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Citizen science and learning outcomes: assessment of projects in South Africa

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Abstract

This study assessed educational goals and learning outcomes in 57 citizen science projects in South Africa. Emphasising data collection as the primary objective, the findings revealed a secondary focus on environmental awareness, protection, and management, as well as education and research advancement. Notably, educational goals were often not prioritised, and formal measures for assessing learning outcomes were infrequently employed by project leaders. The study underscores the necessity for systematic approaches to evaluate the educational impacts of citizen science projects in South Africa.

Keywords Citizen science; Science education

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Introduction

Citizen science refers to the involvement of the public in scientific research processes, including data collection, analysis, interpretation, and dissemination [Heigl, Kieslinger, Paul, Uhlik & Dörler, 2019]. Participants may volunteer their time or receive compensation. The objectives of citizen science projects typically include scientific advancement through data collection, public education and engagement, promotion of scientific literacy and skill development, and social-ecological benefits, such as environmental conservation and policy formulation [Alender, 2016; Turrini, Dörler, Richter, Heigl & Bonn, 2018].

Previous research has demonstrated that citizen science projects can foster skills development, scientific literacy, and personal development, enhance awareness and understanding of science, and increase scientific knowledge and that learning through citizen science can be fostered through emotional, behavioural, cognitive, and social experiences being taken into consideration when engaging with participants [Jordan, Ballard & Phillips, 2012; Phillips, Ferguson, Minarchek, Porticella & Bonney, 2014; Phillips, Ballard, Lewenstein & Bonney, 2019; Kloetzer et al., 2021; Somerwill & Wehn, 2022]. However, the youth of the field and the scarcity of projects designed explicitly for participant education pose challenges in developing tools to measure educational outcomes in citizen science [Brossard, Lewenstein & Bonney, 2005; Phillips, Porticella, Constas & Bonney, 2018; Roche et al., 2020; Wehn et al., 2021].[1]

This study aims to determine whether project leaders of citizen science projects in South Africa incorporate educational goals in project planning and, if so, what learning outcomes they aim to achieve. According to our knowledge, few studies have explored this topic in the South African context [Phillips, 2017; Hulbert, 2016; Hulbert, Turner & Scott, 2019].

To address this research gap and understand citizen science projects and their learning outcomes in South Africa, the study seeks to answer the following research questions (RQs):

1. What are the primary aims of citizen science projects in South Africa?
2. What are the perceived learning outcomes of citizen science projects in South Africa?
3. Do citizen science projects in South Africa have explicit educational goals?
4. What is the current status of evaluating learning outcomes of citizen science projects in South Africa?

Theoretical framework

This study is grounded in three theoretical frameworks: cognitivism, constructivism, and science capital. Cognitivism and constructivism are two dominant learning theories debated since the 17th century. According to Ertmer and Newby [1993], *cognitivism* suggests that learning occurs in the mind through knowledge acquisition. The theory emphasises that knowledge acquisition can occur in various ways, depending on an individual's cognitive processes and desire to acquire knowledge. Personal thoughts, beliefs, attitudes, and values also shape cognitivism. The primary focus is cognitive processes such as problem-solving, language use, concept formation, and information processing. Learning is observable through what an individual knows and how they came to know it [Ertmer & Newby, 1993]. Therefore, citizen science participants can derive valuable learning experiences from their involvement, provided they are motivated and interested in learning. However, these factors are heavily influenced by prior knowledge and experiences [National Academies of Sciences, Engineering, and Medicine, 2018]. Furthermore, the extent of the resources available to them and the quality of infrastructure provided also play a significant role in shaping participants' level of interest and motivation [National Academies of Sciences, Engineering, and Medicine, 2018].

On the other hand, constructivism considers learning an active process of constructing new knowledge based on prior experiences [Ertmer & Newby, 1993]. Learning through experience significantly influences the choices a person makes and the direction a person takes [Bandura, 1971]. Hence, citizen science projects

[1] Given that time has elapsed between our data collection and this paper's review, this must be qualified. Newer developments are reflected in the literature suggested by reviewers and added to the references.

can facilitate the construction of knowledge through active participation in scientific research processes. Therefore, the participant's experiences during the project will largely shape their views and actions towards environmental conservation [Alender, 2016; Turrini et al., 2018].

The theory of *science capital* takes a broader view of learning, encompassing social, cultural, cognitive, and behavioural factors. It builds on the concepts of capital (cultural, social, economic, and symbolic) introduced by Pierre Bourdieu in the late 1970s [DeWitt, Archer & Mau, 2016]. It is relatively new in science learning research [Edwards et al., 2018]. Science capital refers to an individual's science-related qualifications, social networks, and behaviours [Archer, Dawson, DeWitt, Seakins & Wong, 2015]. It also refers to the relationships between the public and scientists and how they shape public perceptions and engagement with science [Hecker et al., 2018].

According to the theory of science capital, the more exposure a person has to science, the higher their level of science capital. Several factors that influence an individual's level of science capital have been identified. These include scientific literacy, scientific-related values, knowledge about the transferability of science in the labour market, consumption of science-related media, participation in out-of-school science learning contexts, knowing someone who works in a science-related job, parental science qualifications, and informal discussions about science with others [Archer et al., 2015; DeWitt et al., 2016; Hecker et al., 2018]. Scientific literacy and science-related values are crucial components of citizen science. Individuals engaging more with science are likelier to develop curiosity, attentiveness, and objectivity [Phillips, 2017]. Participating in a citizen science project, as an out-of-school learning activity, allows individuals to know someone who works in a science-related job and engages in discussions with their peers about science.

Literature review

Citizen science projects are typically developed by scientists and researchers, whom we will refer to as citizen science project leaders. These projects have become increasingly popular in biodiversity and environmental conservation due to their effectiveness in collecting spatiotemporal data [Davies, Measey, du Plessis & Richardson, 2016]. Citizen science enables hypotheses testing and the monitoring of environmental changes by collecting large quantities of data that may not be obtainable through conventional methods [Bonney, Cooper et al., 2009; Geoghegan, Dyke, Pateman, West & Everett, 2016].

Citizen science projects have the potential to have a significant impact on environmental attitudes, behaviour, and knowledge [Somerwill & Wehn, 2022]. They offer an opportunity for the public to take ownership and be more responsible for their environment, understand the scientific process, and be directly involved in producing scientific knowledge [Riesch, Potter & Davies, 2013]. These projects can potentially improve scientific literacy and expertise, as participants have better access to scientists and scientific information, which fosters a better understanding of science due to their involvement [McKinley et al., 2017]. Participating in citizen science projects may also cultivate a desire to pursue a career in science or environmental management and also increase the pool of candidates available for jobs in those fields [McKinley et al., 2017; Turrini et al., 2018].

Through citizen science, scientists can engage with communities and gain access to indigenous knowledge that they may not have had access to previously [Conrad & Hilchey, 2011; Geoghegan et al., 2016; McKinley et al., 2017]. As a result, scientists can learn from participants and possibly to be more responsible in their research [Lewenstein, 2016]. New partnerships between scientists and society can also form increasing public trust in science, often considered a valuable outcome of science engagement [Geoghegan et al., 2016]. In turn, it improves scientific communication and collaboration between researchers and the public [Geoghegan et al., 2016; Gunnell, Golumbic, Hayes & Cooper, 2021].

Scientists initiating citizen science projects aim not only to contribute to research but also to enhance public scientific literacy [Geoghegan et al., 2016; Frensley et al., 2017; Fraisl et al., 2022]. Their endeavours seek to raise awareness, promote positive behavioural changes, and instill a sense of shared responsibility within communities [Geoghegan et al., 2016; Masterson et al., 2017]. By empowering communities to act and fostering collaboration, these projects generate valuable scientific data and enhance scientific communication [Gunnell et al., 2021]. Participants, motivated by personal interests, a connection with nature, and a desire to contribute, engage in citizen science projects for learning opportunities and skill acquisition [Rotman et al., 2014; Alender, 2016; Frensley et al., 2017].

Studies have shown that learning is often an unintended outcome of citizen science projects or rather a by-product of a project, whether or not education is made a primary goal of a project [Phillips et al., 2014; Bonney, Phillips, Ballard & Enck, 2016; National Academies of Sciences, Engineering, and Medicine, 2018]. While the scientific literacy of participants is often the underlying basis of citizen science, both the individual citizen science projects and citizen science research, in general, have yet to fully explore individual or community learning outcomes [Phillips, 2017]. However, some studies have attempted to identify these learning outcomes [see Jordan et al., 2012; Bonney et al., 2016; Phillips, 2017; Turrini et al., 2018].

While learning is often an unintended outcome of citizen science projects, the literature categorises learning outcomes into four areas: scientific knowledge and skills, self-efficacy, motivation and interest in science and the environment, and behaviour and stewardship [Allen et al., 2008; Jordan et al., 2012; Bonney et al., 2016; Phillips, 2017].

Learning through participating in citizen science projects occurs in multiple dimensions: 1) *how learning occurs*, which involves factors that result in learning; 2) the *substance of learning*, which includes the skills and knowledge gained; 3) the *nature of learning*, which refers to the level of participant contribution, and 4) the *design of learning arrangements*, which includes training and resources provided by project leaders [Bonn et al., 2016]. Hein [1991] notes that learning is an active process that occurs in stages requiring intentional and motivated participants.

The nature of learning, specifically the level of participant contribution, has been used to categorise citizen science projects. Therefore, the categorising of projects based on the level of individual participation in the scientific research process is worth noting. Studies have identified three categories of projects based on participant involvement: contributory, collaborative, and co-created [Bonney, Ballard et al., 2009; Miller-Rushing, Primack & Bonney, 2012].

Citizen science projects are categorised into contributory, collaborative, and co-created types. Contributory projects involve participants solely in data collection through observation, identification, or monitoring, representing the majority of citizen science projects [Bonney, Ballard et al., 2009; Becker-Klein, Peterman & Stylinski, 2016]. In collaborative projects, participants engage more actively, contributing to project design, data analyses, and result dissemination, while scientists maintain control of the overall project design [Bonney, Ballard et al., 2009]. Co-created projects are collaboratively developed by scientists and participants, offering participants a hands-on role in defining research questions, gathering supporting information, interpreting data, distributing results, and posing further study questions [Bonney, Ballard et al., 2009; Becker-Klein et al., 2016].

Citizen science projects can also be classified based on their primary goal, such as action-orientated, conservation, investigation, virtual, and education [Wiggins & Crowston, 2011].

Action-oriented projects involve identifying and addressing local community issues with scientific research methods. Conservation projects promote environmental stewardship and primarily involve data collection. Investigation projects focus on scientific research goals and may include educational materials. Virtual projects are similar to investigation projects but occur in a virtual space. Education projects prioritise learning outcomes (and learning can either be formal or informal)[2] and involve collecting data for scientific research purposes [Wiggins & Crowston, 2011].

Despite the various ways projects can be categorised, there was a lack of formal assessment for these projects at the time of data collection. The lack of formal assessments and measurements may be attributed to several factors. Firstly, citizen science research is relatively new and is still finding its way to being fully embedded in mainstream research. Thus, tools and resources for assessment are still emergent and under development. Secondly, project leaders may not have the time or expertise to conduct formal assessments. Thirdly, citizen science projects may not be explicitly designed to achieve learning outcomes [Kieslinger et al., 2017; Phillips, 2017; Turrini et al., 2018].

Due to the limited resources for assessment, project leaders may resort to informal feedback as a means of assessment. For instance, they may view the duration of a participant's involvement as indicative of the learning outcomes achieved [Bonney, Cooper et al., 2009; Turrini et al., 2018]. Despite the potential of citizen science to significantly impact environmental attitudes, behaviour, and knowledge, the full extent of this impact is not yet fully understood. Additionally, up-to-date impact assessment methods and frameworks are not yet fully integrated into practice; very few forms of impact evaluation have been used [Somerwill & Wehn, 2022].

[2]Formal learning relates to learning in the classroom (in a teacher and learner setting). In contrast, informal learning takes place outside the classroom and can result from interacting with other individuals.

Previous studies have shown that only a few projects have been able to evaluate and demonstrate that they have achieved their educational objectives [Jordan et al., 2012; Bonney et al., 2016; Bela et al., 2016; Phillips et al., 2018]. This makes it challenging to fully comprehend the learning outcomes associated with citizen science and whether they are being realised [Turrini et al., 2018].

To comprehensively understand the impact of citizen science projects, leaders should conduct assessments, gaining insights into participant recruitment, learning opportunities, and strategies to enhance project longevity and impact [Jordan et al., 2012]. Recent progress in the citizen science field has introduced valuable tools for assessing learning outcomes. The Developing, Validating, and Implementing Situated Evaluation Instruments (DEVISE) [Bonney et al., 2016], the User's Guide for Measuring Learning Outcomes in Citizen Science [Bonney et al., 2016], and the Interactive User's Guide for Evaluating Learning Outcomes in Citizen Science [Phillips et al., 2017] stand out among these tools.

DEVISE instruments comprise constructs and tools to measure outcomes like interest, motivation, self-efficacy, and skills. The User's Guide provides practical templates for project leaders to evaluate citizen science project outcomes. A condensed version, the Interactive User's Guide, focuses on summative evaluation, describing a project's outcomes, effectiveness, or value after its establishment. These tools equip project leaders with essential resources to assess learning outcomes, enhance recruitment strategies, extend project impact, and gain a better understanding of associated learning outcomes.

It's noteworthy that since this study, new evaluation tools have emerged, such as the Measuring Impact of Citizen Science Tool (MICS) developed in 2022. MICS, although comprehensive in assessing costs and benefits across five domains (society, economy, environment, science, and governance) [Tzilivakis, 2022], does not delve deeply into learning outcomes associated with citizen science initiatives.

Becker-Klein et al. [2016] have proposed a new resource for measuring learning outcomes through *embedded assessments*. Embedded assessments involve measuring participant skill gains within the context of the project and assessing their progress and performance. This can be accomplished using instructional tools and activities that change regularly, forcing the participants to apply skills they have learned during the project.

Methods

Previous research has extensively examined citizen science and education in developed countries [see Bonney, Ballard et al., 2009; Wiggins & Crowston, 2011; Miller-Rushing et al., 2012; Bonney et al., 2016; Turrini et al., 2018]. However, there is a notable lack of research on citizen science projects and learning outcomes in the Global South. This study, therefore, focuses on a developing nation, South Africa, where citizen science projects follow a similar design and execution to those of developed countries but are characterised by greater cultural, educational, and socioeconomic diversity [Weingart & Meyer, 2021].

Conducted in 2020, this research builds on a previous study by Weingart and Meyer [2021]. It evaluates the presence of educational goals and learning outcomes in citizen science projects in South Africa. This study employed a mixed-methods approach, combining desktop research (quantitative) with semi-structured, individual interviews with project leaders[3] (qualitative).

Weingart and Meyer [2021] identified 56 South African citizen science projects, and our desktop research revealed an additional project, resulting in a sample of $N = 57$ South African citizen science projects (Table 1). At the time of this research, some of these projects may not have been active anymore.

Table 1. List of South African citizen science projects ($N = 57$).

	Project
1	ADDO: African Dragonflies & Damselflies Online (OdonataMAP)
2	African Honeyguide Project
3	AS@S Atlas of Seabirds at Sea
4	Astronomical Society of Southern Africa (ASSA) Citizen Science Section
5	Biodiversity Observations
6	Bird Pictures Archive (BirdPix)
7	Birds with Odd Plumage (BOP)
8	BIRP: Birds in Reserves Project
9	Cape Citizen Science
10	CAR: Coordinated Avifaunal Roadcounts
11	Custodians of Rare and Endangered Wildflowers (CREW)
12	CWAC: Coordinated Waterbird Counts
13	DungBeetleMAP
14	EarthWatch Institute: South Africa Expeditions
15	EchinoMap
16	ELMO: South African Elasmobranch Monitoring
17	FishMAP
18	FitzPatrick Institute of African Ornithology: Virtual Museum
19	FrogMAP
20	Hadeda Ibis Project
21	ifoundahedgehog project (IFAH)
22	Iimbovane Outreach Project
23	Karoo BioGaps
24	LacewingMAP
25	LepiMap
26	MammalMAP
27	miniSASS
28	MushroomMap
29	MyBirdPatch
30	NRF∣SAEON CAlender Gardens Project
31	Oceanographic Research Institutes Cooperative Fish Tagging Project (ORI-CFTP)
32	OrchidMAP
33	Penguin Watch
34	Protea Atlas Project

Continued on the next page.

[3]A project leader for this project is defined as a researcher or scientist who oversees the project. They lead in deciding how the project is conducted and what data needs to be collected. This is usually related to a bigger research project they are involved in.

Table 1. *Continued from the previous page.*

	Project
35	Red List Alert
36	rePhotoSA: the repeat photography project of southern African landscapes
37	ReptileMap
38	SABAP1
39	SABAP2: Southern African Bird Atlas Project 2
40	SAFRING: the South African Bird Ringing Unit
41	SANBI SeaKeys: Unlocking Foundational Marine Biodiversity Knowledge
42	ScorpionMAP
43	Sea Turtle Citizen Science Initiative
44	SeaKeys SA Jelly Watch
45	SeaKeys Sea Coral Atlas
46	SeaKeys Sea Fish Atlas
47	SeaKeys Sea Shell Atlas
48	SeaKeys Sea Slug Atlas
49	SeaKeys Seaweed Atlas
50	Southern African Butterfly Conservation Assessment (SABCA)
51	Southern African Reptile Conservation Assessment (SARCA)
52	SpiderMap
53	The Endangered Western Leopard Toad Project
54	ToadNUTS
55	TreeMAP
56	VultureMAP
57	Weaver Watch (PHoWN — Photos of Weaver Nests)

Note. Authors are aware that this might not be an exhaustive list of all citizen science projects in South Africa.

Interviews with project leaders of the citizen science projects in South Africa followed the desktop analysis. The project leaders were invited via email to participate in the interview at a convenient time. The first invitation email was sent in June 2020, resulting in 12 confirmed interviews representing 16 projects. A follow-up email was sent in July 2020 to confirm more interviews, but none were confirmed. Out of the 57 projects listed, 16 were represented by 12 project leaders ($n = 16$), resulting in a response rate of 28.1%. The interviews were conducted within a maximum of 35 minutes; the average interview length was 30 minutes.

The interviews consisted of 16 open-ended questions. The questions aimed to understand what project leaders intended to achieve through their projects [Phillips, 2017], the extent of participant involvement in the scientific process [Bonney, Ballard et al., 2009], the type of training provided to participants [Bonn et al., 2016], whether learning outcomes were evaluated [Turrini et al., 2018], and the perceived beneficiaries of citizen science projects in South Africa. If needed, project leaders were asked to elaborate on some of their answers [Jensen & Laurie, 2016].

After obtaining ethical clearance, project leaders were contacted and interviewed in July 2020. Zoom, a video conferencing platform, was used to conduct the interviews, which were recorded and stored anonymously. All data was compiled in Microsoft Office Excel 365 ProPlus. The transcribed interviews were used in the analysis of the data.

The data collected from the interviews were analysed using content analysis guided by the research questions. A deductive approach was used because similar studies focused on learning outcomes of citizen science projects and using similar groupings have been conducted [Alender, 2016; Phillips, 2017; Turrini et al., 2018].

Results

In this section, we present the results obtained from data analysis collected through interviews and desktop analysis, addressing the key research questions outlined in the study. The findings are organised to provide insights into the primary aims of citizen science projects in South Africa, the presence of explicit educational goals, perceived learning outcomes, and the current status of evaluating learning outcomes. Corresponding data, including the number of responses per category and relevant quotations from project leaders, accompany each research question. By comprehensively examining these results, we aim to contribute valuable insights into the landscape of citizen science projects in South Africa and their impact on education.

Research question 1: primary aims of citizen science projects in South Africa

The analysis of the interviews revealed the diverse aims of citizen science projects in South Africa (Table 2). The predominant focus was on data collection, with 16 projects emphasising the tracking and monitoring of various species. 11 projects underscored environmental awareness, protection, and management, often interconnected with data collection and educational initiatives. 10 projects explicitly mentioned aims such as education and fostering awareness and knowledge among participants. Another 10 projects emphasised advancing scientific research, while six focused on boosting scientists' academic careers.

Research question 2: perceived learning outcomes of citizen science projects in South Africa

Project leaders in citizen science projects reported various learning outcomes (Table 3). 14 projects were to increase awareness about the environment and species. 7 projects' goals were to promote increased responsibility towards the environment. Furthermore, 6 projects stated increasing participants' knowledge about science and the scientific process as their perceived learning outcome. These outcomes were often achieved through hands-on experiences, such as butterfly tracking and angler awareness initiatives.

Research question 3: explicit educational goals of South African citizen science projects

Our investigation into the explicit educational goals of citizen science projects in South Africa unveiled a significant emphasis on scientific objectives. Out of the total sample of 57 projects (from desktop research), 43 project goals were primarily scientific, while only two projects explicitly focused on educational objectives.

Table 2. Responses recorded from interviews with examples for primary aims of citizen science projects in South Africa ($N = 16$).

Project aim	*Number of responses*	*Example*
Data collection	16	"The main idea of butterfly conservation is to track the abundance of butterflies throughout South Africa. (...) butterflies are disappearing, ... but we do not really have much data to support it. So, I thought, maybe we can start tracking now." (Butterfly conservation project)
Environmental awareness, protection, and management	11	"Our long-term aim is to just do continual monitoring of the threatened species. As there are various factors (...) that contribute to the change in the population of the plant species, constant monitoring is required to see how it changes and have updated data of the changes" (Plant conservation project).
Education	10	"We (the project leaders) do a general plant awareness, particularly around threatened species, ..., but we also have a program where we visit tertiary institutions on an annual basis, and we give lectures and organise field trips for students." (Plant conservation project)
Advancing research	10	"Every ring on a bird is put on the database and all re-trapping [and resighting] data as well. We take different measurements of the birds (...) and movement data. This provides data on movement and how long (the birds) live." (Bird conservation project).
Advancing scientists' academic careers	6	"(the data) is (used) to improve our scientific knowledge base and improve public awareness of what the knowledge base is trying to communicate." (Landscape monitoring project)
Generating interest in science and science careers	5	"(This institution) has an education department called (X) for learners' grades 8–12, and every holiday, we do a presentation about the tagging project, why we do it and the different fish we tag." (Fish conservation project)
Making science a part of the culture	4	"One of our key objectives is to create awareness in what is happening to SA threatened plant species and habitats and how the general public and citizen scientists can be involved in conserving and monitoring plants." (Plant conservation project)
Influencing policy	3	"If we can say to the conservation authorities or (...) government that we believe that we have lost 30% of our insects in the past 30 years, and here is the data, then we are in a much stronger position." (Plant conservation project)

Notably, 12 projects aimed at achieving both scientific and educational goals. The interview analysis further highlighted a skew towards scientific goals, with 10 projects, compared to 6 projects with explicit educational goals. This distinction allows for a nuanced understanding of the multifaceted nature of citizen science initiatives and their varying degrees of educational orientation.

Research question 4: current status of evaluation of learning outcomes of citizen science projects in South Africa

Evaluation of learning outcomes in South African citizen science projects exhibited a preference for informal assessments (Table 4). 14 projects indicated relying on informal assessments, emphasising indicators such as repeated contributions as a sign of sustained interest and learning. Only 2 projects employed formal

Table 3. Responses recorded from interviews with examples for perceived learning outcomes of citizen science projects in South Africa ($N = 16$).

Learning outcome	*Number of responses*	*Example*
Raising awareness about the environment and species	14	"(...) I would like for [the participants] to learn a bit about butterflies, but invariably if you go out to look for butterflies in the field, your knowledge of plants and trees will increase." (Butterfly conservation project)
Promoting increased responsibility towards the environment	7	"The project is angler awareness and just trying to educate and teach anglers the correct way to handle fish and to become more responsible anglers." (Fish conservation project)
Increasing knowledge about science and the scientific process	6	"(The) projects teach them [the participants] to be better birders by learning about the birds they encounter." (Bird conservation project)

Table 4. Responses recorded from interviews with examples for the current status of evaluating learning outcomes of citizen science projects in South Africa ($N = 16$).

Assessment type	*Number of responses*	*Example*
Informal	14	"I think the best (assessment) indicator is when people start to contribute repeatedly because they might find it interesting and start looking out more for things and are excited to take pictures. Otherwise, without being there and directly speaking to them [the participants], it is very hard for me [the project leader] to evaluate whether the learning is happening or not." (Animal conservation project)
Formal	2	"We do have an M&E framework that we work with, but that is more geared towards our funders. We tested learners before and after we interacted with them..." (Ant conservation project)

assessment methods. One project leader expressed challenges in evaluating learning directly but acknowledged the significance of repeated contributions as an indirect measure of participant engagement and learning.

Discussion

This analysis aimed to explore the expected project goals of citizen science projects in South Africa by understanding the perceived learning outcomes of these projects and the status of evaluating these outcomes. The diversity of citizen science projects and their goals is reflected in the various project goals presented in the discussion section.

Primary goals of projects

Citizen science projects offer project leaders and participants opportunities to learn more about science. Our research revealed that data collection is the primary objective of the sampled citizen science projects in South Africa. Environmental awareness, protection and management, education, and advancing research also emerged as prominent goals. Project leaders engage participants through education and environmental awareness, protection, and management, aligning with cognitivist and constructivist perspectives on learning. [See Alender, 2016; Turrini et al., 2018].

Aligned with global trends [Alender, 2016; Bonney, Ballard et al., 2009; Becker-Klein et al., 2016; Turrini et al., 2018], the prominence of data collection as a primary aim is consistent with the effectiveness of citizen science in contributing to scientific research processes. However, the limited emphasis on educational goals resonates with global challenges in developing tools to measure educational outcomes in citizen science. The scarcity of projects explicitly designed for participant education is a challenge recognised in South Africa and broader international contexts [Jordan et al., 2012; Bela et al., 2016; Phillips et al., 2018].

Within the South African context, aside from data collection, a goal that emerged frequently was environmental concerns. This is represented by the continuous mention of environmental awareness and protection as a project goal by the interviewed project leaders. South Africa has a rich biodiversity and a strong emphasis on preserving natural resources, which likely influences the focus of citizen science projects [Weingart & Meyer, 2021].

Perceived learning outcomes

Project leaders identified diverse learning outcomes, including increased knowledge about science and the scientific process, enhanced environmental awareness, and the promotion of responsibility towards the environment, showing that regardless of their primary goal, citizen science projects have the potential to promote learning outcomes. This highlights the role of citizen science in promoting environmental education and engagement. In other words, to some extent, learning and engagement with science are encouraged, as suggested by the theory of science capital, independently from the professed objectives of the projects.

Environmental stewardship has been identified as an important learning outcome for environment-related projects worldwide [Conrad & Hilchey, 2011; Riesch et al., 2013; Alender, 2016; Geoghegan et al., 2016; Turrini et al., 2018]. The focus on environmental awareness may be attributed to most of the investigated projects being related to the environment and the biodiversity of plant and animal species. In addition to participants becoming more aware of the environment and their surroundings, they also developed an increased sense of responsibility towards the environment, better known as environmental stewardship. Project leaders also acknowledged the importance of using data to update biodiversity databases such as the IUCN Red List, which informs environmental management and legislation.

The constructivist perspective suggests that participants' competencies play a crucial role in their learning in citizen science projects, as Hein [1991] emphasised. While some projects may require specific skills and knowledge, others may only require a basic understanding of the subject matter [Peter, Diekötter, Kremer & Höffler, 2021]. However, the study's results indicate that most project leaders do not expect participants to possess prior skills or knowledge regarding the project.

Many projects provided participants with clear instructions and resources to engage in self-training. This approach not only facilitates participants' active involvement in data collection but also motivates them to understand the scientific research methodology. A learner-centred approach is applied by empowering participants to learn and comprehend the data they are collecting. This learner-centred approach promotes participants' engagement in the scientific process and fosters their cognitive development as they deepen their understanding of the data collection and scientific research methods [Jordan et al., 2012; Bela et al., 2016; Phillips et al., 2018].

By offering accessible and comprehensible instructions, citizen science projects aim to create a welcoming and inclusive environment that encourages participants to develop favourable attitudes towards science and fosters their engagement and interest in scientific activities. By providing accessible and comprehensive resources, citizen science projects can promote learning outcomes and engagement among participants with diverse backgrounds and levels of prior knowledge.

While many project leaders rely on participants for data collection, few projects embrace a collaborative or co-creation approach [Weingart & Meyer, 2021]. Therefore, when designing citizen science projects, it is critical to consider the level of participant involvement required.

Presence of explicit educational goals

Our investigation into the presence of explicit educational goals in South African citizen science projects revealed a significant disparity. While most projects had scientific objectives, only a limited number explicitly incorporated educational goals, with a minority of the project leaders acknowledging the inclusion of educational aims. This points to a potential gap in project planning, where educational objectives might not be considered adequately.

A point worth noting is the slight contrast in the results of this study compared to that of Weingart and Meyer [2021], where only a small proportion (3.5%) of citizen science projects had educational goals, while 75.4% had only scientific goals. In contrast, our interviews with project leaders revealed that a higher proportion, six out of 16, considered public education one of their goals, highlighting potential variations in defining and communicating educational goals between projects. This variation may be because Weingart and Meyer [2021] did not conduct interviews but instead opted for a survey instrument. Interviews may have provided more clarity on the goals of the sampled citizen science projects, or they may have triggered respective responses because of the positive value attached to educational goals. Alternatively, some projects might not consider it important to mention educational goals on their websites. Therefore, the results indicate that some projects may not communicate clearly that public or participant education is one of their goals, even though they still view education as an essential part of the citizen science project.

While citizen science projects can inspire participants to develop an interest in science and science-related careers, the study found that project leaders did not prioritise this goal. Instead, data collection remained the primary aim of many projects.

This trend aligns with the global challenge identified in the literature, where the youth of the citizen science field and the scarcity of projects designed explicitly for participant education pose obstacles to the development of tools for measuring educational outcomes [Brossard et al., 2005; Phillips et al., 2018; Roche et al., 2020; Wehn et al., 2021]. The scarcity of projects explicitly designed for learning outcomes remains a challenge not unique to South Africa but reflective of broader trends in the citizen science landscape. By addressing this research question, we highlight a critical aspect in evaluating citizen science projects, emphasising the need for a more deliberate integration of educational goals into project planning for a more holistic and impactful engagement with participants.

Status of evaluation of learning outcomes

The assessment landscape in South African citizen science projects revealed a reliance on informal measures to evaluate learning outcomes, such as participant data submissions and social media engagement, highlighting the importance of understanding how citizen science projects assess learning outcomes. Despite the availability of tools like DEVISE and User's Guide, formal assessments are underutilised. This highlights the challenges faced globally in integrating assessment tools into the field and suggests a need for increased awareness and accessibility in the South African context [Somerwill & Wehn, 2022].

Conclusion

To enhance the communication of learning goals in citizen science projects and assist project leaders in emphasising educational objectives, several strategic suggestions can be considered. Firstly, it is crucial to establish clear and explicit learning objectives at the project's outset. Articulating specific educational outcomes provides participants with a clear understanding of the knowledge and skills they are expected to gain, fostering engagement and allowing project leaders to align strategies with educational goals.

Additionally, incorporating structured training programs or workshops into citizen science initiatives can significantly contribute to communicating and achieving learning goals. These sessions can equip participants with scientific knowledge, research methodologies, and relevant skills, enhancing their understanding through hands-on activities and interactive experiences.

Furthermore, utilising diverse communication channels, including online platforms, webinars, and informational materials, can enhance the dissemination of learning goals. Project leaders should leverage these channels for regular communication, reinforcing the educational aspects of the project and providing continuous support. This ensures that learning goals remain prominent in participants' experiences, allowing project leaders to adapt strategies based on participant feedback.

Project leaders should collaborate with educational specialists or institutions to facilitate a greater focus on educational goals. This collaboration can bring pedagogical expertise into the project design, ensuring that educational goals are effectively integrated into the citizen science framework. Educational specialists can assist in developing curriculum-aligned materials, assessment tools, and methodologies that enhance the educational impact of the project while aligning with broader learning objectives.

Ultimately, establishing a feedback loop with participants and incorporating their input into the project's educational strategies is essential. By understanding participant perspectives and continuously assessing the effectiveness of educational approaches, project leaders can iteratively refine their methods to better meet the diverse learning needs of participants. This adaptive approach contributes to the overall success of citizen science projects in achieving meaningful educational outcomes.

Incorporating these considerations into citizen science projects aims to enhance participants' learning experiences, foster scientific literacy, and promote engagement with science and environmental issues. By understanding the underlying mechanisms and influences, project leaders can design and implement more effective projects that align with participants' needs, motivations, and aspirations.

The study found that citizen science projects primarily focus on data collection rather than having an explicit educational objective. Although some project leaders believed their projects contributed to environmental awareness, appreciation, and conservation, such outcomes were often by-products rather than intended goals.

Despite the presence of learning outcomes, such as increased skills, awareness, knowledge, and understanding of science and environmental stewardship, the lack of formal assessments from the projects made it difficult for project leaders to identify if these outcomes were being achieved.

This corroborates the findings from the earlier study [Weingart & Meyer, 2021], namely that the ambitious rhetoric about the potential and functions of citizen science is not matched by the reality on the ground: educational effects are mostly an unintended by-product which is neither consciously planned nor adequately assessed.

In conclusion, this study contributes to the evolving discourse on citizen science by providing a nuanced understanding of the South African context. The findings underscore the need for a more intentional integration of educational goals into project planning to maximise the educational impacts of citizen science projects. The recommendations extend to the broader global citizen science community, emphasising the importance of considering both scientific and educational dimensions for a more holistic and impactful citizen science engagement.

Limitations

Despite the valuable insights gained, this study had limitations, such as a low response rate and a short data collection timeline. Future research could address these issues by using alternative data collection methods, such as follow-up phone calls, to ensure that interview invitations are received and allow for a longer timeline to increase response rates. Also, the reliance on project leader interviews may introduce biases, and the focus on South African projects may limit generalisability. Future research could adopt a more extensive participant-centric approach, including diverse demographic groups. Additionally, the emergence of new tools like the Measuring Impact of Citizen Science Tool (MICS) underscores the dynamic nature of the field, necessitating ongoing exploration of assessment methodologies [Tzilivakis, 2022]. Overall, citizen science projects have the potential to promote public engagement in scientific research and contribute to environmental awareness, but further research is necessary to understand their educational impact fully.

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