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Biodiversity citizen science: Outcomes for the participating citizens

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Abstract

1. Citizen science (CS) is regarded as a promising format in environmental and sustainability education as well as in science education. CS projects often assume that participation in the project influences, for example, participants' knowledge or behaviour.
2. We investigated whether and to what extent biodiversity citizen science (BDCS) projects, from the participants' self-reported perspective, achieve the following six participant outcomes: (a) content, process and nature of science knowledge, (b) skills of science inquiry, (c) self-efficacy for science and the environment, (d) interest in science and the environment, (e) motivation for science and the environment and (f) behaviour towards the environment.
3. For this purpose, we conducted an online survey of 1,160 CS participants across 63 BDCS projects in Europe, Australia and New Zealand. Our survey was aimed at adults participating in CS voluntarily.
4. Survey respondents reported positive changes in all six categories. The most notable result across projects was that self-reported increases in knowledge, self-efficacy, interest and motivation were found to be more pronounced when regarding the environment rather than science. Perceived gains in data collection skills were reported to be higher than gains in skills not directly connected to data collection. Reported behaviour changes primarily concerned communication activities, to a lesser degree also gardening activities, and finally more general environmental behaviour.
5. In addition to these six participant outcomes, respondents mentioned a variety of other positive and negative outcomes, for example, health and well-being, enjoyment, a sense of satisfaction, an increased connection to people and nature but also a more pessimistic view regarding the future of the environment.
6. We conclude that BDCS projects could have a high potential for environmental and sustainability education as well as science education. Further research should investigate individual participant outcomes in more depth and should focus on the factors that influence these participant outcomes. Moreover, exploring the perspectives of both project participants and project coordinators would be valuable.

In this way, it would be possible to improve the development and design of CS projects. As a result, BDCS projects could more effectively achieve outcomes for the participants, for science and for biodiversity.

KEYWORDS
behaviour, community-based monitoring, environmental education, interest, knowledge, motivation, participant outcome, science education, self-efficacy, skill

1 | INTRODUCTION

1.1 | Citizen science and biodiversity

Citizen science (CS), also known as public participation in scientific research (Bonney, Ballard, et al., 2009) or community-based monitoring, involves citizens, that is, members of the general public, in authentic research projects that use scientific methods to collect and analyse authentic data (Miller-Rushing et al., 2012; Pettibone et al., 2017). CS has been widely used in environmental sciences and is particularly popular in a biodiversity-related context. It has been used to enable scientists to involve the general public in biodiversity research, thereby enabling the scientists to collect data that they would otherwise not have been able to obtain (Bonney et al., 2014; Couvet et al., 2008; Theobald et al., 2015).

Biological diversity or biodiversity can be defined as 'the presence and/or abundance of identified taxonomic (e.g. species, genus, family), genetic, or functional groups' (Theobald et al., 2015, p. 237). Biodiversity Citizen Science (BDCS) projects involve citizens in identifying and monitoring biological diversity and collecting biodiversity data (Theobald et al., 2015). These projects are usually field- or nature-based, that is, they take place in outdoor environments and include observation of or interaction with nature. Such projects often involve, but are not limited to, online activities (Peter et al., 2019). In addition, there are biodiversity-related citizen science projects that are run entirely online, for example, projects found on www.zooniverse.org (also see Aristeidou & Herodotou, 2020). However, such projects were not included in our study. As a result of involving citizens in the research process, various articles on the scientific outcomes of CS have been published in peer-reviewed scientific journals (Chandler et al., 2017; Donnelly et al., 2014; Heilmann-Clausen et al., 2019; Irga et al., 2018; Petrovan et al., 2020; Theobald et al., 2015). CS thus makes a substantial contribution to research on biodiversity.

CS has great potential not only for science but also for education. Biodiversity is currently being lost at increasing rates (Hallmann et al., 2017; Mace et al., 2005; Rosenberg et al., 2019). A crucial step in biodiversity conservation is to raise awareness in society of the value and importance of biodiversity (Barker & Elliott, 2000; Navarro-Perez & Tidball, 2012). In addition to raising people's awareness of and knowledge about biodiversity, causing changes in people's attitudes and behaviour is of utmost importance for biodiversity protection (Heller & Zavaleta, 2009; Richardson et al., 2020). Such changes can contribute indirectly (e.g. through reducing consumption and waste and by influencing environmental policies) or directly (e.g. through installing bee hotels or planting native plants) to biodiversity conservation (Deguines et al., 2020; Richardson et al., 2020). CS projects focusing on biodiversity could have the potential to educate the public about biodiversity (Deguines et al., 2018; Peter et al., 2019) and to lead to changes in individual behaviour. Such behaviour changes can be, for example, changed gardening practices such as decreased pesticide use and increased provision of nectar resources for insects, which can directly benefit biodiversity locally (Deguines et al., 2020), or changes in lifestyle such as reducing consumption, recycling more and picking up trash (Chase & Levine, 2017). CS in general is increasingly regarded as a promising format in environmental and sustainability education (Dickinson et al., 2012; Dunkley, 2017; Merenlender et al., 2016) as well as in science education (Wals et al., 2014). While science education 'focuses primarily on teaching knowledge and skills', environmental and sustainability education 'also stresses the incorporation of values and changing behaviors' (Wals et al., 2014, p. 583; also see, e.g. Gough, 2004; Jickling & Wals, 2008; Tilbury, 1995). Both science education and environmental and sustainability education stress the importance of the active involvement of the general public (Stevenson et al., 2013; Wals et al., 2014). CS allows the public to be actively involved in scientific research and to experience environmental science in a hands-on way. BDCS thus has the potential to contribute to environmental and sustainability education as well as to science education connected to biodiversity.

1.2 | Individual participant outcomes of biodiversity citizen science

Scientific research, and particularly biodiversity research, clearly benefits from the involvement of citizens in various research projects. This has been illustrated by the numerous scientific publications based on data collected by citizens, for example, on birds (e.g. Callaghan et al., 2019; Pellisier et al., 2019; Rosenberg et al., 2019), insects (e.g. Deguines et al., 2012; Pellisier et al., 2019; Richardson et al., 2018), sea slugs (e.g. Nimbs & Smith, 2018) and plants (e.g. Brodschneider et al., 2019). Most CS projects are designed and conducted by professional scientists and therefore focus on outcomes for science (Bonney et al., 2015; Phillips et al., 2018). In recent years, in addition to outcomes for science, an increasing number of CS projects have aimed to achieve outcomes for the participating citizens. In fact, many CS projects assume or expect that participants benefit from their involvement in the project, for example, through changes in knowledge, attitudes or behaviour (Cooper et al., 2007). However, whether these assumptions are justified and whether BDCS projects really achieve these (and other) participant outcomes still needs to be evaluated.

Participant outcomes are outcomes of CS projects for the individual participating citizen, as described in the framework for CS project outcomes by Jordan et al. (2012) and the framework for public participation in scientific research (PPSR) projects by Shirk et al. (2012). Participant outcomes can be gains in knowledge or skills, resulting from observations and experiences during participation in the project. These project outcomes on the part of the individual can lead to and influence other project outcomes (Shirk et al., 2012), such as outcomes for the project itself, for the community (Jordan et al., 2012), for social-ecological systems and for science (Shirk et al., 2012). Due to the novelty of CS in education, however, specific participant outcomes of CS have not been well formulated and defined (Phillips et al., 2018).

A comprehensive framework for individual participant outcomes of CS projects was recently developed at the Cornell Lab of Ornithology (Cornell University, USA). The 'Framework for articulating and measuring individual learning outcomes from participation in citizen science' (Phillips et al., 2014, 2018) is based on both literature and empirical data. It mainly draws from the concept of informal science education, also referred to as free-choice learning, that is, lifelong and self-directed learning outside formal education settings (Falk & Dierking, 2002). In particular, the framework is based on informal education frameworks by Friedmann et al. (2008), Bell et al. (2009) and Bonney, Ballard, et al. (2009). The framework developed by Phillips et al. (2018) describes six individual participant outcomes: 'content, process, and nature of science knowledge', 'skills of science inquiry', 'self-efficacy for science and the environment', 'interest in science and the environment', 'motivation for science and the environment' and 'behaviour and stewardship' (Table 1). These outcomes can realistically be achieved (and measured) in environmental CS projects (Bonney et al., 2015).

Several studies have examined participant outcomes of CS projects in an environmental context (e.g. Aivelo & Huovelin, 2020; Ballard et al., 2017; Brossard et al., 2005; Evans et al., 2005; Overdevest et al., 2004; Trumbull et al., 2000; see also Stepenuck & Green, 2015 and Schuttler et al., 2018 for reviews) or, more specifically, in a biodiversity-related context (e.g. Branchini et al., 2015; Chase & Levine, 2017; Cosquer et al., 2012; Deguines et al., 2020; Jordan et al., 2011; Lewandowski & Oberhauser, 2017; Toomey & Domroese, 2013). A recent systematic review analysed peer-reviewed scientific literature with an explicit focus on the individual participant outcomes of BDCS projects (Peter et al., 2019). The review identified the following participant outcomes reported in peer-reviewed studies: knowledge gain, change in behaviour, change in attitudes, new skills, increased self-efficacy, increased interest and other personal outcomes. The authors concluded that BDCS projects have the potential to foster learning about biodiversity and may encourage biodiversity-related action.

TABLE 1 Individual participant outcomes as defined in the 'Framework for articulating and measuring individual learning outcomes from participation in citizen science' (Phillips et al., 2018)

Outcome	Definition
Knowledge	Knowledge of science content (i.e. understanding of subject matter) and the nature of science; understanding of the scientific process and how science is conducted
Skills	Procedural skills such as asking questions, designing studies, collecting, analysing, and interpreting data, experimenting, argumentation, synthesis, technology use, communication and critical thinking
Self-efficacy	The extent to which a learner has confidence in his or her ability to participate in a science or environmental activity
Interest	The degree to which an individual assigns personal relevance to a science or environmental topic or endeavour
Motivation	Goal-driven inclination to achieve a science or environmental behaviour or activity
Behaviour	Measurable actions resulting from engagement in citizen science, but external to the protocol activities and the specific project-based skills of the citizen science project, for example, place-based and global stewardship, new participation and community or civic action

Although various studies have reported participant outcomes of BDCS projects, most studies were based on evaluations of single CS projects, and each study used different study designs and methods. This diversity makes it difficult to compare results and to draw general conclusions. Various authors therefore suggested that studies across several projects should be conducted and a common theoretical framework and common methods should be applied (e.g. Peter et al., 2019; Phillips et al., 2018; Stepenuck & Green, 2015; Stern et al., 2014).

1.3 | Aims of our research

We aimed to address this lack of comparative research by exploring individual participant outcomes of BDCS projects across a broad range of projects, countries and target species, applying a common framework and methods. Following the study by Phillips et al. (2019), who conducted cross-project analyses of six different environmental CS projects, we are, to the best of our knowledge, the first to adopt a large-scale approach, encompassing a larger number of BDCS projects taking place in various countries, to investigate whether and to what extent the six individual participant outcomes proposed in the framework by Phillips et al. (2018) were, from the participants' self-reported perspective, achieved in BDCS projects. The large scale of our study and the substantial sample size allow us to draw more general conclusions than smaller case studies of individual CS projects. We further aim to contribute to adapting and advancing existing frameworks for participant outcomes of CS. Finally, we believe that our research can provide a basis for future and more in-depth studies of individual participant outcomes of CS projects.

2 | METHODS

We conducted an online survey administered to participants of BDCS projects in Europe, Australia and New Zealand, and we analysed the responses quantitatively. Our survey addressed adults participating in BDCS projects as volunteers.

We chose BDCS projects according to criteria described by Peter et al. (2019):

1. Citizen science projects that involve volunteers in monitoring and identifying biological diversity and collecting biodiversity data. We excluded citizen science projects that are only indirectly related to biodiversity, for instance, projects studying bird biology and nesting success, or projects monitoring air and water quality.
2. Nature-based citizen science projects that take place in outdoor environments. Such projects may involve online species identification or data submission, for example, through project websites or smartphone apps, but they are not limited to online activities. We excluded citizen science projects that do not require participants to actually observe or interact with nature, for example, entirely online projects that ask participants to identify species in online photo databases.

2.1 | Data collection

Our study is based on the framework by Phillips et al. (2018) described above, which contains the following six participant outcomes: knowledge, skills, self-efficacy, interest, motivation and behaviour. To investigate these six outcomes, we developed a CS participant survey by analysing and comparing existing questionnaires. For the survey questions regarding skills and self-efficacy, we adapted the following scales provided by the Cornell Lab of Ornithology for use by other researchers: the Skills for Science Inquiry Scale (Phillips et al., 2017), the Self-Efficacy for Environmental Action Scale (Porticella et al., 2017a) and the Self-Efficacy for Learning and Doing Science Scale (Porticella et al., 2017b). We slightly shortened these scales to reduce the length of the questionnaire. In addition, we changed the wording of some items to make them more suitable for use in the English as well as the German version of the questionnaire. The survey questions regarding knowledge, interest, motivation and behaviour were inspired and informed by questions found in a variety of existing questionnaires evaluating participant outcomes, for example, the General Environmental Stewardship Scale (Phillips et al., 2017), and questionnaires used by Jordan et al. (2011), Toomey and Domroese (2013), Chase and Levine (2017) and Lewandowski and Oberhauser (2017). Items were selected for inclusion in our study based on theoretical relevance. The content and wording of these items were adapted to the subject and aims of our study.

We developed the online questionnaire using LimeSurvey software, version 3.17.9 + 190,731. The questionnaire contained mostly closed-ended questions (mainly 5-/6-point Likert-type, multiple-choice) as well as a small number of open-ended questions providing the opportunity for additional comments. While the closed-ended questions were mandatory, the open-ended questions were optional.

The questionnaire consisted of the following sections: questions about the CS project, about the amount and nature of participation, and about perceived outcomes. These self-reported outcomes concerned perceived changes in

- knowledge, such as awareness of species, understanding of biodiversity, learning about species, nature and science;
- skills of data collection and data analysis, etc.;
- self-efficacy towards the environment and science;
- interest in environmental and science topics;
- motivation for environmental and science activities;
- behaviour, such as involvement in environmental activities outside the CS project and
- potential other outcomes.

The questionnaire ended with demographic questions and final remarks. The questionnaire items for self-reported outcomes are available in Supporting Information, Tables S1–S10. The complete questionnaire is available upon request.

We developed an English and a German version of the questionnaire. The questionnaire was originally created in English, to facilitate the international approach of our study across countries. In addition, we developed a German version, reflecting the local setting of our research team, which was based in Germany. The questionnaire was translated into German by two independent translators who were not part of the research team. We then chose the most suitable translations. The questionnaire was pre-tested by 45 members of the general public (36 in German, nine in English) of different ages and educational/professional backgrounds to assure that the questions were clear and easy to understand, and to determine the average time required to complete the survey. The respondents gave us feedback and suggestions for improvement, which we incorporated into the final version of the questionnaire. We aimed to insure the validity of the scales by basing our questions on pre-existing scales and on items found in questionnaires previously used by other authors. The questionnaire was anonymous, and informed consent was obtained from the participants at the start of the survey. The survey was approved by the IPN Ethics Committee.

We contacted the coordinators of BDCS projects in Europe, Australia and New Zealand. We focused on these regions, first, for language reasons, and second, because of the high number of existing BDCS projects in these regions. We did not include North America because the majority of previous studies were conducted in that region (Peter et al., 2019). More than 60 projects agreed to take part and invite their project participants (minimum age: 18) to the survey, either by forwarding an invitation email provided by us to their participants or, if that option was not available to project coordinators, by including the link to our survey in one of their newsletters or by posting a message on their project website. Project coordinators were asked to send a reminder to their participants approximately 2 months after first inviting them to the survey. Due to privacy concerns and data protection issues, we were not able to contact project participants directly. In addition, we were not able to follow-up with all project coordinators who initially agreed to take part in our study, for example, due to staff changes, parental leave, etc. We therefore cannot provide the exact number of CS project participants who received the link to the questionnaire.

The questionnaire was open from 4 July 2019 to 30 November 2019. During that time, LimeSurvey registered 1,466 survey participants, that is, people who opened the link to the survey. In all, 1,179 participants provided at least their country and the name of the CS project they were participating in. We removed the remaining 287 (empty) questionnaires. Out of the 1,179 questionnaires, 19 participants reported participating in CS projects that did not fit into our definition of BDCS projects. That left 1,160 questionnaires for our analysis. Out of these, 915 participants completed the full set of questions.

2.2 | Data analysis

We analysed the quantitative data of the 1,160 questionnaires using IBM SPSS Statistics software version 24.0.0.2. We treated dependent variables (perceived outcomes) as continuous variables, assigning the values 1–5 to answer categories (e.g. responses coded as 1 for strongly disagree to 5 for strongly agree).

First, single items were combined into scales (Table 2). For the items regarding behaviour change, we performed an exploratory factor analysis to determine which items could be combined into scales (for details on the factor analysis, see the Supporting Information, Table S11). As a result of the factor analysis, three behaviour scales emerged: change in involvement in communication activities, gardening activities and general environmental activities. This was followed by reliability analyses (Cronbach's Alpha) for all scales. Items that could not be assigned to a specific scale or items that considerably lowered the Cronbach's Alpha were not included in scales. The reliability was good for all final scales presented in Table 2.

Second, we compared the different perceived outcomes (individual questions as well as scales) to find out which perceived outcomes were most pronounced among participants. We compared the mean values by performing one-way repeated-measures analyses of variance (RM-ANOVAs), including Mauchly's test of sphericity. Whenever sphericity could not be assumed, we used the Greenhouse–Geisser values (Greenhouse & Geisser, 1959).

TABLE 2 Overview of scales

Scales	Number of items	Reliability (Cronbach's Alpha)
Knowledge		
Change in awareness of species	3	0.857
Change in understanding of biodiversity	3	0.951
Learning about species, environment and science	3	0.769
Skills		
Gain in skills of data collection	4	0.845
Gain in skills of data analysis, etc.	6	0.865
Behaviour		
Change in involvement in communication activities	5	0.861
Change in involvement in gardening activities	3	0.747
Change in involvement in general environmental activities	3	0.806
Self-efficacy		
Change in self-efficacy for the environment	2	0.836
Change in self-efficacy for science	3	0.916
Interest		
Change in interest in the environment and in science	4	0.835
Motivation		
Change in motivation for the environment and for science	4	0.804

3 | RESULTS

In this section, we focus on the results of the quantitative data analysis. Additionally, we provide examples of respondents' comments regarding participant outcomes. When we talk about the *majority*, we are referring to a proportion of survey respondents >50%.

3.1 | Citizen science projects

The 1,160 survey respondents came from 12 different countries, the country with the highest number of participants being the UK (439), followed by Australia (223), Germany (164) and Austria (138) (Figure 1). Participants reported involvement in more than 63 different BDCS projects, the top four projects being Garden Bird Watch (UK, 178 survey participants), Wild Pollinator Count (Australia, 158), Breeding Bird Survey (UK, 76) and Kerbtier.de (Germany, 74). In addition to participants from the 63 projects, we received responses from the participants of 38 other projects that were not originally part of our survey (usually only one participant per project). For a complete

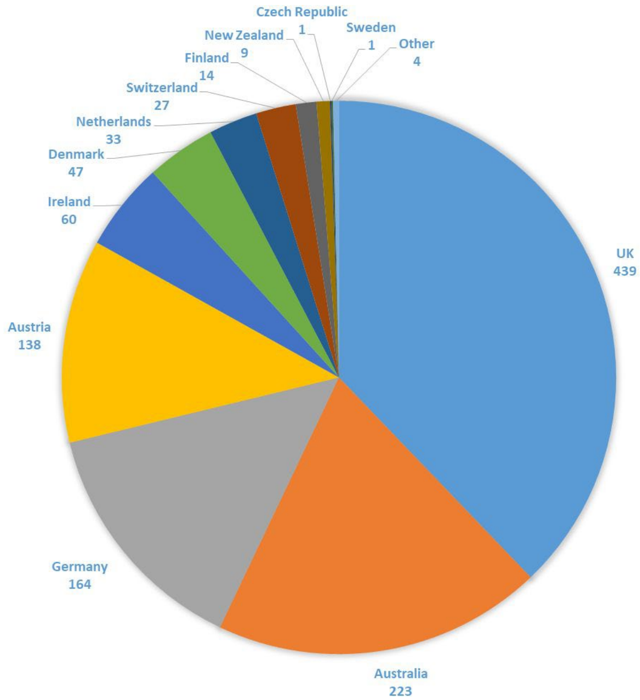

FIGURE 1 Number of survey respondents from each country

list of the 63 projects, please see the Supporting Information, Table S12.

The majority of participants reported that their CS project focused on insects (671 survey participants), followed by birds (600), mammals (302), plants (230), amphibians (195), reptiles (170), fish (69) and other species (mostly invertebrates and fungi, 73). Respondents could choose multiple answers.

3.2 | Participants

The demographic profile of survey participants (Table 3) was almost evenly split between women (52%) and men (48%). The majority of participants were at least 50 years old (77%), lived in rural areas or small cities (55%), had at least a bachelor's degree (68%, though not necessarily in ecological or environmental sciences) and were not involved in environmental/ecological research or management as part of their profession (76%). Both working (full-time, part-time or self-employed; 48%) and not officially employed (retired, out of work, student or full-time parent; 52%) participants were represented.

TABLE 3 Demographic characteristics of survey respondents

Demographic characteristics (*n* = 917)	Respondents (%)
Age	
18–29 years	3.5
30–39 years	6.4
40–49 years	13.3
50–59 years	24.8
60–69 years	35.3
70 years and over	16.7
Gender	
Female	51.9
Male	48.0
Other	0.1
Education	
Some high school	3.5
Completed high school	8.6
Completed trade/technical/vocational training	19.0
Bachelor's degree	27.6
Master's or other postgraduate degree	29.8
Doctorate (PhD, EdD, MD, etc.)	10.6
Other	0.9
Current employment	
Employed full-time	24.5
Employed part-time	12.3
Self-employed	11.1
Full-time housewife/-husband	2.1
Out of work and looking for work	0.9
Out of work but not currently looking for work	2.7
Student	2.3
Retired	43.8
Other	0.2
Professional in env./ecol. research or management	
No	75.9
Yes	24.1
Area	
Urban, inner city, metropolitan (population: 100,000 and more)	16.4
Suburban	29.0
Small city (<100,000)	12.2
Rural or farming community	42.4

3.3 | Participation

Project participants were mostly involved in identifying and recording species and submitting that data to the project database. In addition, participants often photographed the species they recorded. Fewer participants also collected, measured or tagged individual specimens. The majority of respondents had been involved in the project for at least 1 year (87%). Most respondents had actively participated in the project within the last month before answering the questionnaire (64%). The intensity of participation varied among participants: monthly and yearly time commitment varied greatly, the majority investing more than 10 hr per year (60%). The number of organisms recorded for the project also differed widely; 55% of participants had recorded more than 100 organisms for the project.

3.4 | Participant outcomes

Here we focus on the results of the quantitative data analysis regarding participant outcomes.

We provide the proportions of respondents who selected a certain answer (%), values for the number of participants who answered a question (sample size, *n*), averages (mean, *M*), the spread of data around the mean (standard deviation, *SD*), the significance of results (*p*, results are significant if $p < 0.05$) and the size of the observed effect (partial eta squared, η^2) (see Field, 2013). For effect sizes, we followed the widely used suggestions by Cohen (1988), who defined effect sizes as follows: small effect: partial $\eta^2 \geq 0.01$, medium effect: partial $\eta^2 \geq 0.06$, large effect: partial $\eta^2 \geq 0.14$. In addition to these quantitative results, we present some of the participants' comments to provide specific examples of participant outcomes.

3.4.1 | Participant outcome: Knowledge gain

The first three questions were about knowledge concerning species. The great majority of survey participants agreed ('agreed' or 'strongly agreed') that participating in the project had made them more aware of species' presence and behaviour (87%), of the diversity of species that existed in their region (86%) and of the principal threats to these species (72%).

The second set of questions concerned biodiversity. In the questionnaire, we provided the following explanation: 'Biological diversity (or biodiversity) is (among other things) the diversity of species that exist in an area'. When asked about how the project had impacted their understanding of biodiversity, participants agreed that participating in their CS project had increased their understanding of the term 'biological diversity' or 'biodiversity' (53%), of the importance of biological diversity (58%) and of the threats to biological diversity (63%). Please see Table 4 for the statistical summary.

The perceived increase in awareness of species ($M = 4.13$, $SD = 0.74$) was significantly higher than the perceived increase in understanding of biodiversity ($M = 3.67$, $SD = 0.96$), $F(1, 953) = 453.427$, $p < 0.001$, partial $\eta^2 = 0.32$ (large effect).

The final three knowledge questions were about learning: While 75% of participants agreed that, as a result of participating in their project, they had learned a lot about the species they found or observed, 56% agreed that they had learned a lot about the environment and nature in general, and 27.5% agreed that they had learned a lot about how science works. Perceived learning about species ($M = 4.01$, $SD = 0.92$), environment/nature ($M = 3.57$, $SD = 0.97$) and science ($M = 3.01$, $SD = 0.92$) differed significantly, $F(1.881, 1{,}790.884) = 580.045$, $p < 0.001$, partial $\eta^2 = 0.379$ (large effect).

In addition to the quantitative data, respondents commented, for example, that because of participating in the project they had 'a greater awareness of the local bird varieties and populations' (female, age group 50–59 years, UK) and they had started 'noticing more insect, plant and birdlife in our area, particularly indigenous species' (female, 50–59 years, Australia). Another respondent stated that 'by monitoring on a weekly basis I gained insight in the over the year fluctuations of butterfly numbers and the impact of management on their habitat' (male, 50–59 years, Netherlands). Another respondent mentioned that 'I've understood how important even a basic field job is for a bigger study' (male, 60–69 years, Finland).

TABLE 4 Scales and corresponding items for self-reported changes in participants' knowledge (*1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree)

Knowledge scales and items	*n*	Mean*	*SD*
Change in awareness of species	**954**	**4.13**	**0.74**
Increased awareness of species' presence and behaviour	953	4.24	0.81
Increased awareness of the diversity of species that exist in the region	954	4.24	0.82
Increased awareness of the principal threats to these species	953	3.93	0.88
Change in understanding of biodiversity	**954**	**3.67**	**0.96**
Increased understanding of the term 'biological diversity' or 'biodiversity'	953	3.57	0.99
Increased understanding of the importance of biological diversity	953	3.68	1.01
Increased understanding of the threats to biological diversity	954	3.77	1.00
Learning about species, environment and science	**954**	**3.53**	**0.77**
Learning about the species found or observed	954	4.01	0.92
Learning about the environment and nature in general	954	3.57	0.97
Learning about how science works	953	3.01	0.92

3.4.2 | Participant outcome: Gain in skills

The majority of participants agreed that by participating in the project, they had gained or improved their skills of data collection: observe/record species (78%), identify different species (81%), collect data in a standardised manner (64%) and submit their observations to the project database (75%) (Figure 2). Levels of agreement for skills beyond data collection were below 50%: use the project database to answer a question (46%), communicate project findings to others (35%), interpret the meaning of project data presented in maps, charts, graphs, etc. (34%), train others to participate in the project (22%), conduct statistical analyses using project data (13%) and design their own study related to project data (11%).

The differences between these perceived gains in skills (Table 5) were statistically significant, $F(5.865, 5{,}507.132) = 611.224$, $p < 0.001$, partial $\eta^2 = 0.394$ (large effect). In general, the perceived gain in data collection skills ($M = 3.88$, $SD = 0.70$) was significantly higher than the gain in skills of data analysis, interpretation

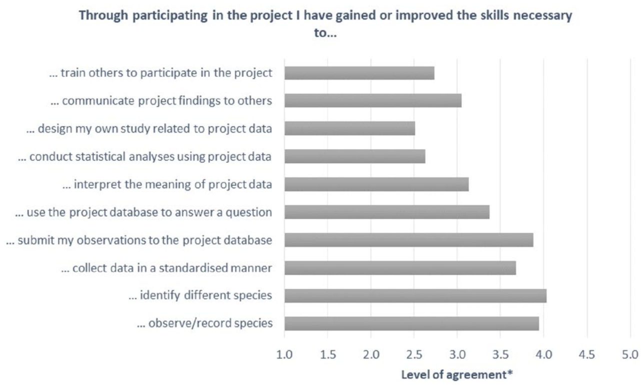

FIGURE 2 Self-reported gains in participants' skills (*1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree)

TABLE 5 Scales and corresponding items for self-reported changes in participants' skills (*1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree)

Skills scales and items	*n*	Mean*	*SD*
Gain in skills of data collection	**941**	**3.88**	**0.70**
Observe/record species	941	3.94	0.84
Identify different species	941	4.03	0.84
Collect data in a standardised manner	941	3.68	0.89
Submit my observations to the project database	941	3.88	0.81
Gain in skills of data analysis	**941**	**2.91**	**0.75**
Use the project database to answer a question	941	3.37	0.99
Interpret the meaning of project data presented in maps, charts, graphs, etc.	941	3.13	0.94
Conduct statistical analyses using project data	941	2.63	0.93
Design my own study related to project data	940	2.51	0.94
Communicate project findings to others	940	3.05	1.02
Train others to participate in the project	940	2.74	1.02

and communication (M = 2.91, SD = 0.75), F(1, 940) = 1,724.236, $p < 0.001$, partial $\eta^2 = 0.647$ (large effect).

Additionally, respondents commented that 'observing and recording daily has sharpened my observation skills' (female, age group 40–49 years, UK) and that participating in the project 'improved my scientific skills as a whole, allowing me to develop them in a context that is meaningful and useful' (female, 18–29 years, UK).

3.4.3 | Participant outcome: Behaviour changes

Slightly more than half of participants agreed that since starting to volunteer for their project, they had changed their actions that may affect the species they observed as part of the project (52%) or the environment generally (55%). When asked about their involvement in specific activities outside their project, participants' answers varied depending on the kind of activity. For one out of the 15 activities, we asked about (talk with others about animal or plant species), the majority of participants (55%) reported that since starting to volunteer for this project, they were more ('more' or 'much more') involved in this activity. A smaller proportion of respondents reported being more involved in the following activities: encourage others to join a CS project (49%), discuss other conservation and environmental issues with friends and family (47%), plant or sow native or insect-friendly plants (47%), collect data on other species and report them to other CS projects (46%), encourage others to sow or plant native or insect-friendly plants (43%), put up nesting boxes or insect hotels (39%), discuss land management practices that affect species' habitat (36%), sign petitions for environmental protection (35%), participate in environmental or conservation efforts (31%), donate to an environmental or conservation organisation (24%), reduce the use of fertilisers or pesticides (23%), participate in habitat restoration projects (17%), give presentations or talks about certain species (14%), and display signs to inform others about species (8%). The majority of respondents who did not report being more involved in the above activities reported that they had been involved in these activities before participating in the project and their involvement had not changed.

Several respondents provided examples of how participation in the project changed their actions: one respondent reported that 'I do less recreational (fun) diving and more conservation-/scientific-orientated diving' (male, age group 30–39 years, Australia). One respondent explained how participating in the project increased her communication activities by 'encouraging my grandchildren to observe and love bees, birds, gardening, etc. by building bee houses, writing stories for them about bees and animals in the garden and bush' (female, 70+ years, Australia). Another respondent reported a change in gardening practices: 'we stopped mowing tree corridors for the woodland birds to find cover. We've planted more bird-friendly trees in the lanes' (female, 40–49 years, Australia). Yet, another respondent explained that 'I have joined and financially support other organisations committed to the preservation of species in their natural habitat' (female, 60–69 years, Australia).

Perceived changes in involvement in the 15 different activities differed significantly, F(10.662, 10,385.185) = 119.378, $p < 0.001$, partial $\eta^2 = 0.109$ (medium effect). When summarising specific activities into scales (Table 6), it became clear that there were significant differences between communication activities (M = 3.56, SD = 0.57), gardening activities (M = 3.45, SD = 0.60) and more general environmental activities (M = 3.37, SD = 0.58), F(1.978, 1,932.501) = 55.196, $p < 0.001$, partial $\eta^2 = 0.052$ (small effect).

3.4.4 | Participant outcome: Change in self-efficacy

We asked participants to report changes in self-efficacy for the environment and for science. Regarding self-efficacy for the environment, the majority agreed that, since starting to volunteer for their

TABLE 6 Scales and corresponding items for self-reported changes in participants' involvement in environmental activities (*1 = Much less involved now, 2 = Less involved now, 3 = Involvement hasn't changed, 4 = More involved now, 5 = Much more involved now)

Behaviour scales and items	*n*	Mean*	*SD*
Change in involvement in communication activities	**978**	**3.56**	**0.57**
Talk with others about animal or plant species	978	3.69	0.75
Encourage others to sow or plant native or insect-friendly plants	978	3.52	0.69
Encourage others to join a citizen science project	977	3.56	0.68
Discuss land management practices that affect species' habitat	978	3.42	0.67
Discuss other conservation and environmental issues with friends and family	978	3.59	0.74
Change in involvement in gardening activities	**979**	**3.45**	**0.60**
Reduce the use of fertilisers or pesticides	979	3.27	0.71
Plant or sow native or insect-friendly plants	979	3.62	0.77
Put up nesting boxes or insect hotels	979	3.47	0.74
Change in involvement in general environmental activities	**979**	**3.37**	**0.58**
Participate in environmental or conservation efforts	978	3.36	0.68
Sign petitions for environmental protection	979	3.45	0.75
Donate to an environmental or conservation organisation	979	3.29	0.63

project, they felt more confident in their ability to make a positive impact on nature and the environment (57%). 50% agreed that they had become more optimistic that they could contribute to solutions to environmental problems with their actions. 56% disagreed with the statement 'Since starting to volunteer for this project it has become harder for me to imagine how I can help to protect nature'. Regarding self-efficacy for science, participants agreed with the following statements: since starting to volunteer for the project, they felt more competent about their abilities to do scientific activities (37%), they felt more confident about their ability to explain how to do scientific activities to others (33%) and they had become better at explaining science topics to others (30%). 56% disagreed with the statement 'Since starting to volunteer for this project, it takes me more time to understand new science topics'.

When comparing the two self-efficacy scales (Table 7), the perceived change in self-efficacy for the environment ($M = 3.476$, $SD = 0.835$) was significantly higher than the perceived change in self-efficacy for science ($M = 3.134$, $SD = 0.821$), $F(1, 933) = 172.083$, $p < 0.001$, partial $\eta^2 = 0.156$ (large effect).

TABLE 7 Scales and corresponding items for self-reported changes in participants' self-efficacy (*1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree)

Self-efficacy scales and items	*n*	Mean*	*SD*
Change in self-efficacy for the environment	**934**	**3.48**	**0.83**
I feel more confident in my ability to make a positive impact on nature and the environment	934	3.56	0.89
I have become more optimistic that I can contribute to solutions to environmental problems with my actions	934	3.39	0.91
Change in self-efficacy for science	**934**	**3.13**	**0.82**
I have become better at explaining science topics to others	934	3.08	0.87
I feel more competent about my abilities to do scientific activities	933	3.20	0.91
I feel more confident about my ability to explain how to do scientific activities to others	933	3.12	0.89

One respondent commented that participation in the project 'strengthened me in my belief that everyone can be involved in and help with science and protecting nature, and that this indeed can make a difference' (female, age group 18–29 years, Australia). Another respondent explained that 'learning about and being able to identify a larger variety of species … gives me more confidence in my role as an early childhood educator' (female, 40–49 years, Australia).

3.4.5 | Participant outcome: Change in interest

The majority of participants reported that participating in the project (slightly or greatly) increased their interest in the species they found or observed (84%), in topics connected with biological diversity (biodiversity) (67%), in environmental issues generally (58%) and in scientific topics or processes (51%).

The perceived change in interest (Table 8) differed significantly, $F(2.668, 2{,}454.623) = 310.14$, $p < 0.001$, partial $\eta^2 = 0.252$ (large effect).

Respondents commented that due to participation in the project 'my interest in bird species has increased strongly' (female, age group 50–59 years, Austria) and that participation 'has given me an extra deep interest in the future of bees' (male, 70+ years, Australia).

3.4.6 | Participant outcome: Change in motivation

Most participants stated that participating in their project (slightly or greatly) increased their motivation to find and record more species or individuals of a species (75%), to protect the species they encountered (73%), to protect the environment generally (63%) and to become more involved in other scientific activities (57%).

TABLE 8 Scales and corresponding items for self-reported changes in participants' interest and motivation (*1 = Decreased greatly, 2 = Decreased slightly, 3 = Stayed the same, 4 = Increased slightly, 5 = Increased greatly)

Interest/Motivation scales and items	*n*	Mean*	*SD*
Change in interest in the environment and in science	**921**	**3.93**	**0.63**
Interest in the species found/observed	921	4.35	0.78
Interest in topics connected with biological diversity (biodiversity)	921	3.92	0.77
Interest in environmental issues generally	921	3.81	0.80
Interest in scientific topics or processes	921	3.65	0.74
Change in motivation for the environment and for science	**921**	**3.96**	**0.63**
Motivation to find and record more species or individuals of a species	921	4.11	0.81
Motivation to protect the species encountered	921	4.10	0.80
Motivation to protect the environment generally	921	3.93	0.82
Motivation to become involved in other scientific activities	921	3.71	0.74

The perceived change in motivation (Table 8) differed significantly, $F(2.719, 2{,}501.335) = 104.907$, $p < 0.001$, partial $\eta^2 = 0.102$ (medium effect).

Respondents commented that as a result of participating in the project they became motivated to 'go out and do something, rather than sit and watch a screen' (female, age group 70+ years, UK), 'help change things for the better' (male, 70+ years, Ireland), 'pass on the skills that I have learned to other people' (male, 40–49 years, UK).

3.4.7 | Participant outcome: Other outcomes

In addition to the quantitative results that we describe above and that refer to participant outcomes defined in the framework by Phillips et al. (2018), we present a number of other personal participant outcomes that emerged during our study.

We asked participants about whether participating in the project influenced their life in any other way (positively and/or negatively). This was an open-ended question. While many answers referred to the outcomes described above, numerous respondents described other outcomes not mentioned in the framework by Phillips et al. (2018). We summarised these outcomes into categories described below. The categories were developed using an inductive approach, that is, they emerged directly from the content of participants' responses. The responses to the open-ended question were sorted according to content by the first author. The resulting categories were then discussed with and confirmed by the fourth author. These categories are not clear-cut; instead, they may overlap slightly. We intended to summarise participants' comments to offer a more complete picture of the variety of other possible participant outcomes.

The answers most often given referred to a feeling of *well-being* (described by 85 respondents), for example, one respondent commented that 'through participation in the project I spend more time in nature' (male, 18–29 years, Germany). Other respondents stated that 'because of the excursions to nature I have become much more calm and relaxed' (male, 40–49 years, Germany), 'I feel more balanced when I spend time in nature and observe and photograph different species' (male, 18–29 years, Austria), 'It has encouraged me to get outdoors and to visit places I wouldn't normally go to' (female, 40–49 years, UK) and 'watching wildlife in the garden can be a valuable distraction from worries' (male, 60–69 years, UK).

In addition to well-being, several responses specifically referred to (physical and mental) *health benefits* (16 respondents). Participants reported that 'going out every week improves my health' (male, 50–59 years, Netherlands), 'I do considerably more hiking in the mountains, which is good for my health' (male, 60–69 years, Austria) and 'my … mental health definitely benefits from participating in the project' (female, 30–39, UK).

The second most frequently described outcome was *enjoyment* (64 respondents). One participant described that 'I get a lot of joy from observing and recording my garden birds' (female, 30–39 years, UK). Especially finding new species seemed to be a source of joy for many participants as these responses show: 'it simply gives me joy to discover species previously unknown to me' (male, 40–49 years, Austria), and 'finding a new insect gives me a real thrill' (female, 60–69 years, Australia).

The third most frequently described outcome was a sense of *satisfaction and contribution* (58 respondents). Examples are as follows: 'This year (2019) has been a bumper year for fledglings in the garden and I feel good about contributing to the success of these species' (female, 50–59, UK), 'I feel I am making a positive contribution to research in the changes taking place in our numbers of birds and insects' (male, 60–69 years, UK) and 'I am also proud to be involved in this worthwhile project' (male, 70–79 years, Switzerland). One participant stated that participating in the project 'let me feel that at the age of seventy I can still contribute to this world' (female, 70–79 years, UK).

Another outcome reported by respondents was an increased *connection to people* (19) *and to nature* (11) as a result of participation in the projects. One respondent described that she 'connected with lots of interesting scientists and community members' (female, 30–39 years, Australia). Another respondent described that 'in the greater area of my home, we found each other and we get together as a group to meet regularly … for excursions to collect data. … And now we have also become friends over the past few years' (female, 50–59, Germany). Several participants described an increased connection to nature, as these responses show: 'I am more engaged with my local environment as a result of walking the transects monthly March–October' (female, 30–39, UK), and 'I … see the birds in my garden as "family"' (female, 60–69 years, Ireland).

Furthermore, several respondents reported that they became *more observant* of their environment and of nature (16), for example, 'it has made me much more observant about what is in my back garden' (female, 60–69 years, Australia) and 'I have to watch butterflies everywhere' (female, 30–39 years, Netherlands).

Several respondents also described how participating in the project affected their *career* (13), for example, 'I'm going back to university to study environmental science' (female, 30–39, Australia), 'I retrained and changed career to become a wildlife ranger' (female, 40–49 years, Ireland) and 'it was one factor in my decision to retire early and then to spend a significant amount of time on citizen science and conservation' (male, 60–69 years, UK).

Some respondents reported an increased *appreciation* (4), for example, a 'greater appreciation of the natural world' in general (female, 40–49 years, UK). Another respondent stated that 'I am generally more observant of pollinators and appreciate them' (female, 18–29 years, Australia).

Finally, several respondents mentioned negative outcomes that referred to a more pessimistic outlook regarding the future of the environment (17), for example, 'since attempting to count bumblebees and not finding as many as there should, I've become more depressed about the future of biodiversity' (female, 60–69 years, UK), and 'I see the enormous environmental destruction by humankind, that depresses me' (male, 60–69 years, Germany).

4 | DISCUSSION AND CONCLUSIONS

The objective of our study was to find out whether and to what extent the six individual participant outcomes proposed in the framework by Phillips et al. (2018) had been achieved in BDCS projects. Survey respondents reported all six participant outcomes suggested in the framework, namely gains in content, process, and nature of science knowledge, gains in skills of science inquiry, increased self-efficacy for science and the environment, increased interest in science and the environment, increased motivation for science and the environment, and changes in behaviour towards the environment. In addition, respondents mentioned positive outcomes not included in the framework, concerning health and well-being, satisfaction, enjoyment, connection to nature and to people, career changes, appreciation of nature, and finally, negative outcomes.

4.1 | Gains in knowledge, interest, motivation and self-efficacy

In our study, participant outcomes regarding knowledge, interest, motivation and self-efficacy had in common that they differed depending on whether they concerned the environment and nature or science. Our results suggest that participants' knowledge, interest and motivation increased most when related to species, less when related to the environment in general and least when related to science in general. Similarly, self-efficacy towards the environment increased more than self-efficacy towards science.

Similar findings, that is, higher increases in knowledge, interest, motivation and self-efficacy regarding the environment and lower increases regarding science have been reported by other authors. Several case studies found gains in knowledge about species (Cosquer et al., 2012; Druschke & Seltzer, 2012; Jordan et al., 2011; Sickler et al., 2014) or more general environmental knowledge (Bela et al., 2016; Branchini et al., 2015; Cosquer et al., 2012; Fernandez-Gimenez et al., 2008; Haywood et al., 2016; Leong & Kyle, 2014). Gains in environmental knowledge are in line with the framework for PPSR by Shirk et al. (2012), which lists gains in content knowledge as one of the typical outcomes of CS. Gains in science-related knowledge are reported less often in the literature. While Bela et al. (2016) and Haywood (2016) reported gains in knowledge about general scientific processes, other authors (Brossard et al., 2005; Jordan et al., 2011) did not find changes in science-related knowledge (e.g. knowledge about the nature of science). Interest as a participant outcome (of BDCS projects) has not been studied as widely as knowledge, but Toomey and Domroese (2013) found an increased interest in general environmental issues. Contrary to our findings, Jordan et al. (2011) did not find changes in self-efficacy towards the environment, which they attributed to an increased awareness of the negative effects of invasive species on the environment. Haywood et al. (2016), however, reported positive changes in self-efficacy regarding CS as such. While an increase in knowledge about the environment or science as a participant outcome of BDCS has been studied widely (Peter et al., 2019), additional results on interest, motivation and self-efficacy regarding the environment and science would be valuable.

The positive results of our study concerning self-reported increases in knowledge, interest, motivation and self-efficacy regarding the environment and nature in general, and biodiversity in particular, are encouraging for environmental and sustainability education. The most prominent result of our study is that participants reported a great increase in knowledge, interest and motivation regarding species. In this way, BDCS might have the potential to contribute to reversing the 'erosion of species experts' (Frobel & Schlumprecht, 2016) and the 'extinction of experience' (Schuttler et al., 2018, see also Gaston & Soga, 2020). Also, by integrating CS into formal education, CS could be an excellent way for children, adolescents, and young adults to experience nature, gain knowledge about species, and develop an interest in species and biodiversity. This could be particularly important as many current biology teachers have limited knowledge about species (Frobel & Schlumprecht, 2016). The number of biology courses that teach species identification at colleges and universities has been declining (Bromme et al., 2004); thus, many biology graduates as well as biology education graduates do not have sufficient knowledge of species (Frobel & Schlumprecht, 2016). Integrating CS into tertiary education might supplement the curriculum and eventually counteract the current decline of species experts (Frobel & Schlumprecht, 2016). In addition, the results of our study are reflected in the UNESCO learning objectives concerning biodiversity, such as identifying local species and understanding the concept of biodiversity and threats posed to biodiversity (UNESCO, 2017). While the results of our study concerning knowledge are certainly encouraging, there is not necessarily a direct connection between knowledge and behaviour change (Jordan et al., 2011). If indeed behaviour change is a goal of environmental and sustainability education (Wals et al., 2014), more in-depth research into connections between knowledge and behaviour change are necessary. Nevertheless, we conclude that BDCS has potential not only for informal environmental and sustainability education but also for formal elementary, secondary and tertiary education.

The results of our study on gains in knowledge, interest, motivation and self-efficacy with regard to science were not as positive as those with regard to the environment. One reason for the lower outcomes regarding science might be participants' initial interest and motivation for joining the CS project. Participants might simply be more interested in nature or the environment and in the species that the project focuses on than in science as such or in scientific topics and methods. Helping biodiversity can be one of the main motivations for people to join BDCS projects (Cosquer et al., 2012; Prévot et al., 2017). Another explanation for these lower outcomes regarding science could be that many projects are simply not designed to change participants' perspectives about science, as Bonney et al. (2015) pointed out. Many project designers assume that participants learn about science because they read or watch the instructions for data collection provided by the project and participate in the project. Bonney et al. (2015) argued, however, that CS participants will not change their perspectives about science simply because they participate in the project. They need to reflect on their role in the project and how this is connected to the whole scientific process. Both Brossard et al. (2005) and Jordan et al. (2011) noted that the projects evaluated in their studies did not contain enough information that explicitly explained scientific processes. Nor did those projects offer sufficient time and opportunity for participants to reflect on the scientific content of the project or on participants' role in the scientific process. From our results, we conclude that BDCS might currently have greater potential for environmental and sustainability education than for science education. There seems to be a need for improved project designs if participants are to benefit from their participation and gain new perspectives about science. This, again, might also be a chance for formal education. In the classroom (or seminar room), teachers (or lecturers) could act as guides and mentors, offering opportunities for reflecting on the project and the scientific processes involved (Aivelo & Huovelin, 2020).

4.2 | Gains in skills

Although the majority of survey respondents reported having gained skills of data collection, a lower proportion reported having gained skills not directly related to data collection. Data collection skills that were found to have increased in other studies on BDCS include species identification (Haywood et al., 2016; Sickler et al., 2014) and measuring specimens (Haywood, 2016). Two studies also reported gains in scientific skills but did not further specify the kind of skills gained (Bela et al., 2016; Fernandez-Gimenez et al., 2008). Jordan et al. (2011) investigated skills not directly connected to data collection. They found that skills related to data analysis had not increased during participation in the project. This prevalence of an increase in data collection skills is also in agreement with the PPSR framework by Shirk et al. (2012).

There are several reasons for the relatively high increase in self-reported data collection skills and the lower increase in other skills. First, most BDCS projects mainly involve their participants in data collection and therefore require data collection skills only. BDCS projects are often contributory and scientist-driven projects and are therefore usually limited to participants collecting data (Bonney, Cooper, et al., 2009). Consequently, these projects are most effective in influencing data collection skills (Phillips et al., 2018). In fact, Stylinski et al. (2020), in a survey of project coordinators and a review of the literature, found that the most common skill required by the great majority of CS projects was 'making and recording reliable/accurate observations or measurements', which included identifying species and measuring and counting organisms (Stylinski et al., 2020), p. 7). Second, data collection skills might be easy to gain with relatively little training. In contrast, gaining skills related to data analysis, interpretation and communication might require more guidance by project staff and more commitment by participants (Pandya & Dibner, 2018). And finally, scientists might simply not need external assistance with data analysis, interpretation or communication (Stylinski et al., 2020). Certainly, the skills required for participation in a CS project need to be in line with participants' level of commitment as well as their interests and abilities (Golumbic et al., 2017). Interest in science as well as motivation for doing scientific activities increased during participation, as stated by half of the respondents of our study. These participants might be keen to learn skills beyond data collection. If projects seek to improve participants' skills beyond data collection, projects will have to develop ways of training their participants and developing their abilities. Contributing data might be a good starting point for engagement with science; additional tasks and responsibilities beyond data collection might then offer more opportunities for a more advanced engagement with science.

Our results suggest that there is a discrepancy between respondents' interest in and motivation for science on the one hand, and their perceived gains in science-related knowledge, self-efficacy and skills on the other hand. About half of the respondents stated an increased interest in science topics, and more than half an increased motivation to become more involved in other scientific activities. But less than one-third of our respondents felt that they learned a lot about how science works, and only one-third felt a higher self-efficacy towards science. Similarly, Brossard et al. (2005) and Jordan et al. (2011) reported that science-related knowledge had not increased in their studies. In addition, while the majority of our survey respondents reported having gained skills of data collection, only one-third of respondents reported having gained skills not directly related to data collection (and it would be interesting to know whether participants would be interested in gaining these additional skills). Jordan et al. (2011) also found that skills beyond data collection had not increased during participation in the CS project. This discrepancy might point towards training needs for CS participants regarding scientific methods and processes. Brossard et al. (2005) and Jordan et al. (2011) argued that participants need to spend more time and get more information on the project's scientific content and process. Bonney et al. (2015) emphasised that participants of CS projects need the opportunity to reflect on their role as citizen scientists within the project and the general scientific process. Training materials and workshops could be developed to provide these opportunities. Through its practical, hands-on, and participatory nature, and by combining theory and practice, CS could be well suited to teaching a variety of scientific knowledge and skills and increasing self-efficacy for science.

4.3 | Behaviour change

Behaviour changes reported by our survey respondents were most pronounced when regarding communication activities and participation in other CS projects, less pronounced when relating to gardening practices and least pronounced when relating to general environmental behaviour not directly connected to the species and activities of the project. Previous case studies of BDCS projects confirm our results. Jordan et al. (2011) and Lewandowski and Oberhauser (2017) also found increased communication activities about the project and the observed species to be the most pronounced behaviour change. Changes in gardening practices, such as planting host plants for insects and using less pesticides, were reported by Cosquer et al. (2012), Toomey and Domroese (2013), Lewandowski and Oberhauser (2017) and Deguines et al. (2020). More general environmental behaviour changes included conservation action (Bela et al., 2016; Haywood et al., 2016; Lewandowski & Oberhauser, 2017), wildlife-friendly behaviour (Druschke & Seltzer, 2012) and general lifestyle changes (Chase & Levine, 2017; Haywood, 2016). While Chase and Levine (2017) reported that one-third of respondents had changed their general environmental behaviour, Druschke and Seltzer (2012) found no changes in behaviour at all. In a recent study, Richardson et al. (2020) found that 'simple nature activities' (e.g. watching or photographing wildlife) contributed significantly to people's pro-nature conservation behaviour. Although the behaviour changes reported by the respondents in our study are certainly positive, it would be desirable for BDCS projects to achieve greater levels of behaviour changes with regard to gardening practices and more general environmental activities, and especially with regard to activities that directly lead to the conservation of biodiversity, as stressed by Richardson et al. (2020).

Various explanations for these differences or even lack of behaviour changes have been suggested. First of all, because participants were self-selected, many of them might have had pro-environmental attitudes and might have been involved in pro-environmental behaviour before starting to participate in the CS project (Bonney et al., 2015; Brossard et al., 2005). In fact, in our study, the majority of respondents, who had not changed their actions, stated that they were already involved in these kinds of actions before joining the project. As one respondent of our survey commented, 'I have been interested in invertebrates for about 10 years, particularly native solitary bee, and have taken part in the (project) because of my interest, it has not changed anything much' (female, 70+ years, Australia). The high level of pre-existing involvement in pro-environmental activities might, to a certain extent, be attributable to the relatively high age of our survey respondents (77% over 50 years old), as Jones et al. (2020) found that older people perceive a greater need for species conservation than younger people. Helping biodiversity conservation might even have been the main motivation for participants to join BDCS projects (Cosquer et al., 2012; Prévot et al., 2017); as one of the respondents of our survey put it: 'The above motivations have ALWAYS been felt… they are why I volunteered for the surveys I do' (female, 70+ years, UK). Second, the lower number of respondents who changed their general environmental behaviour might be due to participants not seeing any direct connection between the project itself or the species observed and potential more general environmental activities (Toomey & Domroese, 2013). And third, individual behaviour changes can be influenced by various factors (Stern, 2000). For example, Deguines et al. (2020) investigated how people changed their gardening practices as a result of participating in CS. They found a number of factors that affected changes in gardening practices related to biodiversity, for example, the size of participants' gardens as well as the presence or absence of fruit trees and the purpose of the garden (growing vegetables or not). Future research could shed more light on the factors that affect and potentially limit behaviour changes that could result from participating in BDCS projects. In-depth interviews with CS participants might provide additional insights. Furthermore, if indeed many of the current CS participants were already involved in pro-environmental activities before joining a CS project, it might be worthwhile to increase efforts to recruit, for example, younger participants who are not yet engaged in such activities.

4.4 | Other individual participant outcomes

Various other perceived outcomes that did not fit into the framework by Phillips et al. (2018) were described by the participants in our study. The outcomes described most often concerned increased health and well-being, a greater sense of satisfaction, increased enjoyment and a greater connection to nature as well as to other (like-minded) people. Fewer respondents mentioned changes concerning their career, gains in confidence and a greater appreciation of nature. Finally, a small number of respondents described negative outcomes such as becoming pessimistic about the future of the environment in general or, more specifically, becoming depressed about the future of biodiversity. Two recent reviews, one of nature-based CS (Schuttler et al., 2018) and the other of BDCS (Peter et al., 2019), also found individual participant outcomes that did not fit into the categories proposed by Phillips et al. (2018). The authors placed them in either a 'well-being' category (Schuttler et al., 2018) or in a more general 'other personal outcomes' category (Peter et al., 2019). Previous case studies found similar outcomes. Benefits were reported for physical (Haywood, 2016) and mental health and well-being (Haywood et al., 2016; Koss & Kingsley, 2010). Koss and Kingsley (2010) and Haywood et al. (2016) found a general sense of satisfaction, contribution or achievement as a result of participating in CS. Enjoyment as an outcome was mentioned by Koss and Kingsley (2010) and Sickler et al. (2014). Several authors reported a greater connection to nature (Chase & Levine, 2017; Fernandez-Gimenez et al., 2008; Haywood et al., 2016; Koss & Kingsley, 2010), and to like-minded people (Cosquer et al., 2012; Haywood, 2016; Lewandowski & Oberhauser, 2017). In addition, trust was described as a participant outcome in two previous studies. Trust between CS participants and other stakeholders, for example, scientists, was reported to have changed positively (Bela et al., 2016; Fernandez-Gimenez et al., 2008) as well as negatively (Bela et al., 2016) for some participants of CS projects. Trust as a positive or negative outcome, however, was not mentioned by any respondents of our survey.

These other participant outcomes, especially the sense of satisfaction and contribution, enjoyment, and connection to nature and people, are associated with citizens' motivation for getting or remaining involved in CS projects (Phillips et al., 2019). Such outcomes may also be associated with behaviour changes towards the environment (Dayer et al., 2019; Evans et al., 2005; Navarro-Perez & Tidball, 2012; Schuttler et al., 2018). It might therefore be worthwhile to pay more attention to such more affective and emotional participant outcomes of CS projects. Phillips et al. (2019) took a step in this direction by including feelings/emotions as an important dimension of engagement in CS. As Phillips et al. (2018, p.7) pointed out, their framework 'is not exhaustive ..., new research will inevitably reveal other learning outcomes that are important to articulate and measure.' A more comprehensive framework for participant outcomes of CS projects could include such additional outcomes.

A greater appreciation of the environment was mentioned as an outcome by several of our survey respondents. Appreciation is an attitudinal construct (Osborne et al., 2003). Attitudes can be defined as 'general and enduring positive or negative feelings about some person, object or issue' (Petty & Cacioppo, 1981, p. 7). The framework developed by Phillips et al. (2018) does not include attitudes as such as an outcome. Instead, Phillips et al. (2018) proposed interest and motivation, two attitudinal constructs (see Osborne et al., 2003), as outcomes. We used the framework by Phillips et al. (2018) as a guideline for our research and defined participant outcomes accordingly. However, as Phillips et al. (2018) pointed out, attitudes encompass more than just interest and motivation. Their framework might, therefore, not cover all attitude changes that take place as a result of participating in CS. The recent review by Peter et al. (2019) found attitude changes to be an important outcome of BDCS projects. These attitude changes included, for example, appreciation for species (Toomey & Domroese, 2013), for the services provided by ecosystems (Haywood, 2016), for nature in general (Chase & Levine, 2017; Toomey & Domroese, 2013), as well as attitudes about scientists (Druschke & Seltzer, 2012) and the value of science (Haywood et al., 2016). Although few participants of our study specifically mentioned an increased appreciation for the species observed and for the environment in general, we think that this could be an important outcome that should be considered and investigated in more depth. Appreciation as well as other outcomes related to attitude changes might be part of a more comprehensive framework for participant outcomes of (BD) CS projects.

Finally, several of our survey respondents mentioned perceived negative outcomes of participating in CS. These negative outcomes referred to a more pessimistic outlook regarding the future of the environment and, specifically, of biodiversity. Negative outcomes of participating in CS have not been reported widely. Bela et al. (2016) reported a decrease in trust between participants and project scientists in some CS projects. Aivelo and Huovelin (2020) mentioned demotivation of participants as a negative outcome, which was caused by participants not finding the organisms they were looking for. Phillips et al. (2019) reported a variety of negative emotions experienced by CS participants, such as uncertainty, frustration and sadness. Reasons for the lack of literature on negative participant outcomes might be that no negative outcomes were found or that negative outcomes were not investigated or published. The respondents of our study were self-selected. It is possible that project participants who felt that participating affected them in a negative way had already dropped out of the project and/or were not motivated to participate in our survey. It might be useful for project coordinators to know about both the positive and the potential negative outcomes of their project. It might enable them to address these issues more specifically and to improve the design of the project or to communicate with participants so that, for example, disappointment at not finding species might turn into learning opportunities and changes in data collection methods (Aivelo & Huovelin, 2020). In-depth research on potential negative outcomes and how to address them could lead to CS projects better achieving desired outcomes.

4.5 | Limitations

Due to the large scale of our study, which spanned various CS projects, and the comparatively large number of survey respondents, our study provides valuable insights into participant outcomes of BDCS projects. However, our study has some limitations that could be addressed through further research. First, because we did not have access to project participants' contact details, the respondents of our survey were self-selected. The survey was not incentivised; we therefore assume, as did, for example, Jones et al. (2020), that many of our respondents may have been highly interested and motivated project participants. Thus, as in many surveys, our results might be subject to response bias. The participation of highly motivated survey respondents can lead to overall positive outcomes and a ceiling effect, which means that changes are harder to detect. This is known to be a problem in CS project evaluation (Cooper, 2012). More sensitive scales as well as additional qualitative methods might be useful in future research. Also, studies that target non-voluntary participants, for example school students, who are not necessarily highly motivated to participate, might avoid a potential ceiling effect. A second limitation of our study is that the survey took place only once. Ideally, participant surveys should take place before and after participation in the project to be able to compare pre-participation responses with post-participation and follow-up responses. However, this kind of study design is difficult to implement in informal contexts with flexible and voluntary/free-choice participation and has therefore rarely been implemented (Aristeidou & Herodotou, 2020). Third, parts of our questionnaire were based on validated scales [the Skills for Science Inquiry Scale (Phillips, Porticella, et al., 2017), the Self-Efficacy for Environmental Action Scale (Porticella et al., 2017a), and the Self-Efficacy for Learning and Doing Science Scale (Porticella et al., 2017b)]. However, there is a lack of validated scales, on, for example, biodiversity-specific behaviour (Richardson et al., 2020); the development of psychometrically validated scales would be useful for future research. Fourth, this article presents self-reported participant outcomes. This means that our results rely on outcomes as perceived and reported by the participants themselves instead of on objectively measured and assessed outcomes. The field of BDCS would benefit from the development of innovative study designs and methods that could measure participant outcomes more objectively without deterring participants, especially in informal contexts. In the meantime, CS projects conducted within formal educational contexts might provide opportunities for assessing participant outcomes in a non-voluntary setting (e.g. Vitone et al., 2016). Finally, our study investigated CS projects that take place in Western societies only. The cultural context can affect participation in CS projects (Chase & Levine, 2016; Tiago, 2017) and might have influenced the results of our study regarding, for example, perceived behavioural and other participant outcomes. A broader investigation of CS projects that take place in and across other cultural contexts would deepen our knowledge in this regard and contribute to an optimised design of BDCS in the efforts to protect biodiversity worldwide (see, e.g. Briggs et al., 2019). Despite these limitations, our study provides valuable examples of individual participant outcomes of BDCS projects.

4.6 | Outlook

Our results suggest that BDCS has potential for environmental and sustainability education and for science education connected to biodiversity. The findings and recommendations of our research can benefit the various stakeholders of BDCS projects such as practitioners, scientists and participating citizens. We hope that our findings might create an awareness among CS project leaders and scientists of the importance of project outcomes not only for science but also for participants. Also, we hope that the results of our study will help the participating citizens to recognise existing outcomes of their projects and to be able to communicate their needs (regarding future outcomes) to project leaders. This could lead to an improved design of CS projects with a stronger focus on outcomes for the participating citizens, from an individual to a community level. Furthermore, our findings can contribute to more comprehensive frameworks for participant outcomes. In addition, we hope that our broad-scale research will provide a basis for future and more in-depth studies of individual participant outcomes of CS projects and for research into the factors that influence (i.e. promote or prevent) such participant outcomes. More in-depth research on how participant outcomes are connected to factors on the side of the participant, such as age and gender, would be valuable. In our study, most respondents were older than 50 years, and gender was balanced. It would be useful to investigate participant outcomes in projects whose participants are younger or in projects that attract predominantly male or female participants. Research into further factors on the side of the participants, such as their educational, professional and other social/cultural background, would also be valuable. As a result, future BDCS projects could be better designed to allow participants with different backgrounds to benefit from their participation in the project in different ways. In particular, insights into factors related to the project itself (project structure and design characteristics) would make it possible to draw conclusions for project development and design. Future research needs to address this gap. In this respect, it would be valuable to explore the perspectives of both project participants and project coordinators. As a result, BDCS projects could be more effective in achieving participant outcomes in addition to scientific outcomes. Ultimately, participant outcomes, such as changes in participants' knowledge of and behaviour towards biodiversity, could contribute to biodiversity conservation, which is urgently needed to stop the current and rapid loss of the diversity of life on Earth.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTIONS

M.P., K.K. and T.D. conceptualised the study; M.P. and T.H. designed the methodology; M.P. collected the data; M.P. and T.H. analysed the data; M.P. led the writing of the manuscript; M.P., T.H., T.D. and K.K. reviewed and revised the manuscript. All authors gave final approval for publication.

DATA AVAILABILITY STATEMENT

The data used for this study are available from the Dryad Digital Repository https://doi.org/10.5061/dryad.0vt4b8gxx (Peter et al., 2021). To preserve participants' anonymity, project names and countries in the dataset were anonymised.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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