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Review

Participant Outcomes of Biodiversity Citizen Science Projects: A Systematic Literature Review

Maria Peter [1,2,*], Tim Diekötter [2] and Kerstin Kremer [3,4]

1 Kiel Science Outreach Campus (KiSOC), IPN - Leibniz Institute for Science and Mathematics Education, Olshausenstr. 62, 24118 Kiel, Germany
2 Department of Landscape Ecology, Institute for Natural Resource Conservation, Kiel University, Olshausenstr. 75, 24118 Kiel, Germany; tdiekoetter@ecology.uni-kiel.de
3 Department of Biology Education, IPN - Leibniz Institute for Science and Mathematics Education, Olshausenstr. 62, 24118 Kiel, Germany; kremer@idn.uni-hannover.de
4 Biology Education, IDN - Institute for Science Education, Leibniz University Hannover, Am kleinen Felde 30, 30167 Hannover, Germany
* Correspondence: mpeter@ipn.uni-kiel.de; Tel.: +49-(0)431-880-5976

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Abstract: Citizen science is becoming increasingly popular as a format in environmental and sustainability education. Citizen science not only allows researchers to gather large amounts of biodiversity-related data, it also has the potential to engage the public in biodiversity research. Numerous citizen science projects have emerged that assume that participation in the project affects participants' knowledge, attitudes, and behavior. We investigated what evidence really exists about the outcomes of biodiversity citizen science projects on the side of the individual participants. For this purpose, we conducted a systematic review of peer-reviewed research articles published up to and including 2017. We found evidence for various individual participant outcomes. The outcome reported most often was a gain in knowledge. Other outcomes, found in several articles, referred to changes in behavior or attitudes. Outcomes reported less often were new skills, increased self-efficacy and interest, and a variety of other personal outcomes. We discuss the research design and methods used in the reviewed studies und formulate specific recommendations for future research. We conclude that citizen science is a promising option for environmental and sustainability education focusing on biodiversity. Partnerships between natural and social scientists in the design and evaluation of projects would allow future biodiversity citizen science projects to utilize their full educational potential.

Keywords: attitude; behavior; environmental education; impact; interest; knowledge; public participation in scientific research; self-efficacy; skill; sustainability education

1. Introduction

An increasingly popular format in environmental and sustainability education is citizen science [1,2]. Citizen science, also referred to as public participation in scientific research [3], engages citizens or members of the public in genuine scientific research projects [4,5]. It has become widespread in environmental sciences and especially in biodiversity research. Citizen science has been used extensively to allow scientists to involve large numbers of citizens in their research on biodiversity and to thereby gather data that they would not have been able to collect on their own [6–8].

1.1. Biodiversity Citizen Science

Biodiversity citizen science projects involve the public in monitoring, identifying, and recording biodiversity [8]. In this context, biological diversity can be defined as "the presence and/or abundance of identified taxonomic (e.g., species, genus, family), genetic, or functional groups" [8] (p. 237). Examples of citizen science projects focusing explicitly on biodiversity are the Big Butterfly Count in the UK [9], Stunde der Gartenvögel in Germany [10], Sauvages de ma rue in France [11], eBird in North America [12], and the Atlas of Living Australia [13]. As a result, numerous scientific articles that use data collected by citizens have been published in peer-reviewed journals [8,14,15]. Citizen science has thereby contributed considerably to research on biodiversity.

In addition to its scientific potential, citizen science is increasingly seen as having great potential as a format in both science education [16] and environmental and sustainability education [2,16,17]. Both emphasize the importance of the active participation of the public [16,18]. Citizen science is, by definition, highly participatory and engaging [17,19]. Biodiversity citizen science therefore has the potential to create a more conservation-literate society [20,21].

1.2. Participant Outcomes

The outcomes of citizen science for biodiversity research are numerous. The large number of publications based on data gathered by citizens demonstrates this. What, however, are the outcomes on the side of the participating citizens? Many citizen science projects have emerged with the goal and assumption that participation in the project has an impact on the knowledge, attitudes, and behavior of the participants [22]. But do biodiversity citizen science projects achieve these goals? Do citizens learn about biodiversity through their participation? Do they change their attitudes and actions regarding biodiversity? Which participant outcomes beyond knowledge, attitudes, and behavior do these projects have?

Participant outcomes explicitly refer to outcomes on the side of the citizen as discussed in the framework for public participation in scientific research projects by Shirk et al. [23] and the framework for citizen science outcomes by Jordan et al. [24]. Participant outcomes are elements such as knowledge, skills, or identity, which result from specific activities, observations, and experiences during project participation. Such individual outcomes can be the basis for—and may therefore ultimately influence—other project outcomes [23]. Other outcomes can be outcomes for science and for social-ecological systems [23] or can be programmatic and community-level outcomes [24].

During the past years, Tina Phillips and her colleagues at the Cornell Lab of Ornithology (Cornell University, Ithaca, USA) developed a "Framework for articulating and measuring individual learning outcomes from participation in citizen science" [25,26]. The framework is based on both empirical data and literature and comprises six individual participant outcomes, which are defined below (Table 1).

Table 1. Individual participant outcomes defined in the "Framework for articulating and measuring individual learning outcomes from participation in citizen science" [26].

Individual Participant Outcome	Definition
Interest	The degree to which an individual assigns personal relevance to a science or environmental topic or endeavor
Self-efficacy	The extent to which a learner has confidence in his or her ability to participate in a science or environmental activity
Motivation	Goal-driven inclination to achieve a science or environmental behavior or activity
Content, process and nature of science knowledge	Knowledge of science content and the nature of science; understanding of the scientific process and how science is conducted
Skills of science inquiry	Procedural skills such as asking questions, designing studies, collecting, analyzing and interpreting data, experimenting, argumentation, synthesis, technology use, communication, and critical thinking

Table 1. *Cont.*

Individual Participant Outcome	Definition
Behavior and stewardship	Actions resulting from engagement in citizen science, but external to the protocol activities and the specific project-based skills of the citizen science project, e.g., place-based and global stewardship, new participation, and community or civic action

These are individual participant outcomes that, according to Bonney and colleagues [19], could realistically be expected of citizen science projects in an environmental context. They are achievable and measurable [19].

Various studies have investigated different kinds of participant outcomes of environmental citizen science projects [27–32]. A review by Stepenuck and Green [33] synthesized the literature on the participant outcomes of environmental citizen science projects published up to the end of 2012. The review identified the following outcomes for individual participants: gain in knowledge, change in attitudes and behavior, attainment of social and personal benefits, attainment of voice in decision making, and an increase in the amount and effectiveness of civic participation. The review provides valuable insights into the participant outcomes of environmental citizen science projects in general. Groulx et al. [34] reviewed the literature with a more specific focus on the participant outcomes of climate change-related citizen science projects. Individual participant outcomes most often mentioned in the reviewed articles were new knowledge, new skills or practices, cause–effect relationships, change in awareness, and new ways of acting. The authors concluded that citizen science has the potential to promote learning about climate change and to contribute to climate change action.

To the best of our knowledge, no review has yet systematically analyzed the participant outcomes of citizen science projects with an explicit focus on biodiversity. We aim to close this gap by gathering the available evidence and by providing a synthesis of research results on the individual participant outcomes of biodiversity citizen science projects. We present and discuss our findings in relation to the framework for individual participant outcomes proposed by Phillips et al. [26].

2. Methods

In order to achieve a comprehensive and thorough overview of the literature, we conducted a systematic review of the literature. Systematic reviews are often conducted within medical science but are also becoming increasingly common in environmental sciences [35] as well as in educational research [36,37]. In contrast to traditional reviews, systematic literature reviews are characterized by a more rigorous and structured process [38]. Systematic reviews aim to be transparent, objective, and replicable, by basing the process on a clearly defined research question and following a well-structured and well-documented search protocol as well as clearly defined inclusion and exclusion criteria that determine which studies to include in the review [39,40]. We conducted the systematic literature review following the guidelines defined in the PRISMA statement (Preferred Reporting Items for Systematic reviews and Meta-Analyses) [41]. The following research question guided our review: What evidence exists about the outcomes of biodiversity citizen science projects on the side of the participating citizens? Figure 1 gives an overview of the systematic process that we employed in order to answer this question.

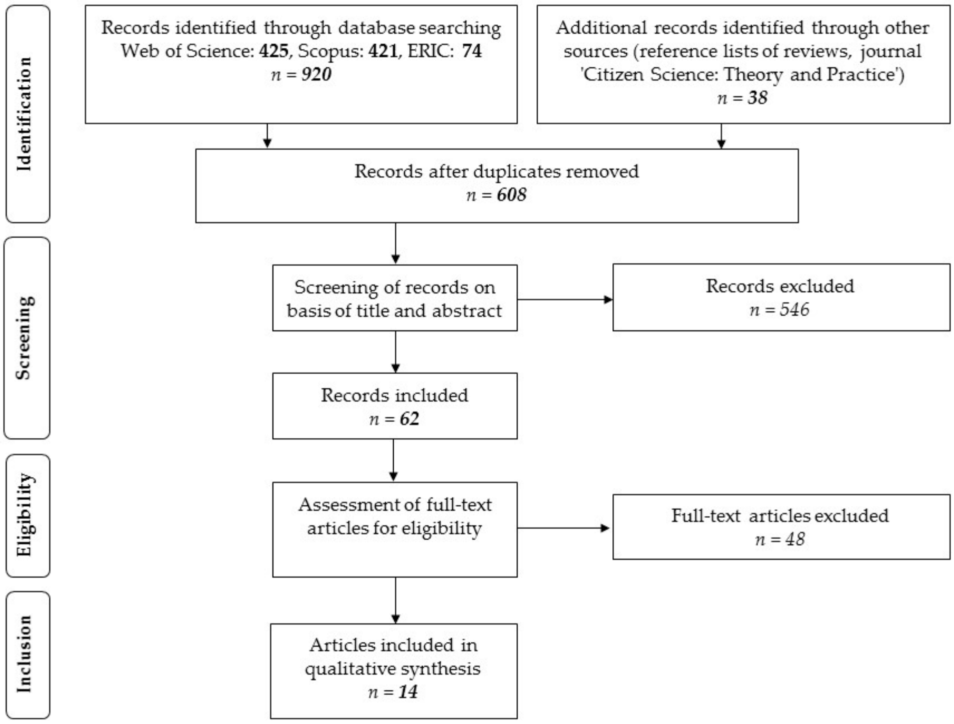

Figure 1. Overview of the systematic search process. Based on the PRISMA statement (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines [41].

2.1. Literature Search

Conducting a systematic literature review is an iterative process [41]. The search protocol was developed, and appropriate search terms were selected by repeatedly searching the academic online databases Web of Science and Google Scholar throughout 2017 for literature on the participant outcomes of citizen science projects. Through these preliminary searches we identified additional synonyms necessary for a comprehensive search.

This iterative process resulted in the final search protocol including the search term "citizen science" and synonyms such as "public participation in scientific research", "volunteer monitoring", and "community-based monitoring". The second set of search terms addressed participant outcomes and included general terms such as "benefit", "impact", and "outcome" as well as more specific terms related to outcomes, for example, "action", "awareness", "interest", and "learning" (the complete search string is available upon request). We tried to be as comprehensive as possible in our database search. However, it should be noted that we did not include all potential synonyms of "citizen science" in the search because some terms such as "participatory research" were found to be used mostly in a medical science context. We might therefore have missed a small number of articles. A search term using the word biodiversity was not included in the final search protocol because the preliminary searches revealed that many potentially relevant articles did not contain the term "biodiversity" or "biological diversity" in either title, abstract, or key words. The use of the search term would have limited the search unnecessarily.

The selected search terms were used to conduct the final online search of Web of Science and Scopus, as recommended by Follett and Strezov [42], and ERIC, a database for educational resources, in late 2017, and again in early 2018, in order to find all relevant literature published up to the end of 2017. The search was based on title, abstract, and keywords. Google Scholar was not used in the final search as this source includes too much non-peer-reviewed literature such as reports, drafts, or teaching materials [42].

In addition to the database search, the online journal Citizen Science: Theory and Practice, established in 2016, was hand-searched, the reason being that the articles of this journal were not indexed in the databases mentioned above. Finally, the reference lists of selected reviews and theoretical papers were searched for additional records not found through the database search [19,23,24,33,43].

2.2. Literature Analysis

The resulting 608 records were screened on the basis of title and abstract, according to the inclusion and exclusion criteria described below. As a result of the screening process, 62 records were considered potentially suitable and downloaded in the full-text version. These 62 full-text articles were then assessed in depth, according to seven inclusion and exclusion criteria. These seven inclusion and exclusion criteria were developed and refined during the process of developing the final search protocol:

1. Citizen science: The articles included in this review focus on citizen science defined as the "engagement of non-professionals in scientific investigations" [5]. More specifically, citizen science involves members of the public who participate in research projects voluntarily, that is, people who are not professionally involved in scientific research [4] and who take part without monetary incentives or requirements [33]. We hereby followed the review approach of Stepenuck and Green [33], who argue that both financial incentives and requirements may influence participant outcomes. Furthermore, citizen science means that the public participates in genuine scientific research [5] that uses scientific methods to collect and analyze authentic data in order to answer specific questions [4]. We therefore excluded articles that studied activities designed exclusively for environmental education, naturalist training, or conservation purposes, i.e., activities that did not involve participants contributing data to authentic scientific research.
2. Biodiversity: Following the review approach of Theobald et al. [8], we included literature focusing explicitly on citizen science projects that involve volunteers in monitoring and identifying biological diversity and collecting biodiversity data. Biodiversity data was defined as "the presence and/or abundance of identified taxonomic (e.g., species, genus, family), genetic, or functional groups, as well as contextual information (e.g., collection date and location)" [8] (p. 237). Citizen science projects only tangentially related to biodiversity, for instance, projects monitoring air and water quality, or projects studying bird biology and nesting success, were not included.
3. Nature-based: The third criterion concerns the spatial context of the citizen science project. As did Groulx et al. [34], we included articles on nature-based citizen science projects. Such projects take place in "outdoor environments marked by biophysical natural elements" [34] (p. 58). These projects may involve species identification or data submission through websites or smartphone apps, but are not limited to online activities. Studies on citizen science projects that do not include any participant interaction with nature, for example, purely online projects that require participants to identify species in online photo databases, were excluded.
4. Individual participant outcomes: We included studies that investigated outcomes on the side of the individual participant or citizen as discussed by Shirk et al. [23] and Phillips et al. [26]. Research on other outcomes, for instance, outcomes for scientists or for the community in general, was excluded.
5. Academic peer-reviewed journals: Consistent with other reviews, we limited our search to articles in peer-reviewed journals in order to ensure a high quality of the reviewed literature [33,34,42].
6. Primary research articles: In this review, we aimed to synthesize the available evidence based on scientific studies that used qualitative, quantitative, or mixed methods. The research method had to be specified within the article. In contrast to the review by Groulx et al. [34], we explicitly aimed to examine empirical evidence. Literature that only mentioned or discussed (probable) participant outcomes without having investigated them was excluded.
7. Publications in English: In order to conduct a transparent and replicable review, we chose to limit our search to studies published in English.

After excluding unsuitable literature, the resulting final study pool consisted of fourteen articles that fully met the seven inclusion and exclusion criteria.

The outcomes reported in the fourteen articles selected were classified into seven categories. The categories were generated through a combination of inductive and deductive processes. We first employed an inductive approach by analyzing the fourteen articles without applying any pre-defined categories [44]. The emerging categories were then compared with existing literature on participant outcomes [24,26,33,45,46]. Through this deductive approach, we modified and adapted our categories. The resulting seven categories are described in the following section. The categories presented in this review comprise only outcomes that emerged from the fourteen articles, and do not comprise the entire range of potential outcomes described within the additional literature. This review does not include a meta-analysis as it was not possible to statistically analyze the various results obtained through the variety of different methods employed in the fourteen studies.

3. Results

3.1. Studies Reviewed

The application of the final search protocol and inclusion and exclusion criteria resulted in a final study pool of fourteen academic peer-reviewed research articles (Table 2). Two of the articles [20,47] reported results from the same research project. The results presented in the two articles overlapped but were not identical. They referred to partly different research methods and results. We therefore included both articles in the review.

Table 2. Overview of the fourteen journal articles included in the review.

Article	Citizen Science Project	Project Country	Focal Species
Bela et al. 2016	14 Projects, e.g., Big Bumblebee Discovery, Catalan Butterfly Monitoring, Ladybird Survey	Europe, e.g., UK, Spain, Hungary	Various
Branchini et al. 2015	Scuba Tourism for the Environment	Egypt	Marine species
Chase and Levine 2017	8 Projects, e.g., San Diego Plant Atlas, Reef Check California	USA	Various
Cosquer et al. 2012	French Garden Butterflies Watch	France	Butterflies
Druschke and Seltzer 2012	Chicago Area Pollinator Study	USA	Bees
Fernandez-Gimenez et al. 2008	18 Projects, e.g., Watershed Assessment and Monitoring, Landbird Habitat Monitoring	USA	Various
Haywood 2016	Coastal Observation and Seabird Survey Team	USA	Seabirds
Haywood et al. 2016	Coastal Observation and Seabird Survey Team	USA	Seabirds
Jordan et al. 2011	Spotting the Weedy Invasives	USA	Invasive plants
Koss and Kingsley 2010	Sea Search	Australia	Marine species
Leong and Kyle 2014	BioBlitz	USA	All species
Lewandowski and Oberhauser 2017	18 Projects, e.g., Cascades Butterfly Project, GTM NERR Butterfly Monitoring Project	USA	Butterflies
Sickler et al. 2014	Lost Ladybug Project	North America	Ladybugs
Toomey and Domroese 2013	Great Pollinator Project	USA	Pollinators

The fourteen articles were found in a wide variety of journals from different disciplines. Most articles were published in scientific multidisciplinary or interdisciplinary journals focusing on the environment, ecology, and conservation. A smaller number of articles were published in social sciences journals. The top three sources were Conservation Biology (three articles), Applied Environmental Education and Communication (two), and Ecology and Society (two). The following journals contained one article each: Biological Conservation, Conservation Letters, Human Ecology Review, International Journal of Science Education Part B, Ocean and Coastal Management, Park Science, and PLoS ONE.

The search was not limited in terms of year of publication. Consistent with expectations, most articles were published relatively recently. The earliest article identified through our systematic search was published in 2008. Between 2010 and 2017, one to three articles were published each year.

In nine out of the fourteen articles, researchers investigated participant outcomes for a single citizen science project. Toomey and Domroese [48] studied two projects, one of which focused on biodiversity. Four authors reported on a study across several projects: eight projects [49], fourteen projects [50], and eighteen projects [30,51].

The majority of articles (ten) focused on projects carried out in North America, two articles investigated projects in Europe, and one study each took place in Africa and Australia. Focal species were mostly animals, few projects explicitly focused on plant diversity.

3.2. Methods Used in the Studies

The study design and methods used to investigate participant outcomes varied greatly among the fourteen articles (Table 3). The majority (nine) of the studies used a post-only study design. Four studies compared pre-participation and post-participation responses. One study involved a follow-up measure six months after participation in the project [32]. None of the studies compared changes to a non-participant group. The number of volunteers that participated in the studies on participant outcomes ranged from 25 [52] to 447 [20]. Researchers employed between one and four different formats of instruments: the most frequently used format was the questionnaire (ten articles), followed by interview (four) and focus group (four), data/document review (two), participant observation (one), and practitioner reflection (one).

Outcomes most often referred to changes reported either by participants themselves (eight articles), or by practitioners, i.e., project scientists and staff (one). One article presented outcomes assessed by the researchers; four articles presented both self-reported and assessed outcomes. In these five articles, outcomes were 'assessed' either through closed-ended (multiple choice) questions [52–54] or through closed- and open-ended questions [32]. Haywood et al. [20] assessed identification skills through the verification of data submitted by participants. Many authors analyzed their data quantitatively (seven articles), four articles reported qualitative results, and three articles were based on both quantitative and qualitative methods.

In addition, the theoretical background of the studies varied. Very few articles based their research on established frameworks or theories of communication or education, such as the theory of planned behavior [55] used by Cosquer et al. [56]. Fernandez-Gimenez et al. [30] used social learning [57] as a framework. Bela et al. [50] based their work on theories of transformative learning [58]. Haywood et al. constructed their own "conceptual model" [20] (p. 478), and Toomey and Domroese developed and described a "citizen science—conservation behavior feedback model" [48] (p. 52).

Table 3. Study methods employed to investigate individual participant outcomes (n.s.: not specified).

Article	Study Design			Outcome Assessed or Reported			Instrument (Number of Participants)						Data Analysis	
	Pre	Post	Follow-up	Assessed by Researchers	Self-reported by Participants	Reported by Practitioners	Questionnaire	Interview	Focus Group	Data/Document Review	Participant Observation	Practitioner Reflection	Quantitative	Qualitative
Bela et al. 2016		x				x						x (n.s.)		x
Branchini et al. 2015	x	x		x			x (212)						x	
Chase and Levine 2017		x			x		x (306)						x	x
Cosquer et al. 2012		x			x			x (30)						x
Druschke and Seltzer 2012	x	x		x	x		x (25)						x	
Fernandez- Gimenez et al. 2008		x			x			x (51)	x (n.s.)	x (n.s.)	x (n.s.)			x
Haywood 2016		x			x			x (71)	x (14)					x
Haywood et al. 2016	x	x		x	x		x (432)	x (71)	x (14)	x (447)			x	x
Jordan et al. 2011	x	x	x	x	x		x (82)						x	
Koss and Kingsley 2010		x			x		x (271)						x	
Leong and Kyle 2014		x			x		x (392)						x	
Lewandowski and Oberhauser 2017		x			x		x (139)						x	
Sickler et al. 2014	x	x		x	x		x (353)						x	
Toomey and Domroese 2013		x			x		x (61)		x (13)				x	x

3.3. Participant Outcomes Investigated in the Studies

We identified seven categories of individual participant outcomes (Table 4): knowledge gain was the outcome most often investigated (described in eleven articles), followed by change in behavior (nine) and change in attitudes (seven), development of new skills (six), self-efficacy (three), and interest (one). A number of other personal outcomes (reported in nine articles) were subsumed in the final category. For the five categories regarding knowledge, behavior, skills, self-efficacy, and interest, we applied the definitions used by Phillips et al. [26] (Table 1). Following Schuttler et al., we extended the knowledge category to include "knowledge and/or awareness of the species, study system, or nature" [46] (p. 407). In contrast to Phillips et al. [26], we included a category regarding attitudes. We added the category because the individual articles that we reviewed frequently used the term 'attitude' when describing participant outcomes. The term 'attitude' can be defined as "a general and enduring positive or negative feeling about some person, object or issue" [59] (p.7). Individual participant outcomes that did not fit into the categories proposed by Phillips et al. [26] were placed in a category called "other personal outcomes". Most articles reported positive findings. Only three articles mentioned any null or negative findings [32,50,52].

Table 4. Categories of individual participant outcomes investigated in the fourteen journal articles (+ = positive results, − = null/negative results, +/− = mixed results).

Article	Outcomes						
	Knowledge	**Behavior**	**Attitudes**	**Skills**	**Self-Efficacy**	**Interest**	**Other Personal Outcomes**
Bela et al. 2016	+	+		+			+/−
Branchini et al. 2015	+						
Chase and Levine 2017	+	+	+				+
Cosquer et al. 2012	+	+					+
Druschke and Seltzer 2012	+	−	+/−				
Fernandez-Gimenez et al. 2008	+			+			+
Haywood 2016	+	+	+	+			+
Haywood et al. 2016	+	+	+	+	+		+
Jordan et al. 2011	+/−	+		−	−		
Koss and Kingsley 2010			+				+
Leong and Kyle 2014	+						
Lewandowski and Oberhauser 2017		+					+
Sickler et al. 2014	+		+	+			+
Toomey and Domroese 2013		+	+		+	+	

3.3.1. Knowledge

The outcome most often addressed by researchers (eleven articles) was an increase in knowledge as a result of citizen science participation (Table 5). Two different types of knowledge were addressed: most authors (eight) focused on environmental or ecological knowledge [20,30,49,52–54,56,60]. Three articles also addressed science-related knowledge in addition to environmental knowledge [32,47,50].

Table 5. Categories of individual participant outcomes and examples.

Outcomes Studied	Examples
Knowledge	… regarding the environment: "increased ecological knowledge" (Fernandez-Gimenez et al. 2008), "content-knowledge about bees" (Druschke and Seltzer 2012), "knowledge of local ecosystems and life-forms" (Leong and Kyle 2014), "learning about loss or endangerment of certain species" (Sickler et al. 2014), "awareness of human behavioral impacts on the environment" (Branchini et al. 2015), "learning about certain species or ecological conditions" (Bela et al. 2016), "understanding of coastal ecology and conservation" (Haywood et al. 2016)
	… regarding science: "knowledge of the nature of science" (Jordan et al. 2011), "learning how science is approached" (Bela et al. 2016), "knowledge about […] science processes" (Haywood 2016)
Behavior	"new individual behavior patterns" (Cosquer et al. 2012), "adapted gardening practices" (Toomey and Domroese 2013), "citizen action emerged" (Bela et al. 2016), "conservation action" (Haywood et al. 2016), "pro-environmental behavioral changes" (Chase and Levine 2017), "personal lifestyle changes" (Chase and Levine 2017), "participation in at least one conservation action" (Lewandowski and Oberhauser 2017)

Table 5. *Cont.*

Outcomes Studied	Examples
Attitudes	… toward the environment: "desire to protect the marine environment" (Koss and Kingsley 2010), "attitude toward bees" (Druschke and Seltzer 2012), "appreciation for bees and the natural world" (Toomey and Domroese 2013), "concern about human impacts on coastal environments" (Haywood et al. 2016), "attitude toward the environment more generally" (Chase and Levine 2017)
	… toward science: "attitude toward science" (Druschke and Seltzer 2012), "value participants placed on science" (Haywood et al. 2016)
Skills	"technical aspects of monitoring design and analysis" (Fernandez-Gimenez et al. 2008), "scientific process skills" (Jordan et al. 2011), "science skills" (Sickler et al. 2014), "how to use scientific methods" (Bela et al. 2016)
Self-efficacy	"sense of confidence" (Haywood et al. 2016) "sense that an individual can have an effect in resolving an issue" (Jordan et al. 2011),
Interest	"interest in environmental issues in the community" (Toomey and Domroese 2013)
Other personal outcomes	"sense of enjoyment" (Koss and Kingsley 2010), "personal satisfaction through the sense of achievement" (Koss and Kingsley 2010), "sense of satisfaction and contribution" (Haywood 2016), "mental and physical health" (Haywood et al. 2016), "belonging to a community" (Cosquer et al. 2012), "feel a broader sense of community" (Lewandowski and Oberhauser 2017), "reconnect people with the landscape and with each other" (Fernandez-Gimenez et al. 2008), "sense of connection to wildlife" (Haywood 2016), "link between the participant and the survey site" (Haywood et al. 2016), "feeling of connectedness to the natural world" (Chase and Levine 2017), "increased trust" (Fernandez-Gimenez et al. 2008)

Environmental knowledge generally reflected the species that were monitored in the course of the project, including, for example, knowledge about bees [52], butterflies [56], invasive plants [32], and endangered or extinct species [54]. Often, environmental knowledge went beyond learning about species. It extended to knowledge of local ecosystems [30,50,60], an understanding of ecology and conservation issues [20,53,56], and awareness of human impact on the environment [30,53].

Science-related knowledge included learning about the nature of science [32] and about general scientific processes [47,50].

All studies that addressed environmental knowledge found an increase as a result of participation in a citizen science project. Unlike environmental knowledge, science-related knowledge was not always found to have increased. While Bela et al. [50] and Haywood [47] reported positive results, Jordan et al. [32] did not find any change in science-related knowledge.

3.3.2. Behavior

The second most frequently studied outcome (nine articles) was a change in behavior as a result of citizen science participation (Table 5). This category includes specific behavior changes connected to the focal species of the citizen science project, for instance, participants adapting their gardening practices to make their gardens more suitable for bees or butterflies [48,56], for example, by planting host plants for butterflies and using less pesticides [51], and participants talking to others about the observed species [32,51]. More general behavior changes comprised conservation action [20,50], involving others in conservation and monitoring activities [51], wildlife-friendly behavior [52], and collecting trash [47,49].

Most authors reported positive behavior changes [20,32,47–51,56]. However, behavior changes were sometimes found to be more superficial and passive than desired, for example, participants reported behavior such as talking about the citizen science project to others [32]. Chase and Levine [49] reported that only one third of the participants changed their behavior, and that this change usually related to personal lifestyle changes. One study did not find any changes in behavior [52].

3.3.3. Attitudes

Changing attitudes as a result of participation was also discussed in a number of articles (seven). Two different types of attitudes were addressed: four articles focused on attitudes toward the environment only [47–49,61], one article focused on attitudes toward science [54], and two articles addressed both [20,52].

Environmental attitudes included specific attitudes toward the species monitored, for example, appreciation for bees [48] or less fear of bees [52], as well as more general attitudes such as appreciation for the natural world generally [48,49] and for the services that ecosystems provide [47], concerns about human impact on the environment [20], and a desire to protect the environment [49,61].

Science-related attitudes comprised general attitudes toward science [52], attitudes about contributing to science [54], and attitudes about the value of science [20].

All studies that addressed environmental attitudes found a positive change in attitudes as a result of participation in a citizen science project, whereby Druschke and Seltzer [52] reported positive changes in only some attitudes, but not in all. The results regarding attitudes toward science were slightly different: while Haywood [47] and Sickler et al. [54] reported positive changes, Druschke and Seltzer [52] did not find any positive changes in attitudes toward science. Instead, the authors even noted slightly negative changes (though not statistically significant) in participants' perception of scientists' interest in involving citizens in research.

3.3.4. Skills

The next most common outcome was the acquisition of new skills. This outcome was addressed in six articles and always referred to scientific skills. Different kinds or levels of scientific skills were investigated. Basic skills included skills directly related to project activities such as accurately identifying species [20,54] or measuring animals encountered during the monitoring activities [47]. These skills were found to have increased [20,47,54]. More advanced scientific skills involved, for instance, distinguishing between correlation and causation. Jordan et al. [32] found that such skills did not change during project participation. Two papers did not further specify the kind of scientific skills gained, but reported positive changes [30,50].

3.3.5. Self-Efficacy

Self-efficacy was an outcome evaluated in three studies. This category comprises a general sense of confidence emerging from the skills acquired through participation in the project [20], confidence in telling others about the species that were the focus of the activities [48], and the sense that an individual can have an effect on resolving environmental issues [32].

Haywood et al. [20] and Toomey and Domroese [48] reported positive changes in self-efficacy. Jordan et al. [32], however, did not find significant changes.

3.3.6. Interest

Interest in science or nature as an outcome of participating in citizen science projects was investigated by one study only. This outcome refers to a general interest in community environmental issues [48]. The authors found an increase in interest.

3.3.7. Other Personal Outcomes

This category summarizes a variety of different personal outcomes reported in nine articles. It includes a sense of satisfaction, contribution, and achievement [47,61], a general sense of enjoyment [61] or, more specifically, enjoyment in contributing to science and to conservation efforts [54], physical [20] as well as mental health [20,61], a sense of connection to nature [20,49,61], to the landscape [30,47], and to wildlife [47], trust between participants and other stakeholders of a citizen science project [30,50], and finally, a sense of belonging to a community [47,51,56].

These personal outcomes were always perceived to be positive. The only exception is the article by Bela et al. [50], which reported mixed results concerning trust: while in some cases trust increased, in other cases trust between project scientists and citizens decreased.

4. Discussion

The goal of our review was to gather the available evidence regarding individual participant outcomes of biodiversity citizen science projects. We identified fourteen peer-reviewed articles that investigated such outcomes. While this is more than what Groulx et al. [34] found in their search for literature on climate change-related citizen science projects (their review included only one study that specifically investigated participant outcomes), we had expected to find a greater number of articles. Theobald et al. [8] identified 388 biodiversity-based citizen science projects worldwide. Since their search was limited to English-language websites, the real number of existing projects might be much higher. It seems that the majority of projects did not evaluate participant outcomes or did not publish the results of their evaluations in peer-reviewed journals.

Reasons for this lack of project evaluations might be the often-lamented absence of established indicators and methods for evaluating citizen science outcomes [62,63]. Due to the absence of specific and clearly defined participant outcomes of citizen science, project leaders might not know which kinds of outcomes to aim for and to evaluate [26]. Obviously, the focus on participant outcomes is still an emerging field.

4.1. Participant Outcomes of Biodiversity Citizen Science Projects

Citizen science projects often claim to have an impact on participants' knowledge, attitudes, and behavior [22]. Through our review, we found evidence for a variety of individual participant outcomes. Outcomes found in at least 50% of the articles referred to knowledge gain and changes in behavior or attitudes. Outcomes reported in less than 50% of the articles were increased skills and self-efficacy, increased interest in the environment, and various other personal outcomes. The evidence gathered through our review suggests that biodiversity citizen science projects have the potential to achieve the participant outcomes they are assumed to have with regard to biodiversity.

The outcomes found through our review show clear connections to biodiversity, and to biodiversity education and conservation. In the studies reviewed, participants gained knowledge about biodiversity, for example, about bees [52], butterflies [56], and endangered species [54], but also about ecology and species conservation [20,30,53]. Participants changed their attitudes regarding biodiversity, for example, they developed an appreciation for bees [48] and for nature in general [49], and also developed concerns about human impact on the environment [20]. Participants also reported changing their behavior regarding biodiversity, for instance, they adapted their gardening practices [48,51,56], got involved in conservation action [20,50], and recruited others to participate in biodiversity monitoring and conservation activities [51]. Furthermore, participants gained skills in species identification [54] and in collecting data on the species found [47]. It is notable, though, that the majority of the studies reviewed focused on citizen science projects that involved monitoring charismatic and well-liked species such as butterflies, bees, ladybugs, and birds. It is common practice to use such so-called flagship species to raise public awareness of biodiversity conservation issues [64]. It would, however, be interesting to explore the participant outcomes of citizen science projects that focus on less charismatic species.

Nine of the fourteen articles investigated participant outcomes that did not fit into the categories developed by Phillips et al. [26]. These other personal outcomes, such as a sense of contribution [47] and enjoyment [61], and a sense of connection to nature [30,49] and to other participants [20,51,56] are strongly connected to citizens' motivation for participating in citizen science projects [65] and therefore have a strong influence on the continued engagement in biodiversity monitoring and conservation activities. In addition, connection to nature can have an influence on attitudes towards the environment [66] and can lead to a sense of commitment to protect the environment [46,67] and to changed behavior towards the environment [29]. In this context, the connection to local biodiversity is particularly important [67,68]; citizen science can lead to such a connection to local nature [20]. Finally, increased trust between the different stakeholders of citizen science projects [30] can lead to more successful conservation and natural resource management programs [69–71] and therefore, ultimately benefits biodiversity conservation.

The participant outcomes found through our review are also reflected in the learning objectives regarding biodiversity and sustainable development goals defined by the UNESCO in 2017, for example, learners are able to understand "basic ecology with reference to local ecosystems", to identify "local species", to understand "threats posed to biodiversity", to "relate these threats to their local biodiversity", to "connect with their local natural areas", and to "connect with local groups working toward biodiversity conservation in their area" [72] (p. 40).

4.2. Gaps in the Literature

Throughout our review, knowledge gain was the outcome found most often. This is not surprising—it was also the outcome investigated most often. The dearth of evidence regarding other outcomes does not necessarily relate to null or negative results. Rather, other outcomes were simply not investigated or reported in many studies. For instance, only three studies investigated "self-efficacy", one study investigated "interest in science and the environment", and none of the studies investigated "motivation for science and the environment", all three being participant outcomes proposed in the evaluation framework by Phillips et al. [26]. The prevalence of studies that focused on investigating participants' knowledge has also been found in citizen science projects not related to biodiversity [33,34], and in environmental and sustainability education in general [36].

One potential reason for this prevalence of knowledge gain as an outcome is that funding for citizen science projects is often tied to projects' ability to educate their participants [17]. The gain in content knowledge might be the educational outcome that is easiest to investigate [36], given that many projects lack sufficient financial resources [19] and the social science expertise [26,34] necessary for a more comprehensive evaluation of project outcomes. Another reason might be that content knowledge is seen by many project leaders as a necessary prerequisite for behavior change [32]. Indeed, people need to have basic knowledge about environmental issues in order to consciously act accordingly [66]. Knowledge, however, is not considered to be sufficient for achieving a change in environmental behavior [16,66]. While there is little consensus on the variables that influence behavior change and on the extent to which they affect behavior, researchers agree that a variety of factors can determine environmental behavior, such as knowledge, attitudes, skills, self-efficacy, emotions, and motivation [66,73]. Other participant outcomes besides knowledge should therefore be the focus of further research, including studies that investigate long-term and sustainable behavior changes.

4.3. Methodological Considerations

Despite knowledge being predominant, other participant outcomes were found by various authors, which is promising. Often, however, the results presented in the reviewed studies are based on outcomes that were self-reported by participants. This means that the results rely on perceived outcomes instead of actual outcomes [48]. In addition, the self-reporting of outcomes can favor socially desirable answers [74]. It might thus be unwise to base a whole study on methods of self-reporting only [75]. Caution might therefore be necessary when interpreting the results of such studies. Future research should include other methods of assessment in addition to self-reporting, for example, embedded assessment as suggested by Becker-Klein et al. [75].

Another issue regarding methodology that we encountered during our review is the great diversity of study designs and methods as well as the scarcity of established theoretical frameworks as the basis of the studies. This was also found in the study by Phillips et al. [26]. This might simply be a characteristic of a new and developing field of research, which citizen science undoubtedly is. In addition, the great variety of available research instruments might pose a challenge to project leaders who need to decide how to evaluate their project [19]. The diversity of studies, however, makes it difficult to compare their results [26]. A possible solution would be to conduct studies across several projects [33,36] using the same theoretical framework and methods [26]. Theoretical frameworks would allow project leaders to define specific goals with regard to participant outcomes and to evaluate whether and to which extent the project was able to achieve these goals. Ideally, such studies would consist of surveys conducted directly before and after participation in the project in order to detect immediate changes. Additionally, follow-up surveys would make it possible to investigate long-term changes in participant outcomes, especially with regard to long-term and sustainable behavior changes. Furthermore, using some form of control- or comparison-group would also be beneficial [36]. The framework developed by Phillips et al. [26] could be a useful basis for such research.

We mentioned above that the lack of certain outcomes does not necessarily relate to null or negative outcomes. In fact, only three of the fourteen studies included in our review reported any null or negative results [32,50,52]. In most research areas, there is a trend against publishing null or negative results [76]. This has also been found to be true in environmental and sustainability education research [36]. One reason might be the potential loss of funding for the project [33]. Another reason might be related to evaluation approaches aligning their measures as closely as possible with project goals, which makes it less likely to obtain null results [36]. However, sharing such results with the research community would allow other researchers and project leaders to learn from and avoid mistakes [76]. This applies particularly to a relatively new and rapidly developing research area such as citizen science. The article by Druschke and Seltzer [52] is a good example of an article reporting and reflecting on the mistakes made and lessons learned.

5. Conclusions

In the course of our literature review, we found evidence for the potential of biodiversity citizen science to impact participants' knowledge, attitudes, and behavior regarding biodiversity. In addition, our review showed that citizen science projects can influence participants' skills and can lead to the increased self-efficacy of participants, an increased interest in the environment, and a variety of other personal outcomes. These results suggest that biodiversity citizen science is a promising format in environmental and sustainability education with a focus on biodiversity.

However, we also identified a need for more research on the participant outcomes of biodiversity citizen science projects, particularly on further outcomes besides knowledge. Such future studies would benefit from the use of common measures and theoretical frameworks such as the one developed by Phillips et al. [26]. For more effective research into participant outcomes, we advocate conducting comparative research studies across projects. Furthermore, biodiversity citizen science projects are often developed and managed by natural scientists. We recommend cooperating with social scientists not only in the evaluation process but also in the whole process of project design in order to ensure the integration of both scientific and participant outcomes. In addition, evaluation results could be published without identifying the projects involved [33]. This would allow citizen science researchers and practitioners to learn from each other without compromising individual projects. Moreover, research across various projects would contribute to an increased understanding of the relationship between individual participant outcomes and project characteristics. We therefore argue for more partnerships between the natural and social sciences in the coming years. These partnerships would work best if scientists from both fields communicated as early as possible about the goals and design of a citizen science project. By this means, citizen science projects could be more effective in achieving participant outcomes that contribute to environmental and sustainability education concerning biodiversity.

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