27
Children and citizen science

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Highlights

- Children can both learn from and contribute to citizen science. Scientific learning can develop children's environmental citizenship, voices and democratic participation as adults.
- The quality of data produced by children varies across projects and can be assumed to be of poorer quality because of their age, experience and less-developed skill set.
- If citizen science activities are appropriately designed they can be accessible to all children, which can also improve their accessibility to a wider range of citizens in general.

Introduction

To date, a cursory examination of the literature tells us that a large number of citizen science projects have been, or are, in the environmental domain. It is thus on environmental citizen science that we focus this work[1]. This chapter suggests why children ought to be involved in citizen science – largely through environmental projects, highlights some case study examples to show positive and negative outcomes of child participation in said projects, comments on the potential contributions to science education and environmental awareness, and highlights some practical considerations of child involvement in citizen science. This work is thus premised on the two-way benefits of engaging children in environmental citizen science:

1. Children can both learn from and contribute to environmental knowledge, education and scientific enquiry; and
2. Where activities take place outdoors, child involvement in citizen science provides access to the environment, enabling children to develop environmental awareness, responsibility, emotional and physical benefits.

As the European Citizen Science Association (ECSA) assert in their formative 'Ten Principles of Citizen Science'[2], 'Citizen science is a flexible concept which can be adapted and applied within diverse situations and disciplines'[3]. It is exactly this adaptability and promotion of diversity which we embrace in this chapter, as we argue that such approaches can open up opportunities, outlined below, for *child* participation, in the *environmental* field. Furthermore, the involvement of individuals, (thus including children), in citizen science is advocated in ECSA Principle 3, which states that 'learning opportunities, personal enjoyment, social benefits, satisfaction through contributing to scientific evidence e.g., to address local, national and international issues [. . .] and influence policy', *inter alia*, may be some of the gains of participation in citizen science projects, and this is very much aligned to the work of environmentalism.

Why citizen science?

Cheng and Monroe (2012, 32) assert that '[h]uman behaviour is implicated in a number of environmental problems. In addition to solutions that can be offered by experts and policy makers, citizens' conservation actions are needed'. Thus, *citizens* and benefactors of the earth need to be responsible for the planet and all that is sustaining and enriching. A 'citizen' can be defined broadly as someone who has a stake in the future of the *global* environment. This chapter also adopts a more localised definition of a 'citizen' as someone who has a stake or interest in their *local* community.[4] Principle 1 of the ECSA Principles[5] avers that 'Citizen Science projects actively involve citizens in scientific endeavor that generates new knowledge or understanding [. . .] Citizen may act as contributors and have a meaningful role in the project'.

Further, citizen science, on a practical level, has the potential to:

1. Educate individuals about the environment in a broad sense, and ecology, species and scientific concerns, among others, in a narrower sense;

2. Be efficient, as local citizens undertaking data collection with qualified and trained experts can save time and money for regulators;
3. Engage at the local level, physically and temporally, rather than being remote or detached. Citizens live and work in their local environment and are more likely to notice, or be affected by, environmental change;
4. Be participatory and contribute to environmental justice. This is particularly pertinent in situations where local authorities or politicians are not willing or able to act on environmental matters.

Based on the above definitions, all children are current and future citizens and have a stake in the natural world.

Developing environmental citizenship

Children have an innate curiosity and desire to experience and learn that can enhance their citizen science experience (Jenkins 2011). Working with children brings insightful questions, new ideas and fresh perspectives on how scientific information is presented and interpreted. Research shows that children are naturally 'exploratory, inquiry-oriented, evidence-seeking' in their learning (National Research Council 2009, 67). The communication and exploration of science in a way that is primarily directed to children will arguably benefit children (*and* laypersons) involved in a citizen science project (Bonney et al. 2016). This child-focused form of communication can thus have multiple positive benefits: Difficult concepts are clearly explained, understanding of environmental problems is arguably made easier, knowledge can then be shared within communities and preconceptions of science and environment can be challenged and 'corrected' (Kambouri 2015a; Kambouri 2015b), particularly as 'the core components of initial science learning are (1) accurate observation, (2) the ability to extract and reason explicitly about causal connections and (3) knowledge of mechanisms that explain these connections' (Tolmie et al. 2016, 2). Citizen science offers the opportunity for children and young people to undertake research and ask questions from their unique perspectives, which may lead to a different understanding of issues, alternative solutions (Wells & Lekies 2006) and learning of distinct skills.

In addition to contributing to scientific enquiry, exposure to positive experiences as a child can have a profound effect in adulthood, particularly in developing responsibility or positivity towards an issue (Jones, Greenberg & Crowley 2015; Edwards et al. in this volume). Positive exposure to the environment as a child is shown to create positive attitudes towards the environment as an adult (Wells & Lekies 2006; Cheng & Monroe 2012). Children are more receptive to specific aspects of the natural world at certain ages, with particular developmental stages crucial in engaging the child citizen scientist as an emerging supporter of science and of the environment (Kellert 2002; White & Stoeck 2008).

Noting the above, an additional argument for the inclusion of children in citizen science is that children are gradually becoming disconnected from nature and the environment (Louv 2005; Miller 2005; Kahn, Severson & Ruckert 2009). There is an abundance of literature examining childhood behaviour (Wells & Lekies 2006; Cheng & Monroe 2012), education (Littledyke 2004; White & Stoeck 2008), psychology (Kellert 2002) and participation (Hart 1997; Wells & Lekies 2006), and the benefits to be gained from exposure to nature through citizen science (Purcell, Garibay & Dickinson 2012). If children find their participation on a nature-focused citizen science project exciting, and the experience of the outdoors stimulating, it could help develop self-confidence, connection to the environment and responsibility and empathy for nature and others. Furthermore, the practical tasks involved, such as preparation of the experiment and data collection and monitoring, can help to develop a sense of responsibility particularly for the work and for the environment and/or species with which they are engaged.

Filling a regulatory and democratic gap

Fluctuating political, social and, *inter alia*, economic circumstances, can arguably have an impact on government budgets and investment in environmental monitoring (Conrad & Daoust 2008). Here, citizen science can potentially fill a regulatory gap through the contributions of volunteers (Shirk & Bonney; Volten et al.; Owen & Parker, all in this volume). Furthermore, it may be easier to organise child participation and engagement as there are ready-formed pools of schoolchildren, scouting groups, activity clubs and so on (Wells & Lekies 2006). Advocates comment that creating a fun and engaging project is central to recruiting volunteers, particularly children (Dickinson et al. 2012). Moreover, an approach to participating in science and environment that is not solely adult-centric could promote inclusivity and a democratic approach to public participation in environmental decision-making (Hart 1997), very much in line with ECSA Principles 1 and 3[6], with adults making a deliberate decision to extend participation and inclusivity in citizen science projects to children. As Silvertown (2009, 467) asserts, 'the characteristic that clearly differentiates modern citizen science from its historical form is that it is now an activity that is potentially available to all, not just a privileged few' (but see also Mahr et al., in this volume, on the history of participatory science). However, commentators observe that we still have a long way to go in making citizen science truly democratic and diverse (Tweddle et al. 2012; Smallman in this volume), though including children is positive step towards these goals.

Citizen science ought not to be limited by age, geographical, racial, economic, (dis)ability, gender or other boundaries, and can be a group or solo activity (Liebenberg 2015; Stevens et al. 2014). Projects can be designed to be appropriate for children and can take place in urban environments or places not typically associated with the exploration of nature, such as schools, yards or windowsills. Projects can also be designed to be inclusive with respect to learning or physical disabilities.

This chapter argues that:

1. Citizen science by definition should be inclusive across gender, ethnicity, class, disability, level of education and so on. A diverse mix of participants contributing to scientific enquiry means that a broad range of perspectives can inform the research. Including children in citizen science further broadens the scope of the research due to their ways of viewing and enquiring about the world.
2. Citizen science may improve access to STEMM fields (science, technology, engineering, mathematics and medicine) for marginalised groups that have been historically excluded. Citizen science projects can be designed in ways that aim to overcome gendered, racial and other biases often associated with STEMM (Ceci & Williams 2011); and,
3. Generating interest or opportunity for engagement in citizen science among groups that might traditionally have been excluded from STEMM fields, or groups that might suffer from environmental discrimination or inequity, has social, educational, health and developmental benefits (European Citizen Science Association 2014, see Robinson et al in this volume; Dickinson & Bonney 2015).

Benefits for child citizen scientists

Physical and emotional

Children in citizen science can profit in their emotional and physical development and well-being. Box 27.1 highlights some of the key benefits of participation.

Interpersonal and social

Understanding and communicating science is arguably vital to the development of a sustainable world. Moreover, interpersonal and social skills are needed to prepare children for a healthy and productive future. Outdoor learning experiences, and particularly citizen science projects, can give children the courage to try new activities with new people, which ultimately have a positive effect on their self-esteem and confidence to

Box 27.1. Physical and emotional benefits of child participation in citizen science and engagement with nature

Sense of inclusion with nature is associated with understanding how an individual identifies his or her place in nature, the value that he or she places on nature, and how he or she can affect nature [. . .] Connectedness to nature, caring for nature and commitment to protect nature are core components of inclusion within nature (Cheng & Monroe 2012, 34, citing Schultz 2002).

Citizen science can:

- engage children with a purposeful and positive activity, which can help improve mental and physical growth;
- get children outdoors and help children to connect with nature;
- help children understand the environment and the important role of ecosystems;
- assist children in claiming some ownership of their environment and provide them with the ability to participate in its guardianship;
- teach children scientific concepts and provide information and data that can be used both to further develop understanding of science and safeguard the environment.

participate in further collaborative opportunities (Dillon et al. 2006). Projects such as community gardens can give children a 'context for learning that addresses multiple societal goals, including a populace that is scientifically literate, practices environmental stewardship, and participates in civic life' (Krasny & Tidball 2009, p.1). For example, the intergenerational Garden Mosaics programme[7] has a variety of activities in urban settings, and seeks to 'integrate learning from the "traditional" or practical knowledge of community gardeners with learning from science resources produced at Cornell University', allowing children both to learn about environmental science and engage in *civic ecology* (Krasny & Tidball 2009, 5) community garden restoration and management initiatives (see further, Tidball & Krasny 2007). Further, the Little Seedlings phenology project (The Conservation Volunteers, online, undated) at a garden centre in Scotland[8] worked monthly (April–August 2014) with children aged 4–12 (some with parents) using The Woodland Trust's Nature's Calendar website survey and recording sheets[9] to record and view seasonal events and the impact of climate change on wildlife. Organisers taught child participants about seasons and the changes they bring to nature, though acknowledged the limitations of younger children (under 7) in collecting data (The Conservation Volunteers, online, undated[10]).

Moving on, we comment below in box 27.2 on some key benefits to children, the environment and to citizen science from child participation in a plastic debris sampling project, while box 27.3 draws out some pros and cons of data analysis by children engaged in a citizen science project.

Box 27.2. National sampling of small plastic debris, supported by children in Chile

1. A wide pool of capable child citizen scientists
   This inclusive project, which combined environmental stewardship with child citizen science, highlights the 'two-way' benefits of citizen science projects. In this case, children from all around Chile and Easter Island both filled gaps in data on the accumulation and abundance of debris on Chilean beaches, and their personal development benefited from engagement in an environmental activity (Hidalgo-Ruz & Thiel 2013, 14). A pilot study was used to first test the protocols and data reporting forms so that adjustments could be made to guarantee data quality (Bonney et al., 'Citizen Science', 2009, 979; Hidalgo-Ruz

(continued)

Table 27.1 Results from the final evaluation survey applied to students (Hidalgo-Ruz & Thiel 2013, 14)

Question	Majority response	Percentage (%)
On a score from 1 to 7, how much fun was this small plastic debris project?	7	61.1
Had you heard about small plastic debris before this project?	No	73.1
Had you participated in an activity related to the environment before this project?	No	61.7
Did you read the story "The journey of Jurella and the microplastics"?	Yes	83.0
On a score from 1 to 7, how interesting did you find the story of Jurella?	7	51.8
Would you like to participate in other environmental activities in the future?	Yes	96.1
What was your favorite part of the project? Please mark one option	Field work on the beach	76.2

& Thiel 2013, 13). The programme ran for two months and involved nearly 1,000 students (from 8 to 16 years old).

2. Positive experiences
   Students completed a survey (see summary in table 27.1) to evaluate their overall satisfaction with the programme and children 'rated the activity with an average grade of 6.3, in which 61% of all students qualified it with a 7 (the best possible grade). The favorite part of the activity was the field sampling (76% of the students)' (Hidalgo-Ruz & Thiel 2013, 14). Roughly three-quarters of the students had never heard of 'small plastic debris' before the programme, and for 62 per cent, this was their first 'environmental activity' (14). Yet, 96 per cent of all students said they wanted to participate in future similar activities (14).
3. Outcomes
   'To validate the data obtained by the students, all samples were recounted in the laboratory. The results [. . .] showed that the students were able to follow the instructions and generate reliable data' and that children who take part in

citizen science projects can engage in ‘a scientific thinking process’ (Hidalgo-Ruz & Thiel 2013, 15) through learning about impacts of pollutants such as plastic debris, in addition to experiencing positive changes regarding their attitudes towards science (Lawless & Rock 1998, 7–8) and potentially the environment (Phillips et al. 2012, 92–93). Further, this case study demonstrates that child citizen science can help in the collection of ‘large-scale spatial [. . .] data on the occurrence and abundance of small plastic debris’ (Hidalgo-Ruz & Thiel 2013, 17).

Box 27.3. Conducting ecological research: Analysing data collected by German schoolchildren

1. Limitations in collection of data by children
   In conjunction with a project investigating dispersal and predation of seeds in rural and urban ecosystems, Miczajka, Klein and Pufal (2015) conducted a study to determine whether children could contribute to an ecological experiment by collecting data qualitatively. In Hamburg and Luneburg, Germany, 14 classrooms with a total of 302 children aged eight to ten years old, with ‘no comparable experience or training in conducting scientific experiments’, were taught 12 lessons by scientists, of which four were dedicated to the citizen science project (5). Six experiments were devised, with different conditions. The children ‘used pre-designed field protocols’ to measure conditions including weather; vegetation cover (using words, such as ‘lots of cover’) and height (using a ruler); treatment and colour of seeds; number of seeds exposed; and number of seeds recovered at the end (4). The scientists conducted the same measurements as the children to compare their data. The study found that ‘only in five classes out of 14, children and scientists provided similar cover estimates’ (5), and the measured range of vegetation heights for scientists was 0–40 cm and for children was 5–800 cm (5).

(continued)

2. Outcome dependent on task
   On the other hand, from a total of 1,680 seeds, the children recorded 83.9 per cent of seeds compared to 88.7 per cent recorded by the scientists. The authors demonstrate that 'seed count data from children and scientists was mostly similar' (and differed significantly only for one particularly small type of seed), while on the other hand there was 'only little concordance in the estimation and measurement of vegetation and height data' (Miczajaka, Klein & Pufal 2015, 5, 7). Therefore, the results show that measuring height and conducting estimates is 'difficult' for children with little experience (5). Conversely, as 'counting is an innate skill for children aged eight to ten because they learn it early', they achieved mostly similar results to the scientists. The authors conclude that it is 'possible to integrate elementary school children as citizen scientists in [ecosystem science] projects . . . if these projects require skills that the children are already familiar with' but that citizen science experiments requiring skills beyond their level 'would require intensive preparation and training' (6). Thus, this case study illustrates that children can contribute as scientists, but it is arguably important to first assess the skills and knowledge required to ensure valuable and more accurate data.

Educational

Citizen science has been credited with 'hold[ing] much promise' (Jenkins 2011, 501) for making classroom-based/laboratory-based learning less boring and science more accessible to children (Jenkins 2011, 505–6; Rodríguez 2015, 14; and see Wyler & Haklay in this volume re: motivating university students). Corrigan (2006, 51) asserts that science educators 'need to have a clear purpose of what they hope their students will learn' for science education to better engage students. Cherry and Braasch (2008, 1) argue that there is a demonstrated need to increase both formal and informal science and climate literacy, and show that citizen science 'works because data collection stimulates experiential and cognitive ways of learning'. Citizen science is also credited with promoting scientific and ecological literacy and offers the potential to develop a lifelong interest in science (Jenkins 2011, 502; Rodríguez 2015, 13–16; Miczajaka, Klein & Pufal 2015, 2).

Pike and Dunne (2011, 494–5; 498–9; 487) state that often UK students are not motivated beyond the compulsory school curriculum to study science after age 16, finding the curriculum fails to enthuse students or they see science as irrelevant to their lives. Jenkins (2011, 504) contends that students might find science inaccessible because they cannot relate to it. Thus, citizen science can be pitched at varying levels of academic ability and experience, and can 'translate' abstract topics into ones that can be visualised (Johnson, Hart & Colwell 2014a, 12–13).

Citizen science can also help to address inequalities in *access* to education (Gommerman & Monroe 2017), particularly in developing countries. Working in groups and using the natural world as the laboratory resulted in a low-cost educational model. The National Research Council (2009, 3) found that there are benefits to learning science through 'informal' environments and that non-school programmes 'may positively influence academic achievement'.

Oberhauser and Prysby (2008, 104), commenting on their Monarch Larva Monitoring Project, observe that from an educational perspective, volunteers, including many children, have learned data collection protocols and had the opportunity to be engaged in authentic research. Many teachers, parents and other youth leaders use this programme to engage children in the scientific process'. A 2015 study by Wells et al. (2015, 2873) documented a 'modest, positive effect on science knowledge among elementary school children in low-income communities' through randomised controlled trials. In addition, school garden science projects benefit the development of the 'whole child' by 'contributing to social, academic, cognitive, and health outcomes' (Wells et al. 2015, 2874). Further, Trautmann et al. (2012, 179) observe that citizen science provides 'meaningful connections to the natural world' for children 'through observation, data collection and [. . .] investigation'. Yet, though there are broader benefits to be obtained from data collection and child participation in citizen science, not all child-centred citizen science projects will yield wholly accurate results or data (see box 27.2 and box 27.3, above).

On a positive note, citizen science allows for children to learn about nature and the environment in an immersive and structured way, benefiting from the solid disciplines and underpinnings of scientific inquiry, while being engaged in an experience that will impact their role as future custodians of the world and also as potential future scientists (Krathwohl, Bloom & Massia 1964; Harlin et al. in this volume). It is clear though that the scientific tasks being undertaken should be tailored to the ability of the participants and potentially employ 'skills that the children are already familiar with' (Miczajaka, Klein & Pufal 2015, 6). Therefore, in spite of some limitations, children who had the chance to undertake actual scientific research and work with 'proper' scientists had a learning experience 'shown to be more effective than education by teacher-centered teaching in other studies'. (Miczajaka, Klein & Pufal 2015, 6).

Curriculum enhancement

Child involvement in citizen science projects can also play a role in formal education and curriculum enhancement. For example, the Greenwave project (1997), an initiative of the Discover Science and Engineering Programme at Science Foundation, Ireland, was 'the longest running phenology network in Ireland in which school children were the main participants' (Donnelly et al. 2014, 1239). According to Donnelly et al. (2014, 1241), over 150 schools participated in this project, which fed into the Primary Science/Social, Environmental and Scientific Education curriculum. Participation in Greenwave was one of the criteria applied to awarding the Science and Maths Excellence mark to schools.

Formally connecting citizen science projects to national curricula helps realise its potential benefits. Where there is not the political expediency to formally adopt or integrate citizen science into the curriculum there is a strong potential for citizen science projects to develop their own school-centred learning materials and lesson plans, which may well feed informally into national learning schemes (see, for example, the Imperial College London/Open Air Laboratories [OPAL] project[11].)

Jenkins (2011, 501) states that 'participation in citizen science projects moves scientific content from the abstract to the tangible involving students in hands-on, active learning. In addition, if civic projects are centred within their own communities, then the science becomes relevant to their lives because it is focused on topics in their own backyards'. However, some guidance is needed, from a teacher, parent or other leader (with some form of scientific expertise) because '[c]itizen science, by definition, relies on co-operation between a range of experts and non-experts, which in many cases, involves some sort of public engagement, education, and data collection' (Jordan et al. 2015, 208).

Participation, engagement and children's voices

Bultitude (2011, 2) comments that '[a] recent major review [. . .] within the UK identified four key cultural factors that have influenced the separation of science from society, resulting in an increased need for scientists to engage with public audiences: 1. The loss of expertise and authority of scientists; 2. A change in the nature of knowledge production; 3. Improved communications and a proliferation of sources of information; 4. The democratic deficit'.

Bultitude acknowledges that these issues might also be relevant outside the UK and the following points in turn suggest how they might be addressed by child citizen science:

1. Loss of expertise. Citizen science engagement with children can expose children to the joy of science, equip them with some key knowledge and enthusiasm for science, and introduce them to the crucial roles of scientists in society. When children are included in citizen science projects, they learn about the rigour of scientific experiments and the importance of scientific integrity, and how to question valid research and evidence. Citizen science can thus increase awareness of the particular areas of scientific study being undertaken (Gommerman & Monroe 2017).
2. Nature of knowledge production within the context of an increasing variety of actors and collaborators producing 'science'. There is clearly a role for children in science and the more they learn how to do science, the better. Citizen science participation can thus be seen as a supplementary form of learning, beyond the curriculum.
3. Proliferation of communication channels and sources of information. In Bultitude's (2011) view, this is positive and can be further nurtured within the context of children and citizen science. Children can be actively engaged in citizen science through games, apps, computers, Geographical Information Systems and other technologies.
4. Democratic deficit. Bultitude (2011) comments on the disenfranchisement of citizens and their disconnectedness from decision-making and participatory processes (see also Smallman in this volume). She points out that 'recent changes in the nature of decision-making processes have created a "democratic deficit", whereby political-scientific decisions are increasingly made outside of the public arena' (Bultitude 2011, 3). As active participants in environmental

citizen science, children are more likely to be informed, understand the local – and global – issues at hand, and ultimately have more to contribute to a discussion or decision-making.

Engaging children in citizen science now – as they will be the future guardians of the environment – is a useful way to teach them about wildlife and habitats, engage them in conservation efforts and attain useful monitoring data and evidence on biodiversity and population health, and other environmental impacts which contribute towards effective environmental management. Hart (1997, 3), cautions, however, 'that all children can play a valuable and lasting role [in environmental protection] but only if their participation in taken seriously and planned with the recognition of their developing strengths and unique competencies'. As Kellett (2005, 10, section 6) asserts, children contribute to research through addition of their 'genuine child perspective', and their ability to communicate with their peers and disseminate information from a 'child voice' Kellett (2005, 10; 16; 19). Furthermore, on a positive note, as Cornell Professor John Losey explains, 'kids are high energy' and their lack of training may arguably lead them to search in places experts may overlook.[12]

Education also develops awareness and the ability to generate an informed opinion. Referring to Corburn's (2005) analysis of citizens in New York who educated themselves about neighbourhood environmental risks and successfully rallied against polluters because their children continually suffered from health issues, Jenkins (2011, 507) observes that:

> if these citizens had citizen science experiences during their science education, just imagine how much more empowered they would feel when facing such challenges. They may have to learn the specifics of the pollution to which they are being exposed, but they would already have authentic science experiences that they could build upon. Science becomes a tool of many that can be used to address concerns in people's everyday lives.

Data quality, ethics and practical considerations

Data quality is a key issue in citizen science (Fowler et al. 2013; Wiggins et al. 2011; Kosmala et al. 2016) and it is also perhaps assumed that children are more *likely* to obtain inaccurate data, due to their age, overexcitement or lack of attention (Miczajka, Klein & Pufal 2015; see also box 27.2 and box 27.3, above). There are not yet many studies comparing the quality of child citizen science data like-for-like with data collected by adults, though Burgess et al. (2017, 116) suggest that there is a 'higher probability' of professional scientists using data collected by retirees for primary research purposes. They are significantly more likely to use data collected by college students or adults with college degrees, and are ultimately more likely to use data collected by college students or adults with college degrees than younger individuals (Burgess et al. 2017, 116–7). As noted above regarding the two case studies (see boxes 27.2 and 27.3), data collection by children will vary from project to project due to variability in project design and goals, scope of the research being undertaken, prior knowledge and age of the children. However, we assert that citizen science projects can be designed to work around the abilities of the children involved (see further, Miczajaka et al. 2015; box 27.3).

Related to the data collection issue, this chapter has also alluded to the need for science to be legitimate, rigorous and accurate (Bultitude 2011), which is also a concern for academics involved in citizen science projects (Riesch & Potter 2014; Wyler & Haklay in this volume). A sensible approach for projects with children is to keep research methods simple, which will produce simple results more likely to be fairly accurate (Riesch & Potter 2014). Other scientists researching citizen science projects have commented that 'there is no such thing as quality of data, it's what you use the data for. Different uses will require different quality' (Riesch & Potter 2014, 112; Williams et al. in this volume). Although quality depends on the age and level of development of the child participants, children can still make valuable contributions to a project, particularly ones that require extensive monitoring over time and space (Miczajka, Klein & Pufal 2015). Furthermore, involving large numbers of children and changing the pool of researchers will increase accuracy. Anecdotal evidence from an OPAL[13] event in 2014 conducting a group-level and species-level identification exercise (trees and bumblebees) indicated that parents tended to 'jump in' and make a species identification based on existing knowledge, whereas children were more methodical, followed the guidance and came to the correct identification more often than their parents (OPAL 2016). To this end, advocates have produced guidelines and methodologies for including children in research (Johnson, Hart & Colwell 2014b). Johnson, Hart & Colwell (2014a) suggest six steps for engaging young children in research (see figure 27.1), including the development of ethical protocols for working with young children[14]. Further below, box 27.4 also suggests some child-centred approaches, following Piaget (Wadsworth, B.J. 2004) and

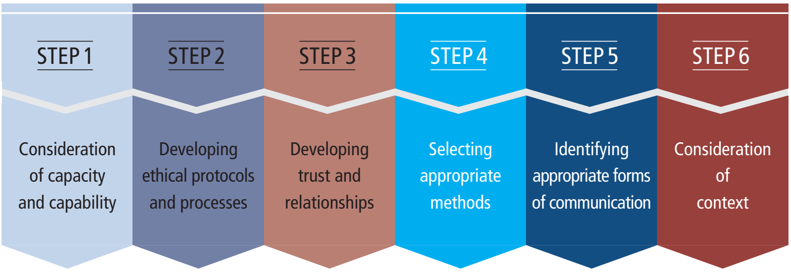

Fig. 27.1 The six steps for engaging young children in research. (Source: Adapted from Johnson, Hart & Colwell 2014a)

Box 27.4. Child-centred learning approaches

Child-centred learning approaches, as promoted by Piaget, fit well with citizen science, which:

- offers an environment within which to facilitate learning, rather than providing direct tuition;
- focuses on the process of learning, rather than the end product of it;
- promotes 'active methods' of learning that require 'discovery' and investigation;
- allows children to learn from each other and from their leaders/facilitators, working collaboratively and in a group;
- means children can be included based on the level of their individual development and ability. Tasks can be set accordingly so all children can be included.

box 27.5 includes some common sense approaches, for the inclusion of children in citizen science.

Going forward

This chapter has outlined reasons for the explicit inclusion of children as a distinct group in environmental citizen science projects. Reasons for inclusion have focused on the contribution that children can make to a

Box 27.5. Common sense policies for engaging child citizen scientists

- Always obtain prior informed consent from parents/guardians **and** children (if there are specific vulnerable children, their school is likely to be aware of this so working with schools is sensible);
- Do not post photographs of child participants or name child volunteers (even if you are thanking them for their involvement) unless consent has been obtained;
- Do not give specific details as to ages, names, addresses, etc. Precise data can include using codes and generic information, so that what needs to be made public will be anonymised.

citizen science project in terms of data collection and monitoring, and also the insights to the project that emanate from their unique childhood perspectives and enthusiasm for learning as a result of being included. In turn, there is acknowledgement that participating children can be from a diverse mix of backgrounds, experiences and ages, and can gain the benefit of formal and informal scientific and environmental education and awareness raising, that can subsequently enhance their interest in and access to STEMM at school and in the wider community, foster the development of positive attitudes towards the environment, promote physical activity and assist in further developing their potential for inclusion in environmental decision-making.

The conclusions, so far, above, have drawn together some of the potential positives of including children in environmental citizen science but the question also needs to be asked as to whether children can really actually contribute to citizen science. Are they too young? Do they lack capacity and experience? Can they do the science 'properly'? Will they behave well? In response to these questions, it is noted in the work that there are shortcomings in relation to including children in citizen science projects, largely centred on the accuracy of data collection. Perhaps, however, the broader benefits of inclusion, outweigh the dis-benefits associated with data collection, and this work has suggested ways to address some shortcomings, for example, through setting scientific tasks for children that are aligned to their unique abilities and skill sets, pitching at an appropriate level of academic ability and experience, and being realistic about what the data will be used for.

Further, just as adults may have colleagues that are difficult to work with, some children might be 'challenging'. This does not mean that they should be excluded – if a citizen science project is engaging and interesting, children are likely to contribute well. Children like to be given tasks and to be productive, and they like to explore and learn when in a stimulating environment (Kellert 2002). To this end, there are many positive contributions that children can make to citizen science and that citizen science can contribute to children. To facilitate this, tasks need to be age-appropriate and with adequate supervision, explanation and guidance. A citizen science project with children is about developing the citizen and also developing the science. For project leaders, respectfully communicating in a way that is aimed at children, building their self-confidence, developing a sense of responsibility and ownership of the work can greatly assist in developing the child and the project.

Children arguably view the environment and their place in it differently from adults. Including children in citizen science means they will learn substantive skills, develop as individuals and hopefully, go on to be custodians of the natural world. Enabling – and encouraging – children to participate in science research projects 'is an empowering process', leading to a 'virtuous circle of increased confidence and raised self-esteem resulting in more active participation by children in other aspects affecting their lives' (Kellet 2005, 10). Furthermore, as demonstrated throughout this chapter, if projects are designed with regard to children's specific skills and abilities, they are able to contribute valuable data and research as citizen scientists. There is, therefore, a double reason for including children in citizen science.

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Notes

1 Though our experience is in the environmental field, we note that citizen science is not limited to the environment. The SciStarter database (https://scistarter.com/citizenscience.html – accessed 28 November 2017) contains environment-related citizen science projects, and some related to psychology, social sciences and computers and technology. There are also projects related to *inter alia,* language, literature, health, data processing, disasters, cybersecurity, war, etc., listed on the Scientific American Citizen Science database (https://

www.scientificamerican.com/citizen-science/ – accessed 28 November 2017) – another example of an excellent repository.

2 European Citizen Science Association, Ten Principles of Citizen Science, https://ecsa.citizen-science.net/sites/default/files/ecsa_ten_principles_of_citizen_science.pdf – accessed 28 November 2017.

3 See note 2, above.

4 Environmental citizen science can also positively contribute to objectives advanced under Local Agenda 21 schemes to achieve sustainable development at the local level. See further, *Constructing Local Environmental Agendas: People, Places and Participation*, edited by Susan Buckingham-Hatfield & Susan Percy, 2005, Routledge.

5 See note 2, above.

6 See note 2, above.

7 Cornell University Civic Ecology Lab https://civicecology.org/outreach/garden-mosaics/ – accessed 30 May 2017.

8 Dobbies, in Kinross, Perthshire, Scotland, https://dobbies.com/events/little-seedlings/ – accessed 25 May 2017.

9 Woodland Trust http://www.woodlandtrust.org.uk/visiting-woods/natures-calendar/ in collaboration with the NERC Centre for Ecology & Hydrology https://www.ceh.ac.uk/ – accessed 25 May 2017

10 See: *Phenology Recording with Young Children,* https://www.tcv.org.uk/sites/default/files/172/files/CSR_Dobbies.pdf – accessed 30 May 2017.

11 The UK Open Air Laboratory Project: https://www.opalexplorenature.org/schools – accessed 30 May 2017.

12 Kids Count: Young Citizen Scientists Learn Environmental Activism: Student researchers become the eyes and ears of environmental scientists, By Evantheia Schibsted, October 2, 2007 George Lucas Educational Foundation, *Edutopia*: 'A comprehensive website and online community that increases knowledge, sharing, and adoption of what works in K–12 education'. https://www.edutopia.org/service-learning-citizen-science – accessed 30 May 2017.

13 'Open Air Laboratories is a UK-wide citizen science initiative founded in 2007 that allows people to get hands-on with nature while contributing to important scientific research.' http://www.imperial.ac.uk/opal/about-us/ – accessed 04 December 2017

14 In terms of getting 'free labour' and 'free data' from children participating in citizen science projects, ethical questions have been raised. Riesch and Potter (2014) comment that many citizens are willing to participate, *pro bono*, in citizen science projects in exchange for the learning and engagement opportunities. Here we will add then, that guardians, school-teachers and parents have to act legitimately in the best interests of the child when consenting to the participation of minors in citizen science projects. We contend that the larger benefits arguably outweigh the pitfalls. Further, any concerns over 'ownership of data,' the role of participants, and safeguarding of precise or personal data can be ironed out at the onset of the project, as seems to be the case in practice, and should not be a barrier to the participation of children in citizen science (Bowser 2014).