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# Contributions from citizen science to science education: an examination of a biodiversity citizen science project with schools in Central Europe

Julia Kelemen-Finan [a]*, Martin Scheuch [b]* and Silvia Winter [c]

[a]naturschutzakademie.at [Austrian Academy for Nature Conservation], Stockerau, Austria; [b]Austrian Educational Competence Centre for Biology, University of Vienna, Vienna, Austria; [c]Institute for Integrative Nature Conservation Research & Division of Plant Protection, University of Natural Resources and Life Sciences Vienna, Vienna, Austria

**ABSTRACT**

Despite the rising popularity of Citizen Science (CS) projects, there is little empirical evidence for effects on learning outcomes, particularly when young people are involved. It is also often not clear how CS projects are linked to science education (SE) research. The aim of this study was to examine biodiversity CS projects in an outdoor school class context and to measure the effects on individual learning outcomes (ILOs) with a perspective for SE. Five learning outcomes considered important for CS were tested: interest, self-efficacy/mastery, motivation, behaviour and attitude. These ILOs were measured via eight different scales and tested in an evaluation study of a large CS project with 428 students aged 8–18. Students recorded hedgehogs, wild bee activity, birds and butterflies in gardens. Results showed that students' interest and motivation, as well as perceived mastery increased during the project. Most remarkably, positive attitudes towards wild animals, natural gardens and biodiversity rose significantly. For most ILOs there were significant differences between age groups: Primary school students showed the highest ILOs and also provided most database entries. The authors describe how well biodiversity CS projects contribute to SE aims and how discrepancies between educational and scientific aims in CS projects may be addressed.

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Citizen science; biodiversity; evaluation; learning outcomes; science education; students; motivation; attitude

## 1. Introduction

### *1.1. Citizen science, science education and students: missing links*

Citizen science (CS), i.e. involving citizens in scientific research projects, has become increasingly popular (Conrad & Hilchey, 2011; Sullivan et al., 2014). CS projects can recruit many people across the globe, thanks to modern communication technology via internet and smartphone apps. To obtain good data quality and quantity, commitment to engage in collaborative research is required from scientists as well as citizens. Most

**CONTACT** Julia Kelemen-Finan julia@kelemen-finan.at www.naturschutzakademie.at naturschutzakademie.at [Austrian Academy for Nature Conservation], B. Schilcher Str. 18, A-2000 Stockerau, Austria
*The authors are contributed equally to this article.

CS projects are classified as contributory, where citizens collect and submit data under guidance of the scientists (Bonney et al., 2009). Scientists' main objective to involve citizens is data acquisition, while volunteers participate for a variety of reasons (Rotman et al., 2012). Important motivational factors are personal interest in the subject, the satisfaction of contributing data to science, and, for projects with environmental focus, contribution to environment protection (Geoghegan, Dyke, Pateman, West, & Everett, 2016; Rotman et al., 2012). CS was also viewed from a science education (SE) perspective with different foci. Wals, Brody, Dillon, and Stevenson (2014) investigated links between SE and environmental education (EE). They considered CS to be an integrative approach to link SE and EE. Mueller and Tippins (2012) argue that CS may increase participation in society and meaningful learning, which contributes to societal transformation (Bela et al., 2016).

With rising popularity of CS projects, there has been an increasing demand to evaluate results and outcomes embedded in an indicator-based framework. In practice, very few CS projects have been evaluated, neither by project teams nor by external evaluators (Geoghegan et al., 2016), especially concerning CS with young people. 'Student-scientist partnerships' have a longer history, with first records dating back as far as Cohen (1997). However, several questions remain unanswered: How successful are CS projects with students? What motivates young people to do voluntary research? Which effects does CS project participation have on young people's attitudes towards science or towards the environment?

Evaluation guidelines (e.g. Phillips, Ferguson, Minarchek, Porticella, & Bonney, 2014) give recommendations for different cultures, but do not specify young people or students in schooling contexts. Projects with young people are usually initiated as group activities within a school context (Ringel, Reischauer, & Suchy, 2014; Schauer, Meikl, Gimeno, & Schwarzenbacher, 2012). The initial commitment for the participation of young people is usually made by adults (e.g. by their role as teachers or parents). Teachers can define aims and may argue that the students gain insight into real research, gain scientific literacy (Cronje, Rohlinger, Crall, & Newman, 2011) as aimed in the PISA framework and develop more informed attitudes towards science (Bybee & McCrae, 2011).

We argue in this paper that at this interface between research and education CS becomes relevant for SE and educational aims at schools. We focus on the perspective of young citizen scientists, and concentrate on educational goals and learning outcomes following the terminology of Phillips et al. (2014). We use this conceptualisation as a link to the students' learning in SE and the possible educational aims related to CS projects.

### *1.2. Learning outcomes and indicators*

The Cornell Lab of Ornithology, a leading institute in the development of CS, has developed a guide for evaluating outputs, outcomes, and impacts for CS projects (Phillips et al., 2014, p. 12). They built on the useful framework for categorising potential outcomes of informal SE provided by Friedman (2008). Although the work of Phillips et al. does not specifically address young people, it was used in our study as a basis and starting point for our investigations. Their extensive framework focusses on individual learning outcomes (ILO), consisting of cognitive, affective and behavioural aspects. This approach intends to address critical questions for understanding the effectiveness of a project, such as to whether it helps volunteers to gain knowledge, increases interest in science, or changes attitudes. Phillips et al. (2014, p. 10) define the following six 'individual learning outcome' (ILO) categories: (1) Interest in Science and the environment, (2) Self-Efficacy, (3) Motivation, (4) Knowledge of the Nature of Science, (5) Skills of Science Inquiry and (6) Behaviour and Stewardship.

The ILO Interest in Science and the environment (1) is defined by Phillips et al. (2014, p. 10) as 'interest in pursuing science and environmental topics, careers, activities and issues'. Interest in Science constitutes 'Strand 1' by the National Research Council (Phillips et al., 2014, p. 9) and includes the experience of excitement, interest and motivation to learn about phenomena in the natural and physical world. The relevance of Interest in Science has also been acknowledged by EU policies, which aim to address a decreasing interest in Science (Hazelkorn, 2015) by implementing political actions to counteract these tendencies.

Within the context of SE, the construct 'interest' is often defined as the combination of interestingness of a subject and the initial interest of a person in this situation. If the situation and the environment are supportive, individual and longer lasting interest can be developed (e.g. Krapp, 1998). Wilde, Bätz, Kovaleva, and Urhahne (2009) define interest as one of the four key factors which are used to measure student's learning motivation within their 'short scale of intrinsic motivation' (KIM; see below).

Self-efficacy (2) applied to participation in CS projects is 'the extent to which a learner has confidence in his or her ability to participate in science […]' (Phillips et al., 2014, p. 10, Figure 3). In an educational context, self-efficacy can be termed 'mastery' or 'perceived competence' and is also part of the four factors for intrinsic motivation (Wilde et al., 2009).

Motivation (3) is a term widely used in a CS as well as SE contexts, with variations of its definition. Phillips et al. (2014, p. 10) use a definition where motivation is 'to pursue science and environmental goals such as STEM careers and citizen-science project activities'. Elsewhere (e.g. Rotman et al., 2012) the term is sometimes referred to as a concept in its own right, or used as a prerequisite, or even a synonym, for interest and engagement (in activities). In a recent survey on British CS projects, Geoghegan et al. (2016) identified three main motivational factors for participants: (1) to help wildlife in general, (2) to contribute to scientific knowledge, and (3) 'It's a valuable thing to do' (Figure 1 p. 30).

Wilde et al. (2009) developed their 'short scale of intrinsic motivation' (KIM) on the basis of the self determination theory by Deci and Ryan (2003) to test students' motivation in a learning context for extra-school activities. The KIM scale includes four factors: interest/enjoyment, perceived competence, perceived choice and pressure/tension, with three items each. The first two, interest/enjoyment and perceived competence (also termed as 'mastery'), refer to the same concepts as the CS researchers (such as Phillips et al., 2014) and thus provide useful items to investigate CS projects with schools.

The ILO Knowledge of the nature of science (4) and 'understanding of the scientific process and how science is conducted by researchers' (Phillips et al., 2014, p. 10) has been tested by Brossard, Lewenstein, and Bonney (2005). They evaluated the Birdhouse Network Project conducted by the Cornell Laboratory of Ornithology. The project influenced participants' knowledge of bird biology but no statistically significant change in participants' understanding of the scientific process could be detected. Trumbull, Bonney, Bascom, and Cabral (2000) analysed corresponding letters of citizen scientists conducting seed preference tests of wildlife birds to investigate the development of scientific thinking. The results suggested that scientific thinking was triggered to some extent. Both studies did not contain young people or a school context. For SE there is more evidence on this, notably the investigation of 'Students-Scientist Partnerships' (e.g. Cohen, 1997; Moss, Abrams, & Kull, 1998; Means, 1998).

Skills of Science Inquiry (5) are closely related to the previous ILO. These skills are defined in a CS context as 'procedural skills such as asking questions; designing studies; collecting, analysing and interpreting data; […] and critical thinking.' (Phillips et al., 2014, p. 10). While we did not find evidence about evaluating this factor in biodiversity CS literature in general, there are numerous reports in SE contexts, such as by Randler and Bogner (2006) and Randler (2008). They conducted experiments to test animal identification skills of students. They recommended that only a small selection of species should be studied, and outdoor field trips should be preceded by proper indoor training. Similar results were found by Bardy-Durchhalter, Scheuch, and Radits (2013), who also noted that students need support by scientists to develop explicit knowledge about the use of biological theories in the identification process.

Behaviour & Stewardship (6) as the final ILO focusses on the change in behaviour (Phillips et al., 2014). This is a desired outcome in form of action, along with the idea of becoming rooted in the place examined and thinking on a global scale at the same time. All political and civic actions that may follow the participation in a CS project are defined as an outcome in this category.

One additional outcome category which is not included in Phillip's evaluation framework is the factor 'Attitudes' and the potential change of attitudes (towards science, or – as relevant in this case – towards the environment). Friedman (2008) subsumes the following under the term attitude: 'measurable demonstration of assessment of, change in, or exercise of attitude toward particular scientific topic, concept, phenomena, theory, or career […]. Attitudes refer to changes in relatively stable more intractable constructs such as empathy for animals and their habitats […].' (p. 9). We presume that attitudes were subsumed by Phillips et al. (2014) in other outcome categories, but due to the fact that attitudes is a separate field of research in SE (e.g. ROSE study Sjoberg & Schreiner, 2010; or PISA: Bybee & McCrae, 2011), it should be defined as a separate category.

Despite the rise of CS projects only few studies exist which document the effects of project participation on attitudes towards science, towards the environment, or a possible attitude change in the course of a project (Bonney et al., 2009). Brossard et al. (2005, adult participants) could not detect any significant change in participants' attitudes toward science or the environment in the project Birdhouse network.

For school contexts Vogt (1998) argues that measuring the development of interests in young people is difficult because it needs to be monitored over a long period of time. Knoll (2013) did not succeed measuring effects of CS projects on student's attitudes, possibly due to a small sample size of 64 students. Collins (2014) showed how students' attitudes improved during a CS project, but only with classroom indoor activities.

### *1.3. School students: a homogenous group?*

When addressing young people, we do not deal with a homogenous group with similar interests and attitudes. In the course of child development, children's personalities evolve between the ages of eight to eighteen (younger people are usually not involved in CS), with implications for CS (Kelemen-Finan, Pröbstl, & Knoll, 2013). SE literature shows that gender and age have considerable influence on science learning. The ROSE study for example (Sjoberg & Schreiner, 2010) showed that boys and girls are interested in different topics and contexts with respect to school science and technology. Wilde et al. (2009) found no differences in intrinsic motivation between the sexes, except for the factor 'perceived competence': Boys rated their own competence higher than girls at the tested age group (10–11 years).

Most studies which are closely linked to the school curriculum are conducted within a narrow age range (Bardy-Durchhalter et al., 2013, 10th grade; Meyer, Balster, Birkhölzer, & Wilde, 2011, 6th grade; Randler, 2008, 5th and 6th grade; Wilde et al., 2009, 10–11 yrs). Thus evidence of age related aspects and attitudes towards science issues are scarce. A recently published quasi longitudinal study for the lower and upper secondary on interest for plants showed that the patterns of students' interest change over lifetime (Pany & Heidinger, 2017).

### 1.4. Aims of this paper

The overall aim was to examine Biodiversity Citizen Science projects in an outdoor school class context, to gain better understanding about their effects on learning outcomes of SE in the field of biology, such as interest, knowledge, motivation, behaviour and attitude (according to Phillips et al., 2014, and Friedman, 2008). Since these constructs are not always consistent with those in SE (as discussed in the previous section), we attempted to reconcile both approaches. We studied the effects on students from the age of eight years onwards.

These were the developmental aims and research questions:

(1) Which individual learning outcomes (ILOs) and indicators suggest the most interesting patterns for further studies?
(2) Do the indicators offer a means of testing differences in age or gender?
(3) What are the implications of biodiversity CS projects for educational aims of SE?

## 2. Method

### 2.1. Evaluation study and sample

We analysed a CS project on biodiversity in gardens 'Nature in your back yard – Citizen Science with schools'[1] (2014–2016). The project had the following scientific aims: (i) to record biodiversity by means of target species groups (hedgehog presence; wild bees' foraging behaviour; selected birds' and butterflies' presence and activities) in private gardens and parks near partner schools; (ii) to analyse the impact of garden management and landscape structure on target species; and (iii) to investigate motivation and factors promoting engagement and commitment of students to biodiversity and CS. Educational goals were to improve students' knowledge on species and habitat-species relationships, as well as raising awareness towards the importance of gardens for biodiversity conservation. According to the classification by Bonney et al. (2009) it was a contributory project.

This CS project joined natural scientists and SE researchers from the University of Natural Resources and Life Sciences in Vienna and the University of Vienna with NGOs, authorities and 16 schools from Vienna and Lower Austria (urban and rural). Over the duration of two years, 428 students from 27 classes, supervised by 21 teachers, participated in this CS project (Table 1).

The teachers were asked to participate in three biodiversity modules with their classes (garden management survey, hedgehog tracking and wild bees' flight/foraging behaviour) and could opt to do one or two additional modules (module 'butterflies': recording of eight target species plus eight optional species; module 'birds': recording of ten target species plus twelve optional species; for details see BOKU, 2018). Teachers received separate teacher trainings by the scientific and educational team for all tasks. Throughout the project, teachers (and some students) were invited to a series of further indoor and outdoor training and feedback workshops. Scientists visited each class at least three times at their respective schools and garden sites for training sessions. The scientists also provided online identification guides, experimental protocols and (training) materials. Wild bee nesting aids and starter kits as well as hedgehog tracking tunnel materials (Yarnell et al., 2014) were handed out to each school to study foraging flight duration of wild bees and hedgehog presence in gardens. Schools that subscribed to the bird or butterfly module received further equipment (e.g. binoculars) to study the abundance and behaviour of a short list of bird and/or butterfly taxa in their gardens. Access to private and public observation sites (gardens and parks) for all students was organised. For the birds and butterflies observation tasks, students were asked to do at least two standardised observation sessions individually or in small groups; and one session each for hedgehog and bee foraging activities. 'Zero' recordings were included. Printed survey forms were used for data collection, data entry was online on a custom-made database application (further details: Winter et al., 2016, written in German).

### 2.2. Development of criteria and indicators to test individual learning outcomes

We used the individual learning outcome (ILO) categories of Phillips et al. (2014) as a basis and incorporated other ideas from the CS and SE literature for this study. In addition, we used our own experience as scientists and educators, to extract feasible ILOs and indicators for suitability within the framework of the school environment and the complexity of the tasks. One criterion was whether the ILO could be reliably investigated with a questionnaire, which is an instrument of subjective assessment by the respondent. Categories which we considered more suitable for external assessment were excluded: 'Knowledge of the nature of science' and 'skills of science inquiry' (Phillips et al., 2014; see Discussion).

**Table 1.** Participating schools and students.

| Code | Name | Educ. level | Age | No of classes | No of students | female | male |
|---|---|---|---|---|---|---|---|
| PR | Primary | 3–4 | 8–10 | 3 | 57 | 28 | 29 |
| LO | Lower Intermed. | 5–6 | 11–12 | 10 | 181 | 75 | 106 |
| UP | Upper Intermed. | 7–8 | 13–14 | 4 | 71 | 45 | 26 |
| HI | Higher | 9–12 | 15–19 | 10 | 119 | 69 | 50 |
| Total | | | | 27 | 428 | 217 | 211 |

For each ILO category one or more indicators were defined. The indicators were expressed by scales (each consisting of two or more individual items). Standardised inventories such as the KIM-scale by Wilde et al. (2009) were used as a basis for the development of scales. For validity, items representing the biodiversity and outdoor aspects, as well as the engagement in scientific tasks, were added, in order to represent all aspects of project activities (see Table in Annex). For four ILOs, a summative evaluation (post survey) was applied, for another ILO a pre–post-design was applied (Table 2). These ILOs are described below for each survey instrument.

ILOs 1–4 were integrated into a summative survey. Our ILO (1) Interest in Science and the environment was addressed by the scale 'liking of the research done' and consisted of six items describing the outdoor biodiversity activities (see Table 2 and Appendix). Our ILO (2) self-efficacy/mastery is based on Phillips et al. (2014) as well as Wilde et al. (2009) and reflects the student's perceived competence at the mastery of their own skills to identify animals. Within the KIM-scale (Wilde et al., 2009) 'perceived competence/mastery', is one of three factors used to describe motivation. In our survey, we used the term 'motivation' (3) as a separate ILO, as suggested by Phillips et al. (2014, see Introduction). To test motivation we applied two scales: First, a scale related to the subject of the project itself: 'wanting to know/learn more about the animals', and second, a scale often referred to in a CS context, the wish to 'contribute to science', thus constituting a 'purpose'. In the KIM-scale, purpose is not addressed as a factor.

Our ILO Behaviour (4) was applied as suggested by Phillips et al. (2014). We used the scale 'Help species in the garden' as an indicator for intended behaviour, rather than for an expression of attitude (as suggested by Friedman, 2008). This seemed justified because students actually reported of activities 'to help species' in their own gardens in the course of the project. The scale was composed of items referring to the animals/animal groups the students investigated.

A final ILO was introduced, which was mentioned by Friedman (2008) in an SE context and incorporated into a pre–post-survey: Attitude (5). In the present study, we aimed at detecting differences in attitude towards wild animals, nature and biodiversity in the course of the project. This was intended to deliver new insights in the effect of CS projects because there is little evidence for the measurement of attitude changes (Geoghegan et al., 2016). Therefore, a range of scales was tested in a pre–post-design. In this paper, we present the most conclusive results, which were those obtained for the following three

**Table 2.** Individual learning outcome categories, scales and method applied for measurement (for items belonging to each scale see appendix).

| ILO (Individual Learning Outcome) category | Scales (used as indicator) | Type of test design |
|---|---|---|
| Interest | Liking of research done | Post survey; Gender & age differences |
| Self-efficacy/ Mastery | (Perceived) mastery of animal identification | Post survey; Gender & age differences |
| Motivation | Wanting to know more about animals Purpose: Contribute to science | Post survey; Gender & age differences |
| Behaviour | Help species in the garden | Post survey; Gender & age differences |
| Attitudes | Liking of the animals Nature garden Awareness and attitude towards biodiversity | Pre- and post survey |

scales: (1) 'Liking of the animals': the popularity of the animals/groups that were investigated; (2) 'Nature garden': importance of garden elements which encourage wildlife; and (3) 'Awareness and attitude towards biodiversity', i.e. positive and negative statements in relation to biodiversity. The items of the third scale were adapted (shortened) from a standardised scale by BFN (2009, p. 36), which was also tested in a CS context by Knoll (2013).

All ILOs were checked for gender and age differences; the pre–post design was applied to the ILO attitude, with items addressed in both surveys.

### 2.3. Data acquisition and statistical analysis

The data for the ILO analysis were obtained from pre- and post-online-surveys with all students participating in the project. For the younger age groups (eight to twelve), the surveys were conducted in a classroom context, supervised by the teachers. Responses were given on a four-point Likert Scale (4: I totally agree, to 1: I don't agree at all, with opportunity of selecting 0: I don't know). If students responded to questions about activities they did not take part in, their answers were excluded from the statistical analysis (this applied to questions related to butterfly and bird activities). As a first step, an exploratory factor analysis was conducted. All items had loads >.4 on their respective predefined scales. Then the confirmed scales and their items were tested for internal consistency (commonly referred to as 'reliability'), by calculating the Cronbach alpha scores for the scales. Table 3 (results section) shows examples for the items as well as the reliabilities within the scales.

Rank sums were calculated for the answers in each scale per person. As the Likert scale cannot be assumed being a metric scale, we decided to use the robust median of rank sums instead of mean values, even though figures might be less intuitively comprehensible. Students which did not answer more than 50% of the items within a scale had their answers for the respective scale removed from the analysis. Missing values for items where more than 50% of the scale were completed were filled by the median of the given answers within the respective scale. This was necessary for obtaining complete rank sums.

The data set was analysed using the programme SPSS for computing exploratory factor analysis, Cronbach alpha scores, means and rank sums for each scale. Kruskal Wallis, Nemenyi's post hoc tests (Pohlert, 2014) and generalised linear models with Poisson error distribution were calculated with the programme R (R Development Core Team, 2016) to identify significant scale differences between gender and age groups. Wilcoxon rank sum tests were used to calculate differences between pre- and post-tests. Cohen's *d* effect sizes were calculated with the lsr package (Navarro, 2015), to compare the practical significance of differences between boys and girls, and pre- post-test results. Figures 1 and 2 were created with plotrix package (Lemon, 2006) and Figure 3 with the likert package (Bryer & Speerschneider, 2015).

### 2.4. Participation rates and other methods to validate results of the ILO analysis

To validate the results concerning the ILOs interest (1) and motivation (3) from the pre- and post-surveys, the quantitative scientific output of the biodiversity data collected by the students was examined. The output was represented by the number of submitted datasets on birds, butterflies, hedgehogs and bees, compared to potentially submitted data (if all students had delivered data according to the instructions). To be able to relate participation to personal interest and motivation (rather than school duty), only data collected outside the training sessions (or joint class activities), by individual students or small groups of students, were counted.

All items were screened and pre-tested by the teachers from all school types to strengthen ecological validity and to keep the language as simple as possible for all students. To validate results from the ILO surveys, students and teachers were also interviewed using open questions.

## 3. Results

### 3.1. Development of interest, mastery, motivation and behaviour

Overall, 309 out of 428 participating students (72.2%) filled out the survey fully or to an extent of completion that their answers could be used. The questions within the scale Liking of Animals were answered by the highest number of students. The items within the biodiversity scale were answered by fewest students, presumably because the younger students did not fully understand the questions. Table 3 shows the reliabilities of the scales.

### 3.2. Differences between age groups: primary students are top

In general, students' responses were very positive, with the medians for each scale being in the upper ranks of scale across the population (Table 4). Most students enjoyed the research activities (ILO interest). The favourite research tasks (individual items, listed in Appendix) across the age groups were the determination of birds and butterflies. The least favourite item was 'filling in data forms' (not included in the scale Liking Research Done).

**Table 3.** Tested ILOs and reliabilities (internal consistency) of scales.

| ILO (IndividualLearning outcome) | Indicator (scale) | No. of Items | Population for Reliability | Cronbach Alpha | Rank sum of Scale |
|---|---|---|---|---|---|
| Interest | Liking of research done | 6 | 165 | .862 | 6 to 24 |
| Self-efficacy | Mastery of animal identification | 5 | 169 | .839 | 5 to 20 |
| Motivation | I want to know more about animals | 5 | 233 | .881 | 5 to 20 |
| | Purpose: contributing to science | 9 | 257 | .825 | 9 to 36 |
| Behaviour | Help species in the garden | 4 | 232 | .8857 | 4 to 16 |
| Attitudes | Liking of animals pre | 4 | 318 | .631 | 4 to 16 |
| | Liking of animals post | 4 | 239 | .701 | 4 to 16 |
| | Nature garden pre | 3 | 317 | .608 | 3 to 12 |
| | Nature garden post | 3 | 256 | .575 | 3 to 12 |
| | Biodiv pos pre | 4 | 270 | .778 | 4 to 16 |
| | Biodiv pos post | 4 | 219 | .777 | 4 to 16 |
| | Biodiv neg pre | 3 | 237 | .697 | 3 to 12 |
| | Biodiv neg post | 3 | 189 | .812 | 3 to 12 |

Note: The full list of items is shown in the Annex. The low population for reliability for the first two learning outcomes is due to the fact that only answers from students which actually performed all the tasks addressed in the items were included in the analysis.

**Table 4.** Results for five ILOs: Differences between age groups according to Kruskal-Wallis test results and respective significance levels.

| ILO | | Interest | Self-efficacy | Motivation 1 | Motivation 2 | Behaviour |
|---|---|---|---|---|---|---|
| Scale | | Liking Research done | Mastery_Animal_ Identification | Know_more_ about_animals | Purpose_Science | Help_species |
| PR | *N* | 47 | 46 | 48 | 48 | 48 |
| | Med | 21 a | 18 a | 20 a | 31 a | 16 a |
| LO | *N* | 79 | 82 | 101 | 122 | 101 |
| | Med | 20 ab | 15 ab | 16 ab | 28 b | 14 ab |
| UP | *N* | 16 | 14 | 56 | 57 | 55 |
| | Med | 19 bc | 13.5 bc | 15 bc | 25 b | 13 bc |
| HI | *N* | 23 | 27 | 28 | 30 | 28 |
| | Med | 18 c | 13 c | 14.5 c | 26.5 b | 12 c |
| Total | *N* | 165 | 169 | 233 | 257 | 232 |
| | Med | 19 | 16 | 16 | 28 | 14 |
| *p*-value | | <.001 | <.001 | <.001 | <.001 | <.001 |

Note: The letters a, b, c show which age groups differ significantly from each other according to post-hoc Nemenyi-tests for multiple comparisons of rank sums. ILO: individual learning outcome; PR-primary level, etc.

For all five scales tested (Table 4) the median of the rank sum was highest for the youngest students (primary school, 8–10 yrs.) and differed significantly from the upper intermediate and higher students. In some cases there were also significant differences between the other age groups (expressed by the letters a, b, c in Table 4). For the scales 'want to know more' and 'behaviour' the primary students even reached the maximum scores (median corresponds to highest rank sum of scale).

Primary students were also overwhelmingly pleased with their ability to master the tasks (Table 4 and Figure 1), followed by the lower intermediate age group (LO). The 13–14 year olds (UP) and the high school students (HI) were most critical about their self-efficacy.

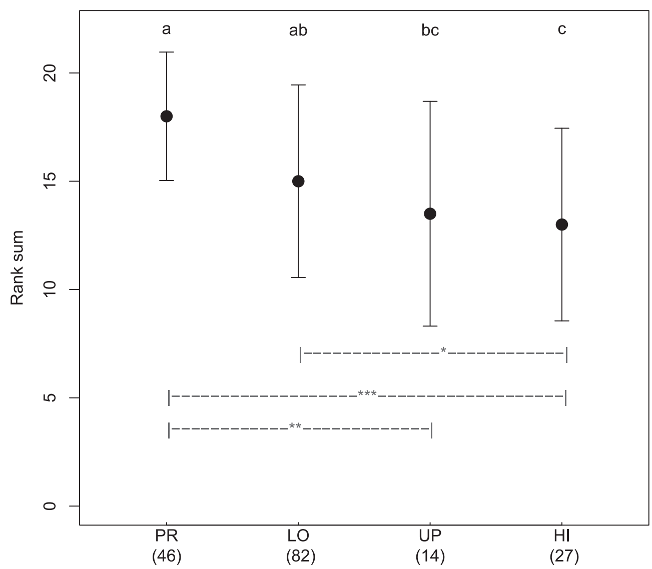


**Figure 1.** Differences between age groups for the scale 'mastery of animal identification' (post-hoc Nemenyi-test). Numbers in brackets show sample size, total $N = 169$; $p$-values: *** < .001, ** < .01, * < .05; more details in Table 4).

### 3.3. Behaviour and attitude: girls benefit more than boys

Small but significant differences in the replies between the sexes were detected for three scales within the ILOs behaviour and attitude (Figure 2): help species and positive as well as negative attitude towards biodiversity (pre and post). For the other ILOs (interest, self-efficacy, motivation) and the scale nature garden (ILO attitude) no significant gender differences were found.

Girls had higher scores for their intention to help species in the garden (Cohen's *d*: .27 small effect). Boys' responses agreed more strongly with negative statements about biodiversity, e.g. 'it is more important to build new houses and roads than to preserve biodiversity' (for full scales see appendix). This result was even stronger at the post-test (pre: Cohen's *d*: .31 small-medium effect; post: Cohen's *d*: .44 small-medium effect)

### 3.4. Attitudes towards wild animals, 'natural' gardens and biodiversity improve

Attitude changes between the start and the end of the project were detected for three scales (Table 3): like animals, nature garden and biodiversity positive.

For the scale nature garden, scores rose significantly from the pre- to post-survey (pre: $N = 317$, med = 10 [3–12]; post: $N = 256$, med = 11 [3–12]; $p$-value pre–post < .001) with a medium to large effect size of .52 (Cohen's $d$). Nature garden elements such as trees, bushes and hiding places for animals were considered more important across all respondents in the post-survey. For the scale biodiversity (positive statements) tests also showed a small but significant rise between the pre- and the post survey (pre: $N = 270$, post: $N = 219$; med = 12 (4–16); $p$-value pre–post < .001; Cohen's $d$: small to medium effect size of .33). Items in this scale included statements such as personal well-being and personal responsibility associated with biodiversity.

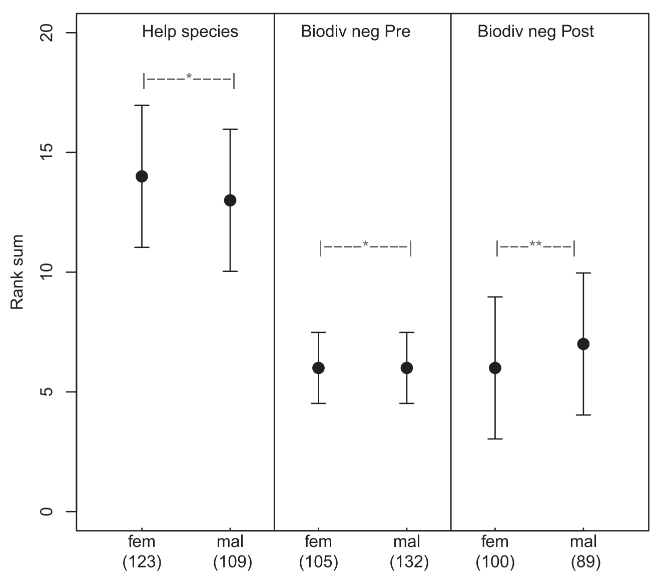


**Figure 2.** Rank sums of three scales with significant gender differences (Kruskal-Wallis test; $p$-values: * < .05; ** < .01). For effect sizes (Cohen's $d$) see text.

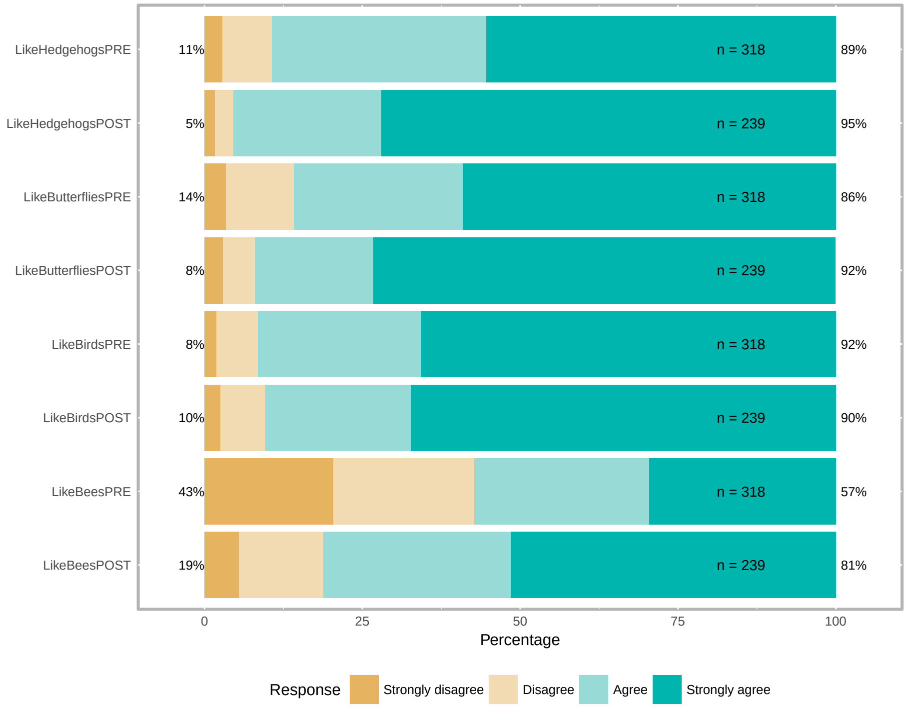


**Figure 3.** Items of the scale 'like animals' showing pre- and post- responses on the Likert-scale (percentages are sums of negative and positive responses: strongly disagree & disagree; agree & strongly agree). Effect sizes between pre- and post-test: highest for bees (Cohen's $d$: .60, medium-large effect, $p < .001$), followed by hedgehog (Cohen's $d$: .43, small-medium; $p = .0004$); butterflies, birds: n.s.

The third scale for attitude, like animals (i.e. the popularity of the observed animals) was already high at the start of the project and increased from a median of 13 (across all age groups) at the pre-survey to 14 at the post-survey: pre: $n = 318$, med = 13 (4–16); post: $n = 239$, med = 14 (4–16); $p$-value pre–post < .01; Cohen's $d$: .46 (medium effect). Regarding the individual animals separately (Figure 3) was even more conclusive. The Likert scales show increases for the liking of the individual species for all animals except for birds. At the pre-survey the bird's popularity scored highest of all four animal groups, followed by hedgehogs and butterflies, and lowest for the wild bees. At the post-survey, the scores for three groups increased (all except for birds, probably due to a ceiling effect), with wild bees showing the strongest increase, and hedgehogs scoring highest in total.

### *3.5. Participation rates and other data analyses*

Figure 4 shows the extent to which individual pupils took part in the outdoor activities. For the hedgehog and the bee flight tasks, the total of 428 students were potential participants (i.e. their classes took part in the task, students were trained and equipped accordingly).

Results show that the participation rates varied strongly between the tasks and also between age groups. Across all age groups, the highest proportion of students participated in the bird activities, followed by butterfly, hedgehog and bee flight activities. With respect to the age groups, primary students were by far the most active participants observing

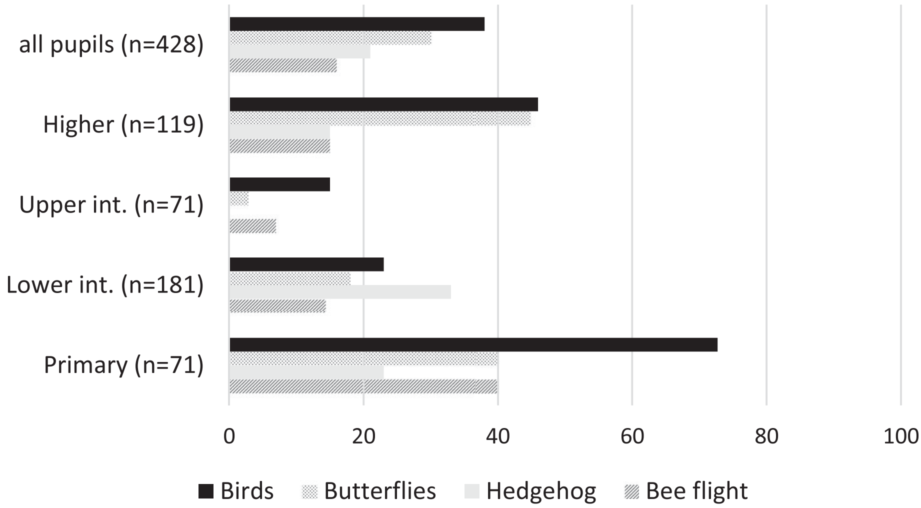


**Figure 4.** Participation rates: Rates of individual students entering data for a task, as a percentage of all potentially participating students. *n* = total number of students in each age group. Potentially participating students (=100%) at the tasks: hedgehog & bees: 428; butterflies: 350, birds: 244.

birds, followed by the oldest age group (Higher). For butterflies, the Higher age group surpassed all others. The upper intermediate were also relatively active with respect to the bird task, but compared to the other age groups, they achieved the lowest participation rates for all tasks. For hedgehogs they did not provide any individual observations.

Responding to the open questions in the post survey, students provided exclusively positive comments about the project, such as the following: for self-efficacy: 'I know a lot more than before. I was very surprised to learn how many different species of butterflies and birds exist and that the birds all sound differently.' (Girl, 14); for behaviour: 'The feeling that I can help the animals – it just feels right.' (Girl, 13).

## 4. Discussion

### *4.1. Individual learning outcomes and further perspectives*

All five learning outcome categories and the respective indicators provided very conclusive results which were validated by other analyses conducted within the project itself. These include the analysis of participation rates, open questions in the student's survey (Winter et al., 2016), and qualitative interviews with the teachers (Panhuber, 2016; Scheuch et al., 2018; Stöckl, 2015). Before discussing the ILOs, the authors would like to point out one aspect of the methodology which may be criticised, namely the lack of pretesting of the instrument (results of the scales presented in Table 2) with a similar (but not the same) sample. All of the values in Table 3 are those of this particular population. Pretesting would have helped to create scales independently from the test situation and thus increase the stability and generalisability of the results. This desirable first step was not manageable within the test case, because of restrictions of project duration and finances. The incorporation of parts of existing validated scales (by BFN, 2009; Wilde et al., 2009; see Methods section) was an effort to alleviate the problem.

The high interest in science (ILO 1) of both male and female students may be due to the fact that it dealt with 'soft science', investigating beautiful creatures in familiar outdoor settings. This is in line with one aspect of the ROSE study: environmental issues are important for all, but especially for girls (Sjoberg & Schreiner, 2010, p. 21; see also Sevinç, Özmen, & Yiğit, 2011). Kelemen-Finan et al. (2013) showed that the most popular aspect for students in CS projects was being outdoors. This may be another reason for the positive responses to the outdoor biodiversity tasks in this study.

Participation rates at the various scientific tasks showed that the quantity of data entries matched the expressed interest and motivation of the students: the highest amount of data entries were provided for birds, with bird activities being amongst the most popular, and birds being the most popular animals. Secondly, primary school students, who gave the highest ratings in the surveys (for all ILOs), also provided most data entries (relative to their numbers).

Next to interest, self-efficacy (ILO 2) or 'perceived competence' (Wilde et al., 2009) is considered one of the most important factors for motivation according to the self-determination theory by Deci and Ryan (2003). Thus it is not surprising that scores for self-efficacy corresponded with those for interest, both being highest for the primary students. There were no significant gender differences for the level of interest nor for self-efficacy. In Wilde's study (with 5th year students, matching our age group of 'Lower Intermediate'), boys rated their own expertise higher than girls, while the interest scores were the same for both sexes. A possible explanation for our girls' interest and perceived competence being equally high as boys' may be that all four scientists conducting the field trainings with the students in the evaluation study were relatively young females. They may have served as role models for girls. This also provides evidence to emphasise the importance of the scientist's image as a real-life-person rather than the stereotyped male 'egghead scientist' (Littledyke, 2008).

Nevertheless, self-efficacy is not an indicator for data quality. Winter et al. (2016) showed for the present case study that although primary students rated their own skills higher than the others, they did not determine birds or butterflies better than their elder students (Primary students: mean: 59% correct answers; older students: mean: 65% correct answers). Primary students were just more confident. We argue that scientists should make teachers aware of these differences between age groups. However, it is the teachers' responsibility to help the students obtaining good results and being self-critical about their skills. It is the researchers' responsibility of dealing with uncertainty in an open manner. This is also an important aspect for teaching nature of science in CS projects (NoS – see below).

Attitude (ILO 5), expressed by the scales 'liking of the animals' and 'nature garden' showed a strong pre–post-increase. While there are several CS projects on observing biodiversity in gardens (Haines, 2017) we are not aware of pre–post-surveys investigating associated attitude changes towards 'nature' or 'friendliness for wildlife' in gardens. In the present study the students could relate their own observations of animals (or the lack thereof and resulting frustration) very clearly to the management practices and structures provided in the garden (Winter et al., 2016). Therefore, the attitude changes were likely to be really a consequence of students' own experiences, rather than a 'socially desirable response pattern' (which could have resulted from the communication of project aims).

The third scale for attitudes (ILO 5), biodiversity, also showed a positive and statistically significant rise, but was smaller than for the two other scales. This may be the reason why attitude tests are not often or not successfully conducted in CS contexts (Brossard et al., 2005; Knoll, 2013; Phillips et al., 2014). However, the biodiversity scale is the only one of our three attitude scales which showed weaker results. Even though the term biodiversity was replaced by a simplified terminology ('Vielfalt' in German), the concept and the items seemed to be hard to grasp for the younger students. Whether this may also be linked to the results that boys agreed more strongly with negative statements about biodiversity, remains unclear. The authors recommend to keep testing the effect of CS projects on attitude changes towards biodiversity, including further items, and to explain the terminology and the concepts thoroughly, because of its relevance for society (see Conclusions).

Finally, the results for behaviour (ILO 4), represented by the scale 'help species', were also positive. The desire to do something for the animals in the garden was high across the sample, with girls scoring higher than boys, and primary school students (often receiving help from their parents) being the keenest. A next step could include a comparison with the pre–post-increase of the scale 'like animals' (ILO 5), to find further evidence for the view that students care for what they know and what they learn to like (here: wild bees; see also Collins, 2014, who showed how attitudes towards ants improved). What remains open is the question of whether Phillips et al.'s (2014) ILO 'behaviour' may be better subsumed under 'attitude', since real behaviour changes are difficult to document.

The last two desirable ILOs suggested by Phillips et al. (2014), 'knowledge of the nature of science' and 'skills of science enquiry', could not be tested with the approaches used in this study. Since they constitute very important learning outcomes both in a CS and in a SE context, they need to be tested by other means, even if it proves to be difficult (Brossard et al., 2005; Moss et al., 1998). Possible methods are open questions with contextual items in the surveys (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) or to conduct guided interviews. Scheuch et al. (2018) interviewed teachers involved in the project in order to document the development of their pedagogical content knowledge (PCK). Results showed that the teachers' focus was on species identification and not on the increase of scientific literacy of students. Similarly to Brossard et al. (2005) they concluded that unless the understanding of the nature of science (NoS) is a specific aim which is targeted throughout a project explicitly, there is a high risk of failing to increase the understanding of NoS.

### *4.2. Implications of biodiversity CS projects for educational aims*

The results show that some of the most important aims of SE, namely to raise interest, knowledge, motivation, behaviour and attitude, can be very well addressed by biodiversity Citizen Science projects in an outdoor school class context. It requires effort, though. Citizen Science with students connects scientists with schools, both institutionalised with very different aims, procedures and world views. All sides, teachers, students and scientists, are requested to make commitments to understanding each other. Scientists have to consider state curriculum and time constraints of schools in their planning. Teachers are requested to invest additional resources for implementing the tasks within the school curriculum. In addition, they need to motivate students to participate actively and to collect high-quality data for the CS project. Both sides must agree on the educational outcome as well as the data quality and quantity required by the scientists. One step to negotiate these aims is to implement co-created projects, where CS project aims and approaches are developed by researchers and citizens cooperatively (Bonney et al., 2009; Mueller & Tippins, 2012).

It appears that the balance between scientific aims and the requirements of the school curricula has been longer and more successfully addressed in Anglo-American than in continental European countries (e.g. Means, 1998, for Students-scientist partnerships). CS projects e.g. such as those conducted by Cornell Lab of Ornithology (US) or the Monarch larva project (https://monarchlab.org/mlmp) develop and include curriculum materials for schools in order to facilitate students' participation (as suggested by Trumbull, Bonney, & Grudens-Schuck, 2005). The authors observe that despite the current increase of CS projects in continental Europe, the trade-off between scientific and educational aims persists. One reason may be a lack of tradition. This results in the researchers` lack of resources for involving citizens in the process of writing research proposals including detailed research questions and methods. Thus most CS projects in Central Europe remain contributory. The implications are that discrepancies between scientific and educational aims persist, affecting outcomes for both (see Brossard et al., 2005; Jordan, Crall, Gray, Phillips, & Mellor, 2015).

One goal should be to urge the respective academic institutions to acknowledge the scientist's role as a science communicator as well as an outstanding scientist. Meanwhile the authors recommend that with respect to the teacher's potentials, scientists are well-advised to prioritise cooperation with school educational levels which enjoy a certain degree of autonomy. The present study showed that in Primary schools CS projects contribute most effectively to SE.

## 5. Conclusions

This study shows how outdoor biodiversity CS projects contribute successfully to SE aims in an outdoor school class context. The students' interest, knowledge, motivation, behaviour and attitude for various scientific issues were raised significantly by conducting research activities with birds, butterflies, bees and hedgehogs. These results have wide implications not only for SE but also for society: if CS biodiversity projects raise awareness, change attitudes and may consequently even change behaviour, these projects also contribute towards reaching the goals of the EU Biodiversity Strategy 2020 (European Parliament, 2016: headline target, p. 8).

The authors agree with Phillips et al. (2014) that an evaluation framework for a CS project should not try to evaluate all (theoretically) possible learning outcomes at once, but focus on a balance of achievable goals and a realistic plan to investigate the achievements. With the indicators presented here, a range of learning outcomes can be addressed very well and effectively. The authors hope that the scales developed here and the results obtained will encourage other researchers to explore the ILOs further, and to encourage teachers to cooperate and improve students' understanding of the nature of science.

## Note

1. https://www.sparklingscience.at/en/projects/show.html?--typo3_neos_nodetypes-page[id]=773.

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## ORCID

*Julia Kelemen-Finan* http://orcid.org/0000-0003-4003-3459
*Martin Scheuch* http://orcid.org/0000-0003-3183-799X
*Silvia Winter* http://orcid.org/0000-0002-8322-7774


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## Appendix

| Learning outcome and Scale | Item – German (original) | Item – English Translation |
|---|---|---|
| Interest: Liking Research done | Ich beobachte und untersuche gerne Tiere im Freien. | I like observing wild animals. |
| | Bienen in den Nisthilfen beobachten hat mir gut gefallen. | I liked observing wild bees in the nest boxes. |
| | Igelspuren nachweisen hat mir gut gefallen. | I liked tracking hedgehog tracks. |
| | Vögel bestimmen hat mir gut gefallen. | I liked determining birds. |
| | Vögel im Nistkasten beobachten hat mir gut gefallen. | I liked observing birds in the nest box. |
| | Schmetterlinge bestimmen hat mir gut gefallen. | I liked determining butterflies. |
| Self-Efficacy: Mastery Animal identification | Ich kann Igelspuren jetzt besser von anderen Spuren unterscheiden als vorher. | I can identify hedgehog tracks better than before. |
| | Ich kenne mich jetzt besser aus mit Wildbienen als vorher. | I know more about wild bees than before. |
| | Ich kann die 8 Tagfalter – Zielarten jetzt unterschieden. | I can identify the 8 butterfly target species now. |
| | Ich kann die 10 Vogel – Zielarten jetzt am Aussehen unterscheiden. | Now I can identify the 10 bird species visually. |
| | Ich kann die 10 Vogel – Zielarten jetzt an der Stimme unterscheiden. | Now I can identify the 10 bird species by their songs. |
| Motivation 1: Know more about animals | Ich möchte noch mehr über Igel herausfinden. | I would like to find out more about hedgehogs. |
| | Ich möchte noch mehr über Wildbienen herausfinden. | I would like to find out more about wild bees. |
| | Ich möchte mich noch besser mit Schmetterlingen auskennen | I would like to be better at identifying butterflies. |
| | Ich möchte Vögel noch besser am Aussehen unterscheiden können. | I would like to be better at identifying birds visually. |
| | Ich möchte Vogelstimmen noch besser lernen. | I would like to be better at identifying birds by their songs. |
| Motivation 2: Purpose Science | Ich bin stolz, einen Beitrag zur Wissenschaft leisten zu können. | I am proud to contribute to science. |
| | Der persönliche Kontakt mit der Betreuerin von der BOKU hat mir gefallen. | I liked the personal contact with the scientist. |
| | Ich habe die Aufgaben im Forschungs-Projekt sehr interessant gefunden. | I found the research tasks very interesting. |

(*Continued*)

Continued.

| Learning outcome and Scale | Item – German (original) | Item – English Translation |
|---|---|---|
| | Mit meinen Leistungen im Forschungs-Projekt bin ich zufrieden. | I am content with my achievements. |
| | Mir ist es wichtig, dass die Ergebnisse meiner Untersuchungen von den Forschern der Universität verwendet werden. | It is important for me that the scientists use my data. |
| | Ich möchte die Gärten und den Schulgarten/Park auch in meiner Freizeit untersuchen. | I would also like to do observations in my spare time. |
| | Ich möchte gerne die Ergebnisse erfahren. | I would like to get the results. |
| | Ich möchte gerne selbst Daten auswerten. | I would like to analyse data myself. |
| | Ich könnte mir vorstellen, selbst Wissenschafter/in zu werden. | I can imagine becoming a scientist. |
| Behaviour: Help Species | Ich möchte gerne etwas unternehmen, um Igeln im Garten zu helfen. | I would like to help hedgehogs in the garden. |
| | Ich möchte gerne etwas unternehmen, um Wildbienen im Garten zu helfen. | I would like to help bees in the garden. |
| | Ich möchte gerne etwas unternehmen, um Schmetterlingen im Garten zu helfen. | I would like to help butterflies in the garden. |
| | Ich möchte gerne etwas unternehmen, um Vögeln im Garten zu helfen. | I would like to help birds in the garden. |
| Attitude pre-post: Liking Animals | Ich mag Igel. | I like hedgehogs. |
| | Ich mag Wildbienen. | I like wild bees. |
| | Ich mag Schmetterlinge. | I like butterflies. |
| | Ich mag Vögel. | I like birds. |
| Attitude pre-post: nature garden | (Was soll mein Garten haben:) Möglichst viele Beeren und Obst zum Naschen | (My garden should have) lots of berries and fruit to eat. |
| | Mit vielen Verstecken für wild lebende Tiere (z.B. Laubhaufen, ein Eck mit Wiesenblumen und Brennesseln, …) | … lots of hiding places for wild animals. |
| | Einen großen Baum zum Hinaufklettern | … a large tree to climb. |
| Attitude pre-post: Biodiv pos | Die biologische Vielfalt in der Natur fördert mein Wohlbefinden und meine Lebensqualität. | Biodiversity increases my wellbeing and my quality of life. |
| | Wenn die biologische Vielfalt schwindet, leidet auch mein Leben darunter. | If biodiversity declines, my life is affected negatively. |
| | Ich fühle mich für die Erhaltung der biologischen Vielfalt verantwortlich. | I feel responsible for the preservation of biodiversity. |
| | Ich möchte gerne erfahren, wie ich selbst zur Erhaltung der biologischen Vielfalt beitragen kann. | I would like to know, how I can help preserving biodiversity. |
| Attitude pre-post: Biodiv neg | Der Bau neuer Häuser und Straßen ist wichtiger als die Erhaltung der biologischen Vielfalt. | It is more important to build new houses and roads than preserve biodiversity. |
| | Viele Berichte über den Rückgang der biologischen Vielfalt auf der Welt sind übertrieben. | Reports about biodiversity losses are exaggerated. |
| | Für die Forschung über die biologische Vielfalt wird zu viel Geld ausgegeben. | Too much money is spent for research on biodiversity. |