundly less effective. Whereas the tools that are part of a program of learning where they help people to understand this is why the tool works. This is why we do this to test that, you know, you kind of teach them the system of science that's around the tool, and then how to create meaning out of the data that is much more profound in terms of learning in terms of change in terms of dealing with environmental risks, in terms of building confidence.
Q: what do you think was the impact of COVID-19 On citizen science learning? Since a lot of it is dependent on hands on training in-person teaching?

PV: Look, I think when we part of formal citizen science institutions, like the sort of formal spaces of doing citizen science. It can become very easy to forget that people have been doing citizen science longer than science itself has existed. The formality of science is actually quite recent, it's not very old. And this idea of who a scientist is, is not very old, either. It's quite a modern idea. And so just because we have formal scientific institutions and formal scientists, and formal citizen science doesn't mean the other type of citizen sciences disappeared, it just means that there are these different approaches. And I think that a lot of citizen science, a lot of citizen scientists, get involved in citizen science because they really care about something going wrong in their environment, in their communities, in the places that they care about. And so, they find ways to try and fix that problem. And one of the ways that they try to do that is through citizen science, because having scientific data helps, it helps to get other people to understand what they're concerned about. So, I think that a lot of the formal citizen science work came to a halt. I think a lot of the informal work did as well, but maybe not as much. Because they they're not really dependent on institutions or, funding systems and things like that. They are just people in communities who are used to mobilizing whatever resources they can and working at the levels that they can. And so, I think whatever work was still possible to do in that informal space, probably still carried on, although the formal space slowed down quite a lot. Yeah, but I mean, I also don't think that stopped, right, the Amanzi Ethu Nobuntu project was born out of work that we were doing during the lockdown, rather than before the lockdown. So, yeah, I don't know. It'll be interesting to see. But I think what probably happened is that there was a reflective moment, because we couldn't be out in the field doing things a lot of projects probably did more careful reflective work and tried to think about their work and evaluate, you know, going forward.

NS: I agree, because most of the teams you worked with in Amanzi Ethu Nobuntu while I was at DUCT, they in very remote places, and you can't get to everyone to train them like in person. So it's challenging, especially do COVID.

Q: Yeah. So and then the last question, because you mentioned that you are familiar with citizen science more so like iNaturalist and iSpot which I've heard of iNaturalist not iSpot so I'm assuming they are like digital platforms?

PV: So iSpot used to be the main one that we used in the country. Before iNaturalist which is now the main one that SANBI and a number of other institutions are using now. but because iSpot couldn't cope with the numbers, so I think the system just disintegrated. But it was for a few years that iSpot was the one that SANBI and so forth were using.

Q: So, my question is we are kind of battling, and tend to use the word remote and learning because we can't rely on online only, especially for rural communities that are located quite far. What do you think is the best approach especially looking at the 4th Industrial Revolution (4IR) and trying to get everyone involved in citizen science work when it comes to teaching citizen science remotely or using digital platforms?

PV: So I'm probably quite a contentious person to ask this question. I don't believe in a one size fits all citizens science. And I think if we get the ethics right, we will get better citizen science. And I think most citizen science projects, especially the former ones don't focus on that. They're very focused on getting their data. And you know, the things that the project managers want to achieve in the world. But this is our shared world. And in South Africa, we already know that there are very problematic views between people who are educated and people who are not, between privileged, or previously privileged, or, you know, including our racial dynamics. And I think we need to remember that the world belongs to everybody. And that everybody has a piece of the puzzle to help us to solve the challenges that we've created together. And so, we can try and convert the world and teach everybody about our version of citizen science and what we think needs to be done. Or we can figure it out together and say, we have this piece, which pieces do you have, bring your pieces, and let's see what we can do together. And we can realize that people have different priorities. People may very much want to help, and to be part of something like citizen science. But they can only do it in the context that they're able too. If they don't have somebody to take care of their children, or an income or access to transport, then expecting them to be part of a particular type of citizen science actually perpetuates injustice, it makes the old injustice as present in a new form. And so, if we're talking about deep rural areas, I think the first place to start is to figure out how to invite people's knowledge as they've been living in those areas with their rivers and the streams and the oceans for many generations. These are modern problems that citizen scientists trying to resolve, but those people have wisdom. They have ways of protecting their rivers, they have an understanding of their water systems, their ecologies, and they might not have a scientific explanation. But they've got pieces that are meaningful for them. And if they have a chance to use those pieces, in conjunction with the science. Well, my research has shown that you make much better citizen science when you do that. And also, then you invite people into their own stories, you don't use them for your story. And I'm not saying that citizen science is about using other people. I know that most citizen scientists very caring, and people are very committed and passionate. But we're committed and passionate in a very colonial way. It's a very modernist colonial way that sees science as the rescuer of people when in fact, those people have been living there in much healthier conditions before science arrived. You know, science is one part of the story. And so if we are looking at working with people, digitally or otherwise, I think that that is, firstly, it's a basic justice. It's basic, we want people to care about what we care about. The least we can do is care about what they care about. We want people to help us build knowledge that we can use, the least we can do is make sure they can use that knowledge too for themselves. You know, that's only right. That's only basic. When we're scientists, we understand that you know. You said you read my paper good, don't plagiarize me, you understand today what it means to plagiarize. But we don't extend that to non-scientist. We don't extend that to people who maybe struggle with the formality or the rationality of science. But they know things. They've kept themselves alive and their children and they know stuff. So I don't know if that's more philosophical than you need. But it's backed up by case studies. I did my PhD and there's good evidence there to show that we get stronger science, and we get stronger knowledge, when we work with different types of knowledges. And when we strengthen the justice of how we work together, rather than focusing on getting as good a quality clean a set of data as we can. Because our problems are caused by the way we live together, they're not caused by how clean our data is. If we live together better, we can make better knowledge.

Individual interviews: Participant 9
Q: Thanks for coming to chat to me today, I have a few questions for you about how you learnt about citizen science. When did you first start learning about cs?
JC: Ya, no problem. It was in about 2011 or 2012? I started when I was working for MMEP (Midlands Meander Education Programme) and we learnt with WESSA, Umngeni Valley, and then later with GroundTruth. We first learnt about miniSASS at WESSA, and they ran a couple of courses, you know, the EETDP in environmental education, you know that 5-day course, and then I mean, it was it was a big thing, I got to work with Mark Graham and the others filming on the Umngeni river. I was involved with that, and then I did miniSASS with the schools that we worked with. Mostly with Bambanani, in the Drakensberg, they were the most involved, but also the other schools that did Water Explorers.
Q: I remember you being very concerned that the way you learnt about miniSASS.
JC: Yes, yes , yes. We had been doing it very superficially. When we did the filming with Mark then we found out that we had not been doing it right. That film thing, he was very specific about the areas that needed to be sampled. When we learnt from the guys at WESSA, they didn't show us how to sample the different habitats and how to time it correctly, all different areas that we needed to be sampled and stuff.
Ya, ya, so ya, we did it with MMEP and then obviously with EcoSchools and it was really good learning how to do it properly from GroundTruth. I have all the videos from GroundTruth, and I used those more than once to make sure I know what I was doing, I went back to them often. I don't think you can be sure of how to do miniSASS after just one lesson. It takes lots of practice, especially to get the ID right.
Q: So after you had had that detailed training do you feel more confident to do the sampling on your own, and to teach others to do it?
JC: Ya, I had had lots of practice, and I can now identify the different mayflies and things, crabs and shrimps are obviously easy, but the other things can be more difficult, and it takes practice to know that you are getting it right. I still need more practice because I haven't done it in a while now – out of action, you know, being a mom and everything. It wasn't easy at first, but it got better.
Q: How do you teach citizen science? What have you found works best for you?
JC: Well definitely the hands-on demonstration part. Kids need to do the activity, you can't just talk about it. We play the miniSASS game before going to the river, that really helps too because once you are at the river it is difficult for the kids to concentrate, they get distracted quickly and don't listen to the whole process.
Q: And, which tools do you use the most? Do you only focus on miniSASS, or do you use other things as well?
I haven't really used the velocity plank, the clarity tube, yes, but not the velocity plank. It doesn't make a lot of sense to me, I'm not sure what it's for. It's difficult to use in a big group, and I don't have one myself, so I don't use it with the schools. I just found it quite difficult getting one and it requires a lot of calculation. The clarity tube is easy to explain to others, it just makes sense. I have a clarity tube of my own.
Q: And then, do you use any other types of citizen science tools besides the miniSASS, and clarity tube?
I have used iNaturalist, but I use that personally, not really with schools or anything like that, ya. Besides that not much else. It's not a peer-reviewed process, so I'm never sure if the IDs are correct.
Q: And in terms of the data generated from these citizen science tools in South Africa, how well do you think it is used? Does it reach its potential in terms of governance?
I'm not sure. I haven't really seen any examples of what its used for. I'm not sure about the verification process, it might have changed, abut I haven't done miniSASS now for a while, but it used to take some time to get your results approved on the miniSASS website. I was also not sure about how they verify results. I mean, I'm pretty sure of how I ID the invertebrates, but even I can make a mistake, with Stoneflies sometimes the school contacts me and says they have found a Stonefly, but I know it's impossible. I'm not sure how that is controlled. It doesn't seem that it is used for reporting like it could be.

Second Round of interviews

Individual Interviews: Participant 10

Q: What was your experience with citizen science? What digital innovations have you used?

LS: When I used field survey for the first time it wasn't that difficult as I had to follow instructions given by the teacher – so it was easy

Field survey is very different from the current app were using and the one used in AEN. I didn't have challenges with the old one but the one being used by AEN is quite challenging as we can't see some of the data we upload form the back end.

Q: How can you make it easier for the users?

LS: We can improve the field survey training by having a trainer who will have an in-person session with the participants and explain step by step on how to use the App whilst allowing for the participants to ask questions for clarity. There also needs to be allocated time within the training for the participants to get used to the App and aren't rushed through the learning process. This will give them time to ask if there's something they don't understand.

The training process also needs to be repetitive, not once off as this can deprive participants of understanding how the app fully works.

The trainer also demonstrated to us how to use the App using practical examples, In which we had to go into the field and record the activity that was occurring there into the App. This helped us learn how to use the App effectively.

When teaching tools such as the Field Survey App, in person training is better than (over the phone/ online) training. There needs to be in field practical demonstration of the App for one to learn.

Individual interviews: Participant 11

Q: What was your experience with citizen science? What digital innovations have you used?

PV: I was already familiar with the field survey app when I started using it.

Q: How can you make it easier for the users? What can be impro

PV: To improve the trainings, it would be useful to have follow up refresher sessions monthly to check if people still understand and know how to use the app. It would also be useful in future that in person trainings are not conducted in large groups, as this can cause some individuals to be left behind as people don't learn at the same rate. Some individuals may be afraid to ask questions as well in such environments. We also gave them resource such as WhatsApp videos to give them refreshers when they forget to use the App.

People aren't attentive during training – so they miss some of the steps in the training process. So, there is usually people who still battle using the App as time goes on. We provide resources but people don't take the trainings more seriously.

Have more in person trainings with individuals where they are given context of where they are geographically.

There needs to be more encouragement given to individuals to collect data – to reward them for their work.

Individual interviews: Participant 12

Q:What has your experience been with citizen science (CS) training?

SV: CS training that was conducted throughout DUCT as an organisation was relatively quite good. Especially in the schools programme that they previously had. Training was easier with school kids as they were more receptive. The training was extensive and done very well – with the DUCT teams being receptive with what they were bring taught. The follow up post the training was very poor which led to poor pick up and understanding of the CS tools.

Q: What digital innovations have emerged whilst you have been involved with citizen science?

SV: People saw the relevance of using the FieldSurvey app – as it shifted from a paper format to a digital one. This bridged the gap of the data collection method. The training and tool itself was quite easy to use and adapt to. It took one of the senior staff 3 months to get used to using the tool which attests to the fast pick up of it. Additionally, using FieldSurvey onsite during training helped the EnviroChamps learn it. Retraining(repetition) and allowing the EnviroChamps to view the backend was key in the training to help them to learn the tool.

With AEN, the numbers were bigger in terms of training – and the training was carried out quite well and there were consistent follow ups. Also, there were WhatsApp videos that demo'ed how to use the App. DUCT was one of the most successful orgs when it comes to using the tool and data collection. The quality of the data collected was poor – but there needed to be follow up and monitoring. So the sinking in of how to use the App was not successful.

So in terms of experiences and conducting training for the app, what I had mentioned was that it was quite a journey, especially in terms of it's different forms, especially with the original sort of filled survey, around pollution monitoring. And being able to use it for that specific purpose. We're virus more in contacts, learning by doing type of practical work. And then, which was I think, very much well received by like the monitors and the work that we did. And then moving into a space now where we had a greater number of our champs, permission monitors. And then we had to diversify things a bit, it wasn't feasible to have contact sessions in terms of carrying out that specific training. So we had to sort of improvise in terms of how that was. And it came through that sort of remote WhatsApp learning or training with delivery components. But I'd have to say that it came well before AEN because I remember us being able to implement that sort of training, but it was usually for, like ad hoc, problem solving, or troubleshooting when certain individuals were using the app are faced with difficulties in terms of using it or there was something wrong, whereby it just started simply with a screen grab and posting on WhatsApp and then either reply in the form of posting it via WhatsApp as well. And then sort of writing an explanation in terms of how things should be done. Or it being like a screen recording that actually just shows the step by step process, with whatever issue you're faced with using the app. And then either that, or even picking up the phone calling and talking and walking through a person through the process of these that specific issue. And this is how you should actually solve it. So the I think it was that sort of movement experience, I think they said it was good. And then with Amanda, it's no one clue. The numbers are larger, rather than feasible to do contact sessions as much. But I think then WhatsApp provided the platform at which point we could sort of do the training remotely, but it also was largely dependent on individuals wanting to sort of engage with content itself. So yeah, that also we found to be very effective, even though it's one might think it's quite easy in terms of being able to put together demoted, those screen recordings, but it actually takes quite some amount of time and demands for you to be quite meticulous with regards to that process. So I sort of said, In my previous clip, it's sort of like being a playwright or acting, whereby if you miss up one line, you need to start all over again. And we'll say it was the same with this as well, whereby if you weren't able to capture or fully sort of put through what you're recording on the screen recording, it has to start over again, whether it was a matter of you being tongue tied or forgetting a specific step, because you had to literally document the step by step process in terms of the training. So yeah, we find ourselves doing many takes for that positive as well as that it was carried out in vernacular nice Zulu. So there was a great deal of understanding with regards to using the application and executing whatever needed to be executed. Yeah. So I think that was the experience in terms of conducting the training using the field survey app and the transformation that moved from more in contact sessions to more remote training sessions. Thanks.

Q: What challenges did you face when training people in citizen science?

SV: I think the challenge was the swelling up of numbers, especially in terms of people that needed to be trained on the usage of the app. I remember in phase one, it was quite a process. I think what I remember was when we did that induction, or tried during the induction, I think it was like 80 Plus. It advice or tips in one community hall embody and how sort of how much of a difficult process that was in terms of trying to carry it out, like hotspotting. I remember, it was like, I think one of the prerequisites of people for that first phase of them being a part of the program was at that smartphones, and they had them that put their smartphones and they were all in the hall. And we had this projector and we tried predicting screen, but then too many people and they couldn't see what was being done. And you had to walk people through and we had like, literally, it was like a massive onboarding. With the little stuff that we had, we didn't have the unfortunately, there wasn't the luxury of amends it to crew that was in phase two. So we had to do that ourselves. Just remember the difficulties in terms of that, getting people to download the app. And then the issues that arose from that in terms of some phones not being compatible data. Your what were some other things data, some issues that one couldn't find an answer to in terms of why it wasn't responding to certain things. And so it was more of like a technical matter that I think the developers of the app themselves had to deal with. So we're sort of stranded in terms of that process in terms of trying to find out what needed to be done, what was missing. And so I think it just brought about that element of like, difficulty in terms of the training, but I think as much as it was a challenge, I think it was an eye opener in terms of the issues and the facts of how difficult it is to actually upscale something of that magnitude to write the numbers, I think, was more manageable with a smaller number. But larger numbers, it was quite difficult to actually try to implement and actually just upscale in terms of usage, wide scale usage of the application. So those are the main challenges in terms of trying to carry out the training. And then there was that constant sort of issue of people get lagging behind in terms of what was going on, because their phones were the issue. And so they had to look on other people's devices to see what was going on. And yeah, so that's gave us those issues, which then popped up the idea of just creating was trying to communicate and engage with them remotely using WhatsApp which also itself, had its pros and cons that I think it had more pros and cons. Yeah, I think that was a major sort of challenge. In terms of the tools of the trade, the application was fine in terms of what it could do. But the tools of the trade being a compatibility of the phones, and was really difficult to answer. Because then the training was ineffective. The tool was actually not functioning in a manner that is supposed to function. People had to learn by doing and if they couldn't learn by doing there was no way they're gonna learn. So those are the issues in regard To the challenges in training, I'm just trying to think of other challenges. Yeah, other than the competitively cell phones and a constant data sort of issue that was a greater part of program, and I think the whole lifecycle of the app as a whole. If people were actually given monies to buy data, it would still be an issue in terms of them properly using it. So I think that was like the major one, but I think overall those are the major challenges with actually conducting the training.

Individual interviews: Participant 13

Q: You have looked at the manuals of the citizen science tools, and the full suite of tools that were put together by Jim and Mark?

TN: that is true

Q: And what are your thoughts on those tools? Are they easily accessible, and understandable to all the people that you have worked with and needed to train?

TN: The tools can be easy to use once you understand them and have worked with them for a while. Initially they can be a bit complex. As Rovers, one of our tasks were to re-write the manuals for the Clarity Tube, Velocity plank, and the miniSASS. We had to read the manuals first, and even we had some difficulty understanding them, and we all have degrees. The language is very technical. I have looked at the other tools too, and I think that they are all very technical. You need to have had experience in those areas to really be able to pick up the manual and use it without someone training you.

Q: How did the Enviro-champs manage with the tools after they had received training?

TN: it depended on the team, some started collecting data, and did it well, other teams still struggled, and we had to organise re-training for them. Some teams needed constant support.

Q: And once you had re-trained those that needed extra help?

TN: Then they were much more confident in how they applied the tools, and they made less mistakes. The re-training was very effective, and it was good to let them have some time to practice with the tools first.

Individual interviews: Participant 14

Q: You have been using the citizen science tools for a long time now?

CR: Yes, the first time I used miniSASS was in 2007 when I started working at Umgeni Valley. I've used most of the tools in the WRC toolbox over the years, except the Spring tool and the Estuary tool.

Q: As a regular user of the Enviro-picture building tool what is you feedback on it?

CR: I have used this tool with pre-school children, learners from all grades including matric, varsity students, young adults, and even senior citizens. The detail in the picture lets the person looking at it make their own understanding, and I have used it to build on what they know, challenge their thinking, and deepen my own understanding of issues from their perspectives. It is a prized possession in my set of teaching resources, I don't think I could run a workshop without it.

Q: Are there any changes you would make to the Spring tool to adapt it for online learning?

CR: The tool would work well when using it with an app like ODK, the questions are logical and done in a step-by-step manner, which would be easy to set up on the app.

Q: You worked closely with the graduates, the "River Rovers" and "Data Detectives" during the Amanzi Ethu Nobuntu Project?

CR: *Yes, I was responsible for training them, and mentored them through their work in training EnviroChamps for the phase 2 of the project.*

Q: What tools did you train them to use?

CR: Their work focused on the clarity tube, the velocity plank, and miniSASS. They took quickly to using the clarity tube, it's quite straight forward to understand, and with some practice were able to understand miniSASS, but they all struggled with the velocity plank.

Q: Why do you think they struggled with it so much?

CR: I think it's mostly the calculations involved, and perhaps that they did not really understand why the tool is important, what kind of data it gives? With clarity tube and miniSASS it's so much more tangible – you can see immediately what the tool is trying to tell you.

Individual interviews: Participant 15

Q: What has your experience been with miniSASS? What potential do you see in digital innovation for the tool?

NP: MiniSASS samples the macroinvertebrate community along a river / stream reach and calculates a water quality / stream health score based on the sensitivities and tolerances of the taxa present (identified to Order-level groupings allowing for easy identification by citizen scientists). MiniSASS is now being explored for countries to use for reporting on the Sustainable Development Goals (SDGs), particularly SDG 6.3.2. and SDG 6b (see https://www.unwater.org/publications/progress-on-ambient-water-quality-632-2021-update/).

As miniSASS currently stands, the accuracy and usefulness of a survey relies heavily on the accurate identification of macroinvertebrates to Order (or Order-level groupings) level by minimally trained citizen scientists. This leaves potential for errors in identification which may impact the accuracy of miniSASS results and ultimately of the river / stream health assessment. To combat this, GroundTruth is working in partnership with CGIAR, the International Water Management Institute (IWMI), and AWS on development of a smartphone application (app) with built in machine-learning (ML) for identification of macroinvertebrates. The app will perform all the normal tasks of capturing information during a miniSASS survey, including taking photos of the sample site, gathering user information, location data, inputting sampling information, and generating (automatically) a miniSASS score. However, the app will also use ML to analyse smartphone images of macroinvertebrates sampled during the miniSASS survey, and provide real-time, precise and geolocated identifications. This will increase the objective accuracy of a miniSASS assessment, ease-of-use, and improve global applicability. These photos will also be stored in open-access databases such as the Freshwater Biodiversity Information System (FBIS) for further use internationally for demographic assessments. Building on the app developments, the miniSASS website (minisass.org) is also being streamlined and modernised to improve data hosting, visualisation, and to interface directly with the miniSASS app.

Individual interviews: Participant 16

Q: You are familiar with the RHA and Spring tool, is there anything you think could be improved for either of those tools?

LH: I don't think there is any modification that needs to be done with both RHA and Spring tool, RHA focuses on the variety of impacts that influences the flow of water in our river system and most tools focuses on a single aspect. The only downfall is that both tools are not wildly spread like the miniSASS and clarity tube and the only limitation on the RHA is that whoever uses it need to read the (Braid, S. 2014. Tools to Determine Enforcement Driven Rehabilitation Objectives on Urban River Reaches-Guideline Document, Water Research Commission, South Africa. Report No: TT594/14), which help with background info and to clearly understand the tool, but this document is not easily accessible to everyone.

Individual Interview: Participant 17

Q: As an Estuarine ecologist, we know that you are familiar with the ecological assessment of estuaries, you are also aware of the citizen science estuary tool. What is your opinion of the effectiveness of the tool, and how could it be changed?

CM: Firstly, the Estuary Background document is unfortunately outdated. A lot of work has been done since the tool was put together by Dr Taylor. For example, our estuary ecosystem classification has changed, and instead of five estuarine types, we now have nine, with a further 3 categories for micro-estuaries! Also, the key buzz word today in the current legislation is the estuarine functional zone, which is critical and is not in the document. The rest of the document is wonderfully comprehensive! It was a great read!

Secondly, the toolkit is quite advanced – speaking about measuring volume of the estuary, volume exchanged and even slope of the beach. I think this is something we touched on a university (!!) Personally, when I'm in the field, I go equipped with field instruments, databases and maps. The water quality probe measures all the general phys-chem. I do not measure beach slope, but this is certainly a useful exercise for budding coastal engineers. I do make copious field observations, covering most of what is mentioned, e.g. flows, vegetation, animal species, depositional areas, erosive areas, including flood and ebb tide deltas, beach dynamics, interferences and modifications, pollution impacts, etc. So, this is all good information. As Dr Taylor states upfront, one should choose a limited number of activities and do those well; because there is a LOT of information covered in this toolkit. The toolkit speaks about measuring the volume and that requires evenly spaced depth measurements across an estuary – this is quite difficult for the average person to do and these days I wouldn't want any child or unexperienced person wading across our impacted estuaries.

I feel that the toolkit is perhaps a bit thin on the faunal aspects. These are things that people can actually see, and it would be good to help them to actually do this activity. Yet this would be something quite difficult to narrow down because there is such a diversity of faunal groups and diversity of habitats. The toolkit doesn't even mention possible ways of sampling different animals…e g. a prawn pump, or netting of fish, or bird watching on exposed banks. I think this could be improved/added to.

Dr Ricky Taylor is a stalwart in the field of estuarine ecology. I don't believe I have much to add to this apart from the faunal aspects. I need to give it more thought.

Individual Interview: Participant 18

Q: How did you find the learning process on the Pluto platform, is there anything you would like Groundtruth to fix or add, to better your learning experience?

AK: I would say that my learning process went really well on Pluto. I would advise that once the Pluto App has been downloaded, it should be able to function without using data. Another thing that I would suggest is that there should be more videos than notes because we tend to understand more through demonstration rather than reading notes. In the miniSASS Tool, I would advise that more macro-organisms should be added on the dichotomous key, to provide more options.

Q: Which tool would you say you learnt the most about on the Pluto platform or which tool would you say we provided the most information for on Pluto?

AK: The miniSASS tool was the clearest tool for me because it made me understand the data collection process. Everybody was just participating when we used miniSASS. This is the tool that gave me satisfaction after analyzing the data, I really enjoyed working with this tool.

Q: If the GroundTruth team was not able to be present during the training rounds and you had to learn on your own via the Pluto platform, would you have been able to learn on your own or did our presence assist you to learn better about the tools?
AK: If the GroundTruth team did not come for in-contact sessions I wouldn't have been able to complete the task on my own, your presence made most of the things very clear for me, such as helping with the demonstrations for the tools. We also wouldn't have been able to plan and create the change project.
Q: How would you improve the Pluto platform so that anyone can learn better about the tools?
AK: I would add more videos on the app than notes because they are clearer. Also doing more practical activities will help understand the tools better.

Individual interview: Participant 19
Q: What suggestions do you have that might improve the PLUTO learning app?
KM: I think PLUTO will be much better if we didn't have to use data. And also, if we can enrol ourselves on PLUTO on any device and still continue where one left off.
Q: How can we improve PLUTO so that we do not have to do in-person trainings?
KM: MiniWET health has so many notes and one question. So, I think if you add more questions on the quiz then we would be able to learn more and verify the knowledge that we have.
Q: Did working in groups help you understand better?
KM: "Yes, working in groups helped a lot because when you don't understand something, at least there's someone else in the group who understands it better".
Q: Which activity helped you understand tools better?
KM: The change project helped a lot because we did it on our own while there were no facilitators. So, this proves that we really understood the tools.
Q: Do you think you would have been able to learn about the tools if there were no in-person sessions? Would you have been able to do all the activities on your own?
KM: "I think in-person sessions helped a lot; I don't think I would have understood as much as I do now. For example, I understood the water clarity tube better but if there were no in-person trainings I wouldn't have understood the E-coli test because there are so many things to consider like water measurements. Another example is the miniWET health had more videos than notes it would have been much better".
Q: Has the course benefited you in any way personally? Have you grown in confidence with regards to the tools?
KM: "Yes, it has helped me a lot because now I have gained a skill and I have grown in confidence with regards to public speaking, it was difficult to engage in groupwork. Also, if I would relocate to another place and come across these environmental concerns, I would be able to introduce these tools to help mitigate the problems".
Q: As you mentioned that you struggled with miniWET health, after it was explained to you, do you still find it difficult?
KM: "Yes, I still fail to understand it properly, even my groupmates find it a bit challenging. As a result, no one suggested that we include it in the change project".
Q: How was your experience with working on the PLUTO APP?
KM: At first, it was difficult, but I quickly adjusted because I'm familiar with online learning. But for the rest of the group, it was quite a struggle and as a result there are some people who ended up not having Pluto on their phones like Sizakele. But at the end of the course everyone was familiar with the APP. If someone didn't understand we would help each other as a group.

Individual interview: Participant 21
Q: How did you find the learning process on the Pluto platform, is there anything you would like GroundTruth to fix or add, to better your learning experience?
SS: The learning process went well, and I was able to complete the course, it was a great learning experience for me. With regards to what can be fixed or added, firstly the app should be more user friendly especially when using it for the first time after it has been downloaded, the sign-up steps must be minimal. Secondly, the video download option should be on the platform if possible and not take you to another site such as YouTube.
Q: Did being part of a group such as your change project team, assist your learning process about citizen science tools. If yes, how did it assist you?
SS: Being part of a group helped me a lot because there are some things that I may overlook or not understand if I am attempting to do the work on my own. When working as a group there are different opinions being shared and we can remind each other of what was said during the training. I would say it helped me that way, being able to get assistance from my group members and especially because we had a change project which required us to rely more on each other as compared to the facilitators. Although group work is challenging, there are benefits of being in a group.
Q: Which tool would you say you learnt the most about on the Pluto platform or which tool would you say we provided the most information for on Pluto?

SS: The MiniSASS tool had the most information, although I do not want to be biased because we used that tool for the change project, but it is the tool I was able to learn the most about.
Q: If the GroundTruth team was not able to be present during the training rounds and you had to learn on your own via the Pluto platform, would you have been able to learn on your own or did our presence assist you to learn better about the tools?
SS: I would have been able to learn on my own, however, there is a lot I would not have understood. Having the team there assisted by providing more context to what was being learnt and making what was being learnt make more sense, which I think would have taken longer if I had done it on my own, so having the team there was of great assistance.
Q: How would you improve the Pluto platform so that anyone can learn better about the tools?
SS: I would prefer to not have the option of downloading notes but rather be able to read them on the Pluto platform or rather have them as one document. Secondly, I would prefer the videos to be in-app.
Q: How would you improve your in person learning experience during the training rounds with the GroundTruth team?
SS: Having the facilitators practically demonstrate how the tools are supposed to be used, this would decrease the time it takes the learners to teach themselves in groups how to use the tools. Than that, the way the team approached the training assisted a lot with understanding what was going on.
Q: Which aspect of the training did you learn the most from?
SS: I learnt the most during in-person training and in groups. Although the Pluto platform provided the necessary information, the opportunity to learn more was when we did our change project, and I could do it practically.

Individual interview: Participant 20
Q: As a person who has recently left school, what has made you decide to be a part of this course?
NM: What made me gain interest in this course is because it focuses on nature, I did not do geography as a subject in high school although I liked it but the school, I went to did not have it as a subject. When I heard that there is a project coming up, I was interested to join.
Q: How did you find learning about citizen science tools on Pluto? If the GroundTruth team did not come to assist in person, do you think you would have been able to learn?
Based on the videos provided, I would have been able to learn from them.
Q: Did being part of a group, such as your change project group, help you in learning about the tools or if there were no groups formed you would have been able to learn either way?
NM: I would have been able to learn, nothing would have changed.
Q: Did being a part of a group, such as the change project group help you to learn, did you benefit in any way?
NM: It did help me learn better, for example I did not understand the MiniSass scoresheet but when I was working with my group, I learnt that I must follow arrows to identify which invertebrate we found.
Q: Is there anything that you think we should fix or add on the Pluto Platform? For example, miniWET-Health was the most difficult for me to understand. What would you say has to be done so that participants learn better about tools such as the miniWET-Health?
NM: Everything was clear to me; I do not think anything else needs to be added.
Q: What aspects on the Pluto platform worked well for you and assisted you to learn better?
NM: The videos. I like learning through visual learning and seeing something being done practically, I understand better.
Q: Has it changed how you feel about yourself at all, knowing these kinds of things?
NM: Yes, it has, it is not the same as before because I did not know anything regarding the course. Right now, I have valuable knowledge and am very eager.

10.3 APPENDIX C – CAPABILITY APPROACH

The capability approach by Amartya Sen, is a theory that is applicable across a variety of disciplines, which emphasises the importance of human development with the aim of creating economic and personal agency, as well as community wellbeing. Within economics, the capability theory, focuses on individual development and personal capacity building using resources such as wealth, income, and most importantly opportunities for personal development (Gasper, 2017). Sen argues that human development should not be dependent on economic growth, but rather empower humans to gain their own economic and personal agency which can afford them opportunities to make better choices and enhance their standard of living. He argues that “the usefulness of wealth lies in the things that it allows us to do” (Kuhumba, 2018 pg. 129). A large component of citizen science work is capacity building through training. Training in citizen science affords participants the opportunity to engage in accredited courses that serve to expand their scope and knowledge within the environmental science field. In this way, citizen science is recognised as facilitating a potential learning pathway, in which participants can capacitate themselves to access better economic opportunities in the future.

There are a variety of citizen science courses already available, and in the process of being developed, that could provide participants with these learning pathways. The diagram below (**Figure 10-1**) provides an example of a potential learning pathway.

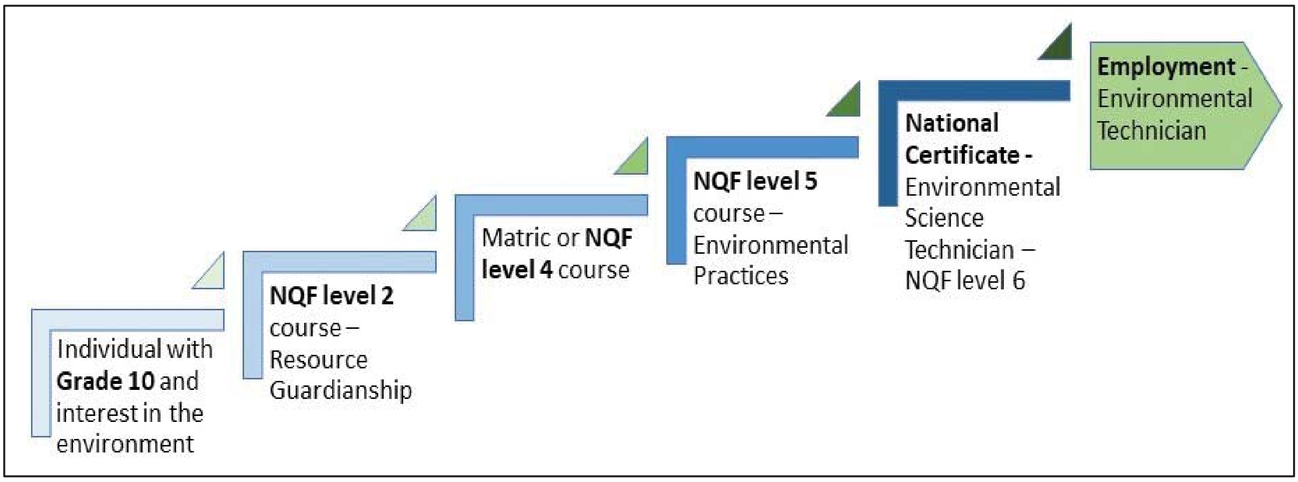

Figure 10-1: Flowchart showing learning pathway progression.

Some of the accredited courses participants could be exposed to include: SASS5; the miniSASS short course (currently non-accredited); Social Learning through Citizen Science (in the process of being accredited at NQF level 6 at Rhodes University) which are offered by GroundTruth. Other organisations, such as WESSA, provide a variety of courses at a NQF level 2 and 5. Most participants that engage with these courses, are able to access better work opportunities, which ultimately helps them afford a better quality of life. Thus, through the engagement with citizen science, they develop a stronger economic and personal agency.

10.4 APPENDIX D – FACTORS USED FOR THE MULTI-CRITERIA ANALYSIS

Factors Considered for the MCA

For the MCA analysis, the case study was selected by considering to the social, connectivity, environmental and water factors. The characteristics that were considered for each factor is listed below.

Social Factors

The social factors used to inform the MCA were selected based on the study's objectives. **Table 3-1** above provides a detailed overview of how the datasets for each theme were derived. The reasons for the selection of these factors are defined in detail below.

- **GenderFACTOR**: This factor was derived from the 2011 Census data from the percentage of males and females of the population for each ward. It was considered to follow the general government mandate of prioritising gender equality. This factor was derived by weighting the population percentage in each ward, 60% in favour of females and 40% for males.
- **RaceFACTOR**: This factor was created from the 2011 Census data and was generated by weighting the percentage of each Ward’s race factor. This factor was derived by weighting the population percentage in each Ward 30% in favour of the Black population and 10% for the other racial groups as 10% of this factor. This factor was included to address historical racial discrimination, which has led to inequalities in employment opportunities and basic services. The effects of this injustice still exist and affect the Black population the most. Despite the effort made by South Africa to close this gap, more needs to be done to achieve equal access to opportunities and basic services for all (Statistics South Africa, 2019).
- **%BlackFEMALEyouth**: The data for this factor was derived from the 2011 Census data and described the percentage of each ward’s population that is Black, female, and between the ages of 18 and 35 years of age. This demographic was included due to the inequalities that still exist due to gender discrimination engrained in the patriarchal societies in South Africa. Primarily in rural areas, women are still considered “less than” (Gibbons *et al*., 2017). Therefore, this factor is essential when looking at marginalised communities as an opportunity to capacitate them with skills that could provide learning pathways and create empowerment opportunities for this demographic.
- **PovertyRISKmedian**: The data for this factor was derived from calculating the median proportion of the population living under the Poverty Line. This level is considered as those living with less than R945 per month (Galal, 2022). Years after democracy, South Africa is still faced with poverty, which threatens the well-being of many of its citizens (Kehler, 2001). This factor was therefore important to consider as the opportunities provided through involvement in learning about citizen science could be used to address some of this inequality.
- **%Unemployed:** This factor was generated from the 2011 Census data and was calculated as a percentage of each ward that was not employed. This factor was considered due to the current challenge of a high unemployment rate still faced by South Africa (Graham *et al*., 2018). It is hoped that the outcomes of the broader study that this current research falls under will address this situation by initiating learning pathways that lead to employment within the water or environmental sector.
- **%YOUTHunemployment:** the youth unemployment factor was calculated as a percentage of people between 18 and 35 who were categorised as unemployed. This factor was considered in addition to the total unemployment factor for each ward, as it was felt that this was a specific demographic that the remote learning system would target when it was trialled. In South Africa, the youth is the most affected age group regarding unemployment. Despite the continued development of the South African economy, a lack of integrated policy design and implementation and cyclic poverty keep young people from disadvantaged socio-economic backgrounds from moving into the economic space (Graham *et al*., 2018). Involvement in citizen science could be an opportunity to address this, with this demographic especially.

AverageANNUALincome: The average annual income per household for each ward was extracted from the 2011 Census data. This factor is seen as an indication of poverty and risk and was thus included in the social factors for the MCA.

Connectivity Factors

These factors were important to consider as they indicate how well connected each ward's population is to the internet. As the remote learning system would potentially run through an online application or a communication application, such as WhatsApp, the participants would need some access to a smartphone and cellular networks. Many people in South Africa experience a lack of access to this type of technology. The broader study that this report formed part of aimed to develop a remote learning system that can work within these limitations. Therefore, the envisioned community needed to exhibit a lack of access to the internet and cellular technology.

Unfortunately, recent, widespread, reliable data of this nature was not readily available. Network connectivity data is restricted to major centres and road networks and does not give an accurate indication of what the access to the internet and cellular network companies are outside these regions. For the purposes of the MCA, the following layers were created to indicate the potential for connectivity across the whole province of KZN. However, it is recognised that this data may not reflect the true circumstances as they are currently[28]. To validate the extrapolations made from the use of these layers, an independent researcher based in the final selected community was interviewed; their observations of the level of connectivity were included in the description of the final community in an attempt to verify the assumption made in the extrapolation of the connectivity datasets. The study aimed to work within a community with limited access to technology and the internet, so those communities with lower access to phones and the internet were favoured in the prioritisation process.

- **%noPhone:** Data from the 2011 Census collated information regarding the number of households that had access to a telephone, either in their house, on their street, or within their neighbourhood. This factor is a percentage of households with no access to a telephone.
- **%internet access:** No data was available from the 2011 census on how many households had access to the internet at a ward level. However, data was available at a district level from the KwaZulu-Natal District statistics released in 2016. This data was extrapolated to the ward level to calculate the percentage of households that had access to the internet.

Water Factors

The citizen science tools that will be used in the remote learning system focus on the biomonitoring of the health of water systems (Rivers and Wetlands). As these systems are the focus of the citizen science applications that will be taught to the selected community, it was logical that the community selected to trial the learning system should face water issues of some kind. The water factors compiled for the MCA were derived from what was relevant from the 2011 Census data and the SANBI Strategic Water Source Areas (SWSAs) 2017 data. The following factors were included in the analysis:

- **%otherTOILETS:** This factor is the combined percentage of the total number of households per ward of all other types of toilets other than flushing toilets connected to a water-borne sewage system. It includes pit latrines, the bucket system, and those households with no toilet facilities. This factor was included as it was indicative of households that are possibly more “rurally situated” and those where sewerage systems could easily cause health hazards or local water pollution during floods.
- **WEIGHTEDwaterClimateRisk:** This dataset was created from the 2011 census using the data depicting the water source for each household. The sources of water were listed as either: municipal, borehole, rain tank, spring, dam, river or stream, water tanker, or vendor. Those factors that were most at risk of being affected by the potential changes due to Climate Change were weighted by a more significant proportion than those that would be least affected. The final “Weighted Water Climate Risk” factor indicates those communities whose water supply would potentially be most affected by Climate Change.

[28] Should data become available within the period of the broader study, these factors can be recalculated and updated for the final report.

- **totalPAWproportion:** The Plant Available Water (PAW) for each ward was calculated as a combined proportion of the PAW scores by the area they covered in each ward. This factor was included because it indicates how much water is available to plants for their growth and biomass production. Those areas with low PAW scores can be regarded as areas that experience a water risk, especially if the community relies on subsistence farming.
- **%NOaccessPIPEDwater:** the data for this layer was derived from the 2011 Census data. This dataset is the percentage of households in each ward that do not have access to piped water and rely on the water they need to fetch from a dam, river, stream, or spring. Communities that need to rely on these water sources are regarded as being at a higher risk of water shortages.

Environmental Factors

Certain environmental factors were included in the MCA; these datasets were derived from the data available from the NRM Working for Wetlands management programmes, SANBI databases, and KZN Ezemvelo data. The datasets that were deemed relevant to the MCA are listed below:

- **KFACTproportion:** K-Factor is a measure of the erodibility of the soil in a region. This layer was calculated from the K-Factor values for KwaZulu-Natal as a combined proportion of the area covered by each K-Factor in a ward (Schulze, 2007). This layer indicates how vulnerable each ward is to erosion, which would have an effect on the siltation of rivers, streams, dams, and wetlands in each ward. It would indicate the potential for environmental degradation in the region.
- **CBA%WARD:** The Critical Biodiversity Areas (CBA) dataset for KwaZulu-Natal was used to generate this layer (Driver *et al*., 2012). The CBA values for KwaZulu-Natal were used to calculate a median percentage relative to the area of each ward. This data shows how much of each ward is covered by a Critical Biodiversity Area, thus indicating its importance ecologically.
- **PRESENCEofPriorityWETLAND:** The list of Priority Wetlands was used to generate this layer (Van Deventer *et al*., 2018). The presence or absence of a Priority Wetland in each ward was recorded using a value of either 1 (present) or 0 (absent). The purpose of this layer was to indicate whether the ward contained a Priority Wetland.

10.5 APPENDIX E – WARDS WITH THE HIGHEST PRIORITISATION SCORES

Table 10-1: Wards with the highest 5% primary prioritisation score

Ranking	Ward identification number	Primary Prioritisation Score (Rounded off)
1	52502006	100
2	52701009	99
3	52701006	97
4	52701007	97
5	52601005	95
6	52701005	94
7	52306001	94
8	52701002	94
9	52101001	93
10	52101006	93
11	52701008	93
12	52101004	93
13	52806012	93
14	52606016	92
15	52606024	92
16	52701004	91
17	52402013	91
18	52606023	91
19	52606018	91
20	52802013	90
21	52103015	90
22	52103005	90
23	52702016	90
24	52103002	90
25	52103009	90
26	52801013	89
27	52101005	89
28	52205002	89
29	52205003	89
30	52605010	89
31	52103003	89
32	52402001	89
33	52806006	89
34	52306011	89
35	52806013	89
36	52305008	89
37	52502007	89

10.6 APPENDIX F – INTERVIEW WITH LOCAL RESEARCHER

1. What is your role in this project?

“My role in the project is to collect and capture data in the household surveys at SAEON”.

2. What are the most common socio-economic factors faced by the different communities/ wards represented by the dataset?

- *“Water shortages, the only way to get stable water supply is by getting a borehole and it costs R21 000 to install and only a few have the funds.*
- *High unemployment rates, for most of these communities where the tourism industry is not doing too well there are no job opportunities.*
- *Network or reception issues. Only a few areas in the whole area have good stable internet.”*

3. The questions below are based on the sections in the questionnaires (feel free to provide a summary of your findings, they don’t need to be specific):

   3a. Section B: What is the state of water supply in the communities/wards represented by the datasets?

“So, people don't have water. They have taps provided by the municipality, but others haven't had water in those taps in over 10 years. Those who do still get water from taps get them maybe once in 3 weeks sometimes 6 months. Other people get water from streams or springs—those who still have them. And those who can afford install boreholes and that's the only way to have a stable water supply”.

   3b. Section C: What is the state of household income in the dataset represented by the communities?

“I mean it's poor. Most people are dependent on pension and child support grants for a stable income and then some get their income from craft and cultivation. But it's not a lot of money”.

   3c. Section E: What is the current state of climatic conditions of the ULM area?

“They get very little rainfall, and it gets really hot in summer. All their problems come from the change in their climate. They used to get a lot of rain in the past, but in the recent 20 or so years, they have been struggling with rainfall and hence they have water issues, wetlands and springs drying up and all that”.

10.7 APPENDIX G – PRELIMINARY HOUSEHOLD SURVEY DATA

Preliminary Analyses of MCP Household Data

Note: the results contained are estimates from the WRC project: C2020/2021-00430 "advancing water and income security in the unique Maputaland coastal plain: a strategic decision-support tool to explore land-use impacts under a changing climate". This information provides the best estimates for selected indicators. Results might slightly change in the future with more information captured and the data cleaned. The data was collected in communities within and close to the lake Sibaya catchment area; Mabasa (Ward 5, 9, 15 and 24), Zikhali (Ward 2, 3, 8 and 19) and Tembe (Ward 5 and 8) traditional. **Table 10-2** shows how households (HH) in different communities' access water. HH water supply refers to states of water security in HHs, thus 66% of HHs in Mabasa are able to access some form of water. The same applies to Zikhali, and Tembe.

Table 10-2: Household Water Access and Supply

Primary Water Source	Mabasa *n=82*	Zikhali *n=78*	Tembe *n=63*
Rainfall	9	7	1
Borehole	17	23	21
Piped water	42	13	19
Wells	0	1	2
Neighbour's borehole	5	16	1
River	5	4	0
Lake	0	8	15
Spring	0	1	3
Buys Them	1	5	0
Communal infrastructure (borehole and Tanks)	3	0	0
HH water supply?	66%	66%	50%

HH's total average yearly income by ward is shown below (**Table 10-3**). These are weighted averages to ensure better estimates and it is easier to work with annual figures, especially in dealing with economic indicators, which monthly income can be derived from.

Table 10-3: HH Total average yearly income

Mabasa		Zikhali		Tembe	
Ward	***Average Income Per Year***	***Ward***	***Average Income Per Year***	***Ward***	***Average Income Per Year***
5	R38 547.00	2	R29 352.00	5	R29 760.00
9	R23 760.00	3	R37 808.00	8	R39 030.00
15	R38 160.00	8	R36 468.00		
19	R39 871.00	19	R36 936.00		
24	R11 520.00				

The National poverty line is R945.00 per month (as of 2021), this works out at R11 340.00 per individual. The results shown above are for households, not individuals which means that most of these incomes would be used to support two or more individuals. The data does not reflect how many people occupy a household, on average.

Table 10-4, presents different ways HHs generate income. The values are in percentages explaining how much of the sampled population generates income from these sources. For example, 73% of HHs in Mabasa indicate that they receive grants and 4% generate income from selling craft work. Employment was omitted because it requires intense data cleaning and validation.

Table 10-4 Sources of Income

Sources of income	Mabasa	Zikhali	Tembe
Grants	73%	60%	75%
Cultivation	15%	13%	10%
Craft	4%	29%	22%
livestock	7%	1%	11%
Medicinal Plants	9%	3%	0%
Natural Resources (wine, marula, etc.)	2%	1%	3%
Forestry	1%	9%	8%

Table 10-5 presents employment rate figures by ward and tribal area. For example, the results for Ward 5 in Mabasa shows that 22% of surveyed HHs indicated that they at least have a family member who is working and the overall employment rate in Mabasa is 36%. A Family member refers to a person who spends 5 days or more in the household per week.

Table 10-5 HHs Employment Statistics

Ward	Mabasa	Zikhali	Tembe
2		11%	
3		16%	
5	22%		5%
8		16%	37%
9	4%		
15	7%		
19	2%	5%	
24	1%		
HH Employment rate	36%	48%	42%

Table 10-5 presents a table on how HHs view their food security status by ward and tribal area. In the Mabasa area under ward 5, 24% of HHs are food insecure. This is exacerbated by the changing climate. Further data on this is currently being collected and requires intensive cleaning. This data can be shared at a point in future if requested.

Table 10-6 HHs Food Security Status

Ward	Mabasa	Zikhali	Tembe
2		13%	
3		33%	
5	24%		17%
8		17%	11%
9	46%		
15	25%		
19	44%	25%	
24	0		

10.8 APPENDIX H – LETTER OF PERMISSION FROM THE MABASA TRIBAL COUNCIL

MABASA TRADITIONAL COUNCIL

INKOSI K.T.H NXUMALO

Enquiries: Miss B.S Thwala | Telephone: 0814492387 | Private Bag: P.O. Box 2
Navrae: | Telefone | Privaat Sak: Mbazwana
Imibuzo: | Ucingo | Isikhwama: 3974

February 2023

To: GroundTruth team (Gugulethu Tshabalala, Nkosi Sithole, and Charlene Russell)
From: Inkosi Nxumalo, Mabasa Tribal Council

<u>**Re: Permission for the participation of 10 community members from the Mabasa Royal House**</u>

Pertaining to a GroundTruth project in collaboration with the Water Research Commission (WRC): this serves to confirm that the GroundTruth team introduced the GroundTruth/WRC Online citizen Science Learning Programme project to the Mabasa Traditional Council on the 13th of February 2023. It is understood that the GroundTruth team will be piloting a learning platform for citizen science training with 10 community members of the Mabasa community.

Thus, in response to a request letter dated 13 February 2023, after due consideration the Mabasa Tribal council, under the authority of Inkosi Nxumalo grants permission for GroundTruth to:

1. Pilot a citizen science learning platform with 10 community members of the Mabasa community; and
2. Conduct follow-up interviews, focus group sessions and observation of the training for evaluation of the citizen science training.

The GroundTruth led research project, funded by WRC, recognizes the impact COVID-19 has had on citizen science learning and training in the field of water resource management. This has led to a reduction in data collection and training in the past two years, which has proven just how urgent different thinking about the role of citizen scientists post COVID-19. By harnessing the benefits of technology, training in citizen science can be enhanced and extended to reach more people, as well as those marginalized due to their location, socio-economic background, access to education, and access to online technology. To address these challenges, the project has developed a remote learning platform to support the citizen science training of communities faced with challenges in network connectivity and internet access. Through the piloting of this learning platform with the 10 participants, the participants will have an opportunity to learn about biomonitoring tools to assess the health of their local water systems, increase their knowledge and understanding of citizen science, translate the meaning of the citizen science data and what to do with it once it has been collected. Ultimately, the project hopes to empower citizens by increasing their scientific knowledge.

10.9 APPENDIX I – COURSE ADVERTISEMENT

Advertisement for the Training Course that was circulated within the Tribal regions

GroundTruth
Water, Wetlands and Environmental Engineering

WATER RESEARCH COMMISSION

SHORT COURSE:
CITIZEN SCIENCE TRAINING
May to July 2023

Left: Application of the Velocity Plank to measure stream velocity. Top right: Demonstration of Clarity Tube to school children. Bottom right: Rovers identifying macro invertebrate from the miniSASS sample.

Course overview

The GroundTruth led research project, funded by WRC, recognizes that by harnessing the benefits of technology, training in citizen science can be enhanced and extended to reach more people, like those marginalized due to their location, socio-economic background, access to education, and access to online technology. To address challenges of network connectivity and internet access, the project has developed a remote learning platform to support the citizen science training of communities. Through the piloting of this learning platform with the 10 participants, the participants will have an opportunity increase their knowledge of citizen science and learn about biomonitoring tools to assess the health of their local water systems.

The piloting of the learning platform will follow a 4-part training that will take place as interactive in-person and online sessions over a 3-month period. The sessions will be run by two facilitators from the GroundTruth team. The training will include follow-up assessments after each session.

Minimum requirements:

- Must have a Matric (Grade 12) certificate,
- Must be able to read and write (isiZulu and/or English),
- Must be able to operate and have access to a smartphone (you do not have to have one of your own),
- and be willing to learn.

Ideal attributes:

- lives within walking distance of a wetland or stream,
- Advantageous to have an interest in the environment.

Please note that the successful candidates will not receive any monetary retribution for their time.

Please submit your CV to the secretary at the Mabasa Tribal Council office by the 10th of March 2023 by 2pm. Alternatively you can direct your queries to nkosi@groundtruth.co.za

10.10 APPENDIX J – CHANGES MADE TO THE REMOTE LEARNING SYSTEM

Details of the Changes Made During The Learning Engagement

Round	Date	Workshop	Group	Online design	Challenges or opportunities	Changes made for next round
1	15-19 May	Introduction W/S	Mabasa	LMS version 1: • meet the instructors' videos. • Picture overview of what CS tools are available. • Picture building via Miro board. • 3-part videos for the instructions for each tool (safety, site, selection. and sampling method) • SADC miniSASS context-based video for miniSASS. • Quizzes – simple T/F and MC for all tools except miniWET-Health. • Videos loaded as High-Res YouTube links.	• 1)Participants could not access videos outside of the training times, because it cost them airtime to download and watch. • Quizzes and Forum could also not be accessed offline, and as such were not used by all participants. • Some that did the quizzes said that they were too simple and not challenging enough. They were ready to "prove" their knowledge and were disappointed by what the quiz asked of them. • 4) Difficulty understanding the forum questions. Participants expressed a need to have the language changed, or the question translated.	• Videos sent via WhatsApp. • Videos loaded as Low-Res versions and embedded into the LMS. • Instructions on how to make a DBI net and how to tell the difference between a dragonfly and damselfly added.
2	5-9 June	Introduction W/S	Zikhali	LMS version 2: • meet the instructors' videos • Picture overview of what CS tools are available. • Picture building via Miro board • 3-part videos for the instructions for each tool (safety, site, selection, and sampling method) • SADC miniSASS context-based video for miniSASS • Quizzes – simple T/F and MC for all tools except miniWET-Health	• DBI manual too big to download. • Two of the participants were unable to go through the course due to the not having access to a smartphone and not having data. • The participants engaged with the picture building activity during the in-person training session instead of MIRO. • Participants struggled to understand the learning material for the mini-WET Health short course and subsequently majority of the participants did not attempt it.	• Have added the step-by-step instructions for each tool but are missing the context and the deeper understanding of when the tools are useful, and how they would be used together to collect a story using the data. Video content needs to be created to fill these gaps.

Round	Date	Workshop	Group	Online design	Challenges or opportunities	Changes made for next round
				• Videos loaded as Low-Res MP4 and embedded into LMS • LMS app and all content downloaded during contact session.		
		Tools Workshop	Mabasa	LMS version 2 (as above)	• Participants struggled to engage and understand the mini-WET Health learning content, and subsequently did not attempt it. • Participants were challenged with data when during the course.	• Facilitators explained the miniWET-Health tool in detail during the in-person training. This gave participants an opportunity to ask questions and learn from their fellow participants. • Remade the miniWET-Health tool video and added annotations and diagrams to the video • Participants opted to use the library Wi-Fi – to overcome the data challenge.
3	9-14 July	Tools Workshop	Zikhali	LMS version 3 (as above)	• The participants interpreted and demonstrated the miniSASS tool incorrectly during the in-person training session. • The participants struggled with using miniWET-Health and did not attempt it.	• The facilitators explained and demonstrated the miniSASS tool to the participants. Thereafter the participants had to demonstrate the miniSASS tool back to us, to gauge their understanding of the tool. • Added another miniSASS quiz. • Redesigned the other quizzes to adjust their complexity
		Wrap up Workshop	Mabasa		• Participants shared that they had trouble understanding the miniWET-Health and faced data challenges.	• Facilitators explained the miniWET Health tool in greater detail and responded to some questions from the participants.
4	7-10 August	Wrap-up workshop	Zikhali	LMS version 4 (as above)	• Participants requested an infield demonstration of the citizen science tool.	Facilitators and the participants went in field and practically talked through and demonstrated the tools.

10.11 APPENDIX K – OUTREACH AND DISSEMINATION WITHIN THE COMMUNITY OF PRACTICE

Throughout the project, the researchers participated in various meetings and workshops where information about the project was shared (Table 7-1). These activities lent insight into various aspects of the research, and assisted to refine the research outputs, as outlined in the Table below.

Table 10-7: Record of how knowledge of the research project has spread through the community of practice.

Date	Participants/Meeting title	Purpose	No.	Learning taken from meeting to advance this research project
01/04/2022	Jim Taylor/GroundTruth	Citizen Science connections across projects Meeting ORASECOM / Country Representatives / Clarifying the JBS III strategies	5	Devising a COP tracking table as part of report tools Developing a table to record useful readings to allow easy and direct sharing among researchers. Links with UNICEF and AEN project – overlap and strengthening of all projects
12/04/2022	DUCT/AEN/ GroundTruth	To decide on the level of standard and target market for the PO module-based training	5	
05/05/2022	DUCT/GroundTruth/ AEN	To get clarification on Module 1 and 2 resource packs for adaptation for initial rollout.	5	How do we make the training more interactive on a WhatsApp platform? How do we support the Project Officers' learning process?
06/05/2022	UNICEF/WESSA/DUCT/GroundTruth	progress to date discussion of Amanzi Ethu (pilot 1 and 2), status and potential next steps with the Yoma funds to support the innovative project in the green economy	14	Deficit development – framing the gaps and opportunities. Overlaps with UNICEF and AEN – Database development and management
11/05/2022	DUCT/AEN	To get feedback from the Rovers team on their experience of the module-based training so far.	3	How do we overcome the network challenge of PO groups located in remote areas? How do we make the training more context-specific/situational?
12/05/2022	GroundTruth/DUCT/ WRC/SAEON	Introducing the project to the reference group	15	The ID of a community as a case study: caution was shared to be aware of stakeholder fatigue in the uMngeni Catchment during the selection process Community selection will be driven by the data process – through leveraging existing partnerships
09/06/2022	GroundTruth	To discuss workflow, structure, and task allocations (inclusive of time allocated for each team member) Defining and refining the evaluation tools that may be adopted throughout the project duration.	4	Reflect on our feelings of the meeting and our expectations for the project. Developed standard questions for the interviews Identified the interviewees
15/06/2022	GroundTruth, Jim Taylor, Rob O'Donoghue	To discuss learning theories to inform the learning framework for the project.	5	How to make the training more situational by learning from the CHAT theory?
31/08/2022-01/09/2022	AEN/DUCT/UNICEF/ GroundTruth/ DSI	To discuss and capture the learnings from phase 2 of the AEN programme and plan a way forward.	10	Process of getting the Wetland course accredited, which we hope to leverage for the WRC project course. Explore online platforms to use

Date	Participants/Meeting title	Purpose	No.	Learning taken from meeting to advance this research project
				for the WRC project and make the training more situational/context specific.
13/04/2023-14/04/2023	GroundTruth, SAEON, UKZN	Citizen Science tools train the trainers 2-day workshop	12	A two-day course for facilitators. The course focused on methods and approaches that are inclusive and stimulate change. The training was focused on citizen science and how environmental change can be initiated through engagement with community-led science. Concepts of Social Learning and the Action Learning Framework were applied.
20/04/2023	UNISA, UWC, Chair of Citizen Science Global Partnership, Earth Watch Europe, United States International University (USIU-A), Nairobi, Kenya	World Earth Day presentation	312	Gave a presentation on what Earth Day means to me and provided an overview of remote learning to support the training of communities in citizen science tools for the biological monitoring of water systems
03/05/2023	Reference Group Meeting	Presenting the current progress of the project to the reference group	14	Presented on project progress, displayed the online learning platform trialled for training and explored various open-source platforms. Discussed how the course will be piloted with a community in a deeply rural area and documented how the participants manage to access the course, how the learning is taking place, what challenges emerge, and how these can be overcome.
04/05/2023	Project training team – Training meeting	Preparation for facilitating the online training.	6	All facilitators for the online training, including the students who would be using the online training for their own research with other communities, attended training to run through the training schedule, activities, and objectives of each session.
04/08/2023	IAIA Student group presentation	Presentation to the KZN Student Association of IAIA at UKZN	45	Brief presentation and description of the project, its aims, and focus on the student body as part of their careers evening. Gaining interest and future potential use of the final product from the students.
4/08/2023-05/08/2023	Green Learning Pathways research – partners meeting	Meeting with representatives from Rhodes University, DUCT, UNICEF, GroundTruth and other partners to open the process of learning pathway research for citizen science in the River Commons.	22	What has been learnt from this project through the WRC will be expanded upon through new research with Rhodes University and the River Commons. This aims to apply to the QCTO to acknowledge the work that Citizen Scientists do in the River Commons as a recognised occupation. This research will map the learning pathway using the YOMA miniSASS online course as its pilot.
17/08/2023	Africa Regional Centre of Expertise – regional meeting	Co-hosts of the Africa regional meeting	200	Briefly introduced the participants working in Environmental Education throughout Africa to the project and its developments. Reflecting on EE trends throughout Africa and what that means for citizen science training in this space.
20/09/2023	EEASA conference	Presented the project at the EEASA conference	20	The presentation was well received, and the learning that has taken place was found to be exciting. A question was asked on how the training can be accessed via WhatsApp and not on an LMS.

Date	Participants/Meeting title	Purpose	No.	Learning taken from meeting to advance this research project
21/09/2023	miniWET-Health workshop with the Maputuland Coastal Biodiversity Forum.	Following the workshop held by Heidi Van der Venter, the same participants of the forum participated in a workshop exploring the use of the miniWET-Health tool. Participants had diverse experience in the field of wetland assessments and ranged from interns from the DFFE, DWS, and SAEON to experienced independent ecologists and regional ecologists from EKZNW, SAEON, and DWS.	20	The workshop process was observed and reflected upon, and the feedback from the participants was gathered and used to adapt and refine the tool further.
12/10/2023	Keynote Address at the opening of the Invertebrate Hall at the KZN Natural History Museum.	Attendees of the event were introduced to citizen science tools that use invertebrates, such as miniSASS and the DBI. Both of which are featured on the online learning platform. This Research project was introduced in the address, and the focus of the project was shared with the attendees, who ranged from Museum directorates to school learners and teachers.	65	Many people were interested in the role that citizen science plays and how online learning could assist the knowledge of these methods to spread. The Teachers in the group were especially interested.
20/10/2023	WRC/UKZN State of Rivers Workshop	This was the first workshop of a new WRC research project run through UKZN. The partners that attended mapped out their various projects and activities from around KZN, South Africa and throughout Africa. The various advances in citizen science and citizen science's role in monitoring the state of rivers in South Africa were discussed.	54	Reflections and observations from the workshop were included in shaping the final report for this research study, including adding to the literature used in the introduction.
31/10/2023	Nature Connect – miniWET-Health and other wetland citizen science methods workshop	Nature Connect, based in the city of Cape Town, reached out to GroundTruth because they wanted to learn more about citizen science for wetlands. This workshop was run to introduce them to the updated wetland tool and other methods that add value to it.	15	The teaching approach for the miniWET-Health tool, which was developed during this project, was trialled with this group of participants. The workshop was run in Table Bay Nature Reserve and used a wetland system that was quite different from the systems in the Maputuland coastal plain where the previous workshop was run. It was beneficial to see that the tool can be applied successfully in different systems. Feedback from the participants was recorded and used to refine the tool further.
TOTAL NUMBERS			**851**	