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Two ways of acquiring environmental knowledge: by encountering living animals at a beehive and by observing bees via digital tools

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ABSTRACT
Pollinating animals are profoundly affected by the current loss of biodiversity, a problem that is of concern to science, policy-makers and the public. One possibility to raise awareness for pollinator conservation is education. Unfortunately, insects such as bees are often perceived as frightening creatures; a negative emotion that may hinder successful learning processes. Thus, any educational initiative must conquer this obstacle and promote conservational knowledge. Using a quasi-experimental design, we evaluated the effectiveness of an educational programme using two student-centred learning approaches: One by encountering living honeybees (*Apis mellifera*) at a beehive ($N = 162$), the other by using an eLearning tool connected to a remote beehive ($N = 192$). We monitored secondary school students' environmentally relevant knowledge of bees, their environmental attitudes and their perception of bees in regard to conservation and dangerousness. The results indicate that both approaches lead to the acquisition of conservational knowledge in the short and medium term. Direct experiences with nature are regarded as crucial, but using an eLearning tool in environmental education constitutes an outstanding alternative to acquire knowledge. Adolescents with low 'green' attitudes responded positively to the online beehive, and the perceived danger of bees played no role in the learning process.

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Introduction

Pollination is a natural, key process in all terrestrial ecosystems that ensures the sexual reproduction of flowering plants. A majority of world food crops rely on the service of pollinators such as insects, birds and other animals. Not only luxury goods such as chocolate or coffee fall into this category, but rather fruits, vegetables and seeds contributing to nutritional security for mankind and fauna (Abrol, 2012). Hence, human well-being and the balance of nature are directly dependent on these plant–animal interactions and are affected to various degree by pollinator decline (Potts et al., 2010) and global biodiversity loss (Díaz, Fargione, Chapin, & Tilman, 2006). Insects, particularly wild and domesticated bees as primary pollinators, have attracted particular attention (Potts

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et al., 2010). Research and policy have already reacted, counteracting the decline of pollinators: For instance, the drivers, the extent and impact of the bee decline have been studied, but controversially discussed. Major stressors such as habitat loss, parasites or pesticides are assumed to be interacting factors and their extent varies in different parts of the world (Goulson, Nicholls, Botias, & Rotheray, 2015; Potts et al., 2010). Nevertheless, there is a common understanding of the necessity of raising awareness towards pollinator conservation on global and local levels (Byrne & Fitzpatrick, 2009). Worldwide campaigns and conventions have already focused on this issue. For instance, the first assessment of the recently formed Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) concerned itself with 'Pollination and Pollinators associated with Food Production', with the aim of suggesting options for action on the part of policy-makers (Díaz, Demissew, Joly, Lonsdale, & Larigauderie, 2015). At the local level, public awareness for the environment in general and pollinators in particular must be raised using formal and informal education (Abrol, 2012; Kearns, Inouye, & Waser, 1998).

Environmental knowledge and attitudes

The educational aim is to convince people of the importance of our natural resources and to encourage more pro-environmental behaviour (Potter, 2009). Educational programmes must build upon different influencing factors, such as environmental knowledge and attitudes that lead to the forming of a person's environmental competence (UNESCO, 1976). Many studies in recent decades have been dedicated to the discovery of influences and interrelations between those factors in order to systematically foster pro-environmental behaviour. Initial theories described simple models with linear progressions from knowledge to attitudes leading to an intended behaviour (e.g. Fishbein & Ajzen, 1975). These early models have today been further elaborated, and are based on complex constructs involving a variety of dimensions and influencing variables (Kaiser, Wölfing, & Fuhrer, 1999). For instance, environmental knowledge as a precondition of conservation performance can be encapsulated in several dimensions: While 'System Knowledge' includes an understanding of natural processes within ecosystems, 'Action-related Knowledge' and 'Effectiveness Knowledge' relate more to peoples' behavioural options of conserving the environment through their own actions and knowing how effective these options would be (Frick, Kaiser, & Wilson, 2004). Acquiring knowledge within all three dimensions is essential, as factual or system knowledge alone would not necessarily lead to pro-environmental behaviour (Roczen, Kaiser, Bogner, & Wilson, 2014). In the same model involving the three dimensions of environmental knowledge, attitudes towards nature act as strong predictors of conservational performance and influence knowledge, and vice versa. It is therefore important to focus on both cognitive (e.g. knowledge) and affective (e.g. attitudes and values) learning issues in order to successfully promote peoples' conservation performance.

Effectiveness of educational initiatives

The effectiveness of educational interventions in an environmental context is well documented. The potential of educational modules on cognitive achievement has been demonstrated repeatedly. For instance, environmental knowledge focusing on different topics (e.g. plants, marine ecology, water) may be acquired not only through long-term (e.g.

Bogner, 1998; Liefländer, Bogner, Kibbe, & Kaiser, 2015) but also through short-term interventions (e.g. Fančovičová & Prokop, 2011; Sattler & Bogner, 2016). Moreover, studies have demonstrated the ability of educational settings to positively influence environmental attitudes (e.g. Bogner, 1998; Fančovičová & Prokop, 2011; Johnson & Manoli, 2010).

Many methods and approaches have been used in relevant studies and depend completely on the particular topic and on the audience: Self-regulated work stations (e.g. Sattler & Bogner, 2016; Sellmann & Bogner, 2013), field trips (e.g. Ballouard, Provost, Barré, & Bonnet, 2012; Randler, Ilg, & Kern, 2005), visits in zoos or aquariums (e.g. Ballantyne, Packer, Hughes, & Dierking, 2007) and many more besides have been successfully implemented. Especially, the impact of direct and indirect experience of nature on environmental knowledge, attitudes and behaviour has received particular attention in research (Duerden & Witt, 2010; Zelezny, 1999). A meta-analysis of Zelezny (1999) showed that environmental behaviour can be influenced more effectively by implementing classroom-based interventions compared to non-traditional settings (e.g. field trips). However, a key aspect for the effectiveness of the investigated programmes has been even more the active participation of students, which itself was more likely in classroom interventions. In contrast, Duerden and Witt (2010) reported that environmental attitudes could be more supported by direct experience with nature, whereas environmental knowledge may be increased by both direct and indirect experience. An effective way to support environmental knowledge, attitudes and behaviour would be a combination of both, methods that allow active participation and providing opportunities to experience nature. While the success of such learning depends strongly on the methods employed, internal factors such as emotions and/or motivation, as well as external (e.g. cultural, institutional) and demographic factors must also be taken into account (Kollmuss & Agyeman, 2002).

Especially, in the case of learning with living animals, effective educational initiatives may be hindered by negative emotions like disgust, aversion or fear (Bixler & Floyd, 1999). Insects, including pollinators, and other invertebrates are often perceived as disgusting or frightening animals (Davey, 1994; Kellert, 1993) which may pose major barriers in environmental education. Although insects with practical value are perceived more positively (Kellert, 1993), bees nonetheless are associated with fear (Arrindell, 2000; Gerdes, Uhl, & Alpers, 2009), perhaps caused by individual experiences with bee stings or just the knowledge of bees' capacity to sting (Schönfelder, 2016). Reducing fear and increasing interest should be prioritised in educational settings (Schönfelder & Bogner, 2017). Other studies report that the use of living animals has the potential to evoke learning success at a cognitive (Hummel & Randler, 2012) as well as an affective level (Ballouard et al., 2012). However, the key to success in these studies was assumed to be to direct experience in the form of physical contact.

In the case of pollinators, keeping or handling in classrooms is often difficult or impossible. Visiting a beehive, in a school garden or in the neighbourhood at a local beekeeper site, would allow direct experience. However, active participation by close observation or touching the animals is impractical when larger classes are involved. Further difficulties could occur if weather conditions or seasons are not appropriate, or simply if no bee expert is available. Education on pollinator conservation embedded in normal school life thus requires alternative approaches and methods to ensure effective learning.

Digital tools as educational 'newcomers' easily allow active participation (Fauville, Lantz-Andersson, & Säljö, 2014). Especially in the context of citizen science, information and communication technologies (ICT) such as computers or smartphones have already been employed to engage people in environmental issues (Wals, Brody, Dillon, & Stevenson, 2014). A variety of tools are meanwhile available, from games and simulations even to virtual museum visits leading to cognitive achievement as well as students' engagement (for review, see Fauville et al., 2014). However, there is a lack of studies investigating the learning outcome concerning environmentally relevant knowledge. Due to the novelty of this approach in this field, to our knowledge, there are no studies on the use of ICT tools in regard to pollinator conservation.

Purpose

The primary aim of our work was to empirically evaluate the effectiveness of an educational programme on pollinator conservation. We conducted two similar studies each using a different approach: *Study 1* examined the use of living animals, whereas *Study 2* used an eLearning setting. The following research questions were applied to both studies:

(1) Do students show cognitive achievement with respect to environmental knowledge about bees after performing an environmental education programme?
(2) To what extent do environmental attitudes and perceptions of bees affect cognitive achievement with respect to environmentally relevant knowledge about bees?

Methods

Participants

Our sample consisted of 354 students from different secondary schools in Bavaria, Germany, divided into two subsamples: 162 fifth to seventh graders (10–13 years) participated in our educational programme 'Let it Be(e)' with living bees at a local beehive (*Study 1*: 51.23% female; age $M \pm SD = 12.72 \pm 1.12$), 192 eighth graders (13–15 years) participated in our programme 'HOBOS – The flying classroom' using a remote beehive via eLearning (*Study 2*: 39.58% female; age $M \pm SD = 13.87 \pm 0.60$). Forty-six eighth graders served as a test–retest group without participation in either of our modules (*Control*; 52.17% female; age $M \pm SD = 13.35 \pm 0.56$). Data from 16 classes from five different schools were collected. Participating students were only included when parents had given their permission and teachers were willing to participate in the study.

Environmental education programme

The overall aim was raising awareness of pollinator conservation by using bees as an example. To be more specific, we intended to promote appreciation for bees as pollinators, necessary organisms for humans and nature. Since the species is well known, indigenous and part of all German curricula, we considered only honeybees (*Apis mellifera*). Following Schönfelder (2016), students' conservational concerns towards bees can be addressed by increasing interest in the species and reducing the perceived danger of the insects.

Besides including affective elements to capture students' emotions, our programme focused on cognitive elements by giving participants supportive information to further their understanding of ecological interrelations, as well as additional information of interdisciplinary relevance to awaken their interest. We developed two three-lesson modules (135 minutes) structured each in workstations. Both modules covered similar learning content, but differed in the manner of encounter with living bees.

In *Study 1,* students participated in the programme labelled 'Let it Bee' that consisted of four hands-on workstations and a visit to a beehive located on the school grounds. Two workstations covered structure and construction of honeycombs, as well as the bees' communication in the dark beehive. The other two workstations dealt with the bees' usefulness for humans and nature and their death caused by human impact. Students were also introduced to the viewpoints of different interest groups (e.g. farmers, politicians, citizens) and were asked to develop action options which help to conserve the species. One additional part to the workstations was the visit to a beehive. In small groups of 8–10, students were guided by a beekeeper who had set up a beehive in the school grounds for a few weeks. The beekeeper had been instructed to conduct standardised tours of the beehive, but was allowed to answer students' questions individually. Participants closely observed the honeybees on the combs after opening the hive, conducted measurements (e.g. hive temperature) and interviewed the beekeeper on prescribed interview questions which were purposeful for the content of the learning programme (for more details, see Appendix 1).

In *Study 2,* students participated in the programme 'HOBOS – The flying classroom'. The workstations were structured into four units, each with two station activities. Similarly to *Study 1*, the content covered honeycomb construction, bees' life in the dark beehive as well as their ecological and economic importance and the current risks to which they are being exposed (see Appendix 2). However, instead of visiting a beehive, students visited a remote beehive using the online platform HOBOS (HOneyBee Online Studies; http://www.hobos.de/en). HOBOS is an interactive online tool linked to a beehive in Würzburg, Germany, that is available for research purposes. This equipment offers the possibility of observing honeybees via live streams by the use of specific cameras installed at different angles inside and outside the beehive. Furthermore, a light barrier, a scale for weighing the hive, further sensors and technical equipment recorded data over years which can be retrieved using an interactive chart tool. Together with additional information on honeybees, the live stream and the chart tool allow for student-centred learning projects. In our programme, HOBOS was embedded in half of the workstations of *Study 2*. For instance, students had to observe the hive entrance via live stream counting the outgoing honeybees in order to calculate the pollination rate during a specific time period.

Following the self-determination theory, both learning programmes were structured in workstations with small experiments and further hands-on material (Deci, Vallerand, Pelletier, & Ryan, 1991). Groups of three or four students completed the assignments at the workstations cooperatively in a self-regulated way. To ensure an efficient workflow, we offered each workstation twice in the classroom. A workbook leads the participants through the workstations with information and all tasks to be solved. After completing a workstation, students could compare their answers and solutions in a self-directed way with sample solutions on the teacher's desk.

Instruments and procedure

Our studies followed a quasi-experimental design with pre-test, post-test and retention test (Figure 1). A knowledge test was applied one to two weeks before (T0), immediately after (T1), and six to nine weeks (depending on school holidays) after participation in the programme (T2). Data of both studies were gathered using similar paper-and-pencil questionnaires. We applied an ad hoc multiple-choice test on content knowledge consisting of 27 items. The test covers the contents of the educational programme in order to measure students' cognitive achievement. As we intended to investigate changes in environmentally relevant knowledge, we only selected appropriate items (e.g. 'How can people improve the nutrition supply for bees?', 'Why could pesticides pose a risk for bees?') for subsequent consideration.

We applied a semantic differential on the perception of bees (Schönfelder, 2016) to quantify attitudes towards conservation and the perceived danger of bees. Students positioned themselves on a nine-point scale between bipolar adjectives in reference to the statement 'I think bees are … '. For this study, we used two subscales at test time one (T0): *Conservation & Usefulness* (CONS, 3 items, e.g. necessary – unnecessary) and *Danger* (DANG, 2 items, e.g. safe – dangerous). The Cronbach's alpha was .78 for Conservation & Usefulness, and .80 for Danger.

Additionally, we applied (at T0) the 2-MEV scale (Bogner & Wiseman, 2006) in its modified version (Kibbe, Bogner, & Kaiser, 2014), to measure two orthogonal aspects of environmental attitudes: *Preservation* (PRE) and *Utilization* (UTL). In order to limit the questionnaire's length, we used only 11 (5 for PRE, 6 for UTL) items of the original 20-item test battery. Shortening the 2-MEV scale has already been used successfully in recent studies (e.g. Liefländer & Bogner, 2014; Schneller, Johnson, & Bogner, 2015). The selection criterion in our study was a factor loading above .40, referring to Kibbe et al. (2014). Cronbach's alpha was .65 for PRE and .51 for UTL. For the 2-MEV scale, we used a 5-point Likert scale with a range from 1 (strongly disagree) to 5 (strongly agree).

The three applied instruments were embedded into larger questionnaires with a total of approximately 55 items (further items on, e.g. personality factors, situational emotions) taking each about 20 minutes for students to complete. The control group completed the same multiple-choice test twice (T0, T1), but without participation in any of our educational modules (Figure 1).

Statistical analyses

We selected 11 items from the multiple-choice test battery that refer to the environmentally relevant workstations in the educational programme. To analyse the quality of these

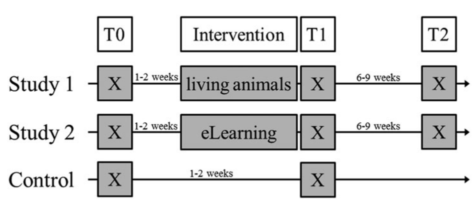

Figure 1. Study design with time frame for *Study 1*, *Study 2* and the control group. Note: X displays an applied knowledge test.

ad hoc knowledge items, we used a probabilistic model and scaled them with a simple Rasch model for dichotomous items (Bond & Fox, 2007). Each student's item response was coded 0 (incorrect answer) or 1 (correct answer). The Rasch analyses were computed using the programme ACER ConQuest 3.

All further statistical tests were conducted with IBM SPSS Statistics 22. To investigate changes in knowledge due to the programme participation, we first calculated a total score for environmentally relevant knowledge for every student for all test times. Due to a non-normal distribution using Kolmogorov–Smirnov-tests ($p < .001$) and Q–Q-plots, further analyses of both studies were based on non-parametric tests. Initially, changes in knowledge within the three test times were evaluated using Friedman's ANOVA and Wilcoxon's *post hoc* analyses. We additionally calculated effect sizes r according to Field (2013). Second, relationships between knowledge and attitudinal variables were analysed using Spearman's Rho. Due to multiple testing, we used Bonferroni correction to avoid cumulative Type-I-errors (Bender & Lange, 2001). Additionally, we separated two groups for each of the attitudinal factors using median splits and we compared both groups (low scorer/high scorer) performing Mann–Whitney-U-tests.

Results

First, we present the results of the Rasch analyses of the applied knowledge scale. Second, we examine the effects of the educational programme on students' environmentally relevant knowledge in both studies. Finally, we determine the extent of attitudinal factors on students' knowledge due to the programme participation.

Quality of the instrument

Initially, we scaled our knowledge item set (*post hoc*) using a dichotomous Rasch model in order to determine the scales' fit statistics, item discrimination and reliability. For all testing points, the difficulty of each item was calculated, providing information about the item fitting (Table 1).

The mean square statistic tests the relative difference of the variance between an observed item/person value and the expected value predicted by the Rasch model (Wright & Stone, 1999). With our sample size ($N_{\mathrm{T0}} = 298$; $N_{\mathrm{T1,T2}} = 249$), weighted fit mean square should range approx. between 0.85 and 1.15 (Wu & Adams, 2002). All our items at all testing points fall into this acceptable range. The fit t-statistic provides

Table 1. Item fit statistic, item discrimination and reliability listed for all testing points.

		T0	T1	T2
wMNSQ	Minimum	0.96	0.94	0.95
	Maximum	1.04	1.04	1.08
t	Minimum	−0.90	−0.80	−0.80
	Maximum	0.80	0.70	1.60
Item-total corr.	Minimum	0.26	0.31	0.35
	Maximum	0.51	0.56	0.55
Reliability (I)		0.97	0.92	0.94
Reliability (EAP/PV)		0.46	0.56	0.61

Notes: Abbreviations found in the statistics: Mean square of the weighted item fit (wMNSQ) and its standardised (*t*) form, Reliability of the item separation (I) and of the person separation (EAP/PV).

a standardised value of the fit mean square statistic taking mean and variance into account. An indication of misfit would be values outside of the range of −1.96 to +1.96 (Wu & Adams, 2002), but our *t*-values are all inside this range. Another quality criterion of our items is the indices of discrimination, which is given by the item-total correlation. As Adams and Wu (2002) report, a discrimination coefficient higher than .25 is desirable. Finally, we considered the item separation and the person separation reliability of our test for all testing points. Our scales show high item reliability indicating a good replicability with the same set of items (Bond & Fox, 2007). In contrast, our instrument only showed moderate person reliability. This index shows the replicability of the same persons with another set of items measuring the same construct.

Knowledge increase and persistence

We observed no significant differences between the control group's environmentally relevant knowledge scores at the two test times ($Mdn_{T0} = 6.13$, $Mdn_{T1} = 6.67$). On the contrary, participants in *Study 1* showed a significant knowledge gain over three test times ($Mdn_{T0} = 5.50$, $Mdn_{T1} = 7.07$, $Mdn_{T2} = 6.71$; $\chi^2(2) = 69.634$, $p < .001$) as did students who participated in *Study 2* ($Mdn_{T0} = 6.66$, $Mdn_{T1} = 8.74$, $Mdn_{T2} = 8.22$; $\chi^2(2) = 86.964$, $p < .001$). The pair-wise comparisons of all three test times are presented in Table 2.

Correlation of the attitudinal variables

We correlated students' mean scores of environmental values PRE and UTL with the knowledge sum scores of all three test times (Table 3). While we found no relationship between the factor PRE and the applied knowledge in *Study 1*, correlations between PRE and the pre-knowledge as well as the knowledge six weeks after participation were detected in *Study 2*. Unlike PRE, the factor UTL correlated negatively with knowledge at all test times in *Study 1*. However, in *Study 2,* UTL correlated negatively only with the pre-knowledge.

We also correlated the individual perception of bees with respect to conservation and danger with environmentally relevant knowledge about bees (Table 4). In both studies, we found similar patterns. Although the factor conservation correlated significantly with the pre-knowledge and less, but still significantly, with the knowledge after six weeks, we found no relationship with the knowledge immediately after the environmental education

Table 2. Inner-group comparisons of knowledge levels.

	z	*p*	*r*
[a]*Study 1*			
T1–T0	−6.94	<.001***	−.46
T2–T0	−6.15	<.001***	−.41
T2–T1	−2.40	.016*	−.16
[b]*Study 2*			
T1–T0	−8.41	<.001***	−.51
T2–T0	−6.36	<.001***	−.39
T2–T1	−4.54	<.001***	−.28
[c]*Control*			
T1–T0	−1.78	n.s.	n.s.

[a]$n = 115$.
[b]$n = 134$.
[c]$n = 46$.

Table 3. Correlation between the factors Preservation/Utilization and the cognitive knowledge.

Knowledge	T0	T1	T2
Study 1			
Preservation	n.s.	n.s.	n.s.
Utilization	−.266*	−.249*	−.266**
Study 2			
Preservation	.254*	n.s.	.243**
Utilization	−.258**	n.s.	n.s.

Notes: Spearman's correlation coefficient r_s; T0 = pre-test, T1 = post-test and T2 = retention test; Level of statistical significance p after Bonferroni correction: $^{**}\alpha \leq .001$; $^{*}\alpha \leq .008$.

Table 4. Correlation between the factors Conservation/Danger and the cognitive knowledge.

Knowledge	T0	T1	T2
Study 1			
Conservation	.385**	n.s.	.254*
Danger	n.s.	n.s.	n.s.
Study 2			
Conservation	.341**	n.s.	.217*
Danger	n.s.	n.s.	n.s.

Notes: Spearman's correlation coefficient r_s; T0 = pre-test, T1 = post-test and T2 = retention test; Level of statistical significance p after Bonferroni correction: $^{**}\alpha \leq .003$; $^{*}\alpha \leq .016$.

programme. In contrast to the factor conservation, the perceived danger did not correlate at all with knowledge at any test time.

When dividing the participants of each study into low and high scorer in regard to the four attitudinal variables, we found differences in knowledge levels (Figures 2 and 3). While students with high or low PRE scores in *Study 1* showed no significant differences in knowledge, students with high or low UTL values did. Participants in *Study 1* who reported of a high UTL value had less environmentally relevant knowledge on bees compared to those with a low UTL score which remained stable over three test times. By contrast, students in *Study 2* with high PRE scores as well as students with low UTL scores show significant more pre-knowledge, but not after the programme.

Even more significant are the differences in knowledge levels of students with high or low conservational perception values of bees. In both studies, participants with high CONS scores have significant more pre-knowledge and knowledge six weeks after the programme than those with low CONS scores. Low and high scorer in regard to the perceived danger of bees do not differ in their knowledge levels within both studies.

Discussion

Two effective learning approaches

As expected, both approaches of our educational programme significantly improved students' environmentally relevant knowledge about bees. It is encouraging that even short-term interventions may promote a positive attitude towards conservation, especially against the background of the current loss of pollinators (Potts et al., 2010). The

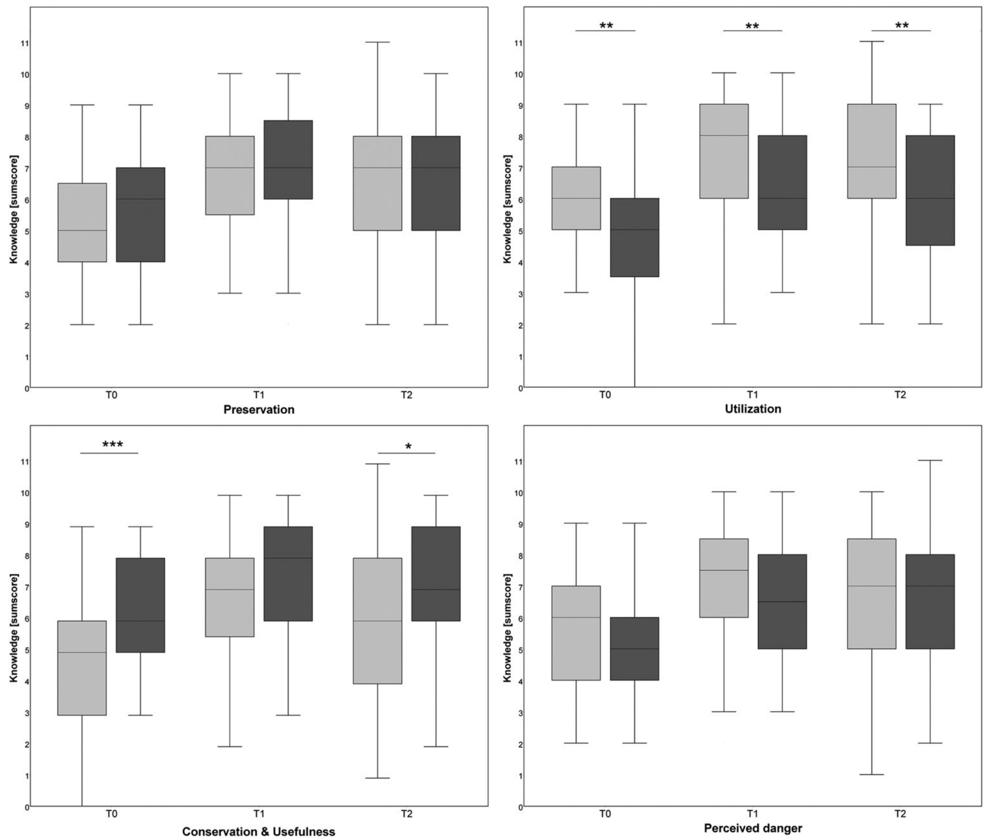

Figure 2. *Study 1*: Sum score of environmentally relevant knowledge of the three test times classified into their attitudinal preference. Note: low scorer (light grey) and high scorer (dark grey); T0 = pre-test, T1 = post-test, T2 = retention test.

knowledge gain in our studies was assessed not only in the short term, immediately after our programme, but also in the medium term, 6–9 weeks later. This result is in line with recent studies with environmental context: For instance, Fančovičová and Prokop (2011) reported cognitive achievement concerning knowledge of plants three months after participation in a short-term outdoor programme. Quite similarly, Sattler and Bogner (2016) demonstrated a persistent cognitive outcome in the area of marine ecology and conservational issues even six weeks after attending an instructional half-day zoo visit. In addition, there are studies demonstrating a long-term effect (6–12 months) in a more general environmental knowledge after one-day outdoor educational initiatives (Bogner, 1998; Farmer, Knapp, & Benton, 2007). However, most studies evaluating educational programmes with regard to cognitive outcome have focused on field trips and outreach settings such as zoos or aquariums. Although encountering plants and animals and experiencing nature is crucial to support connectedness to nature, pro-environmental attitudes and behaviour (Rickinson, 2001), day-to-day schoolwork must nevertheless focus on conservational issues within regular lessons as well. Hence, presenting two effective approaches with respect to pollinator conservation easily adapted to normal school life is a promising message for educators.

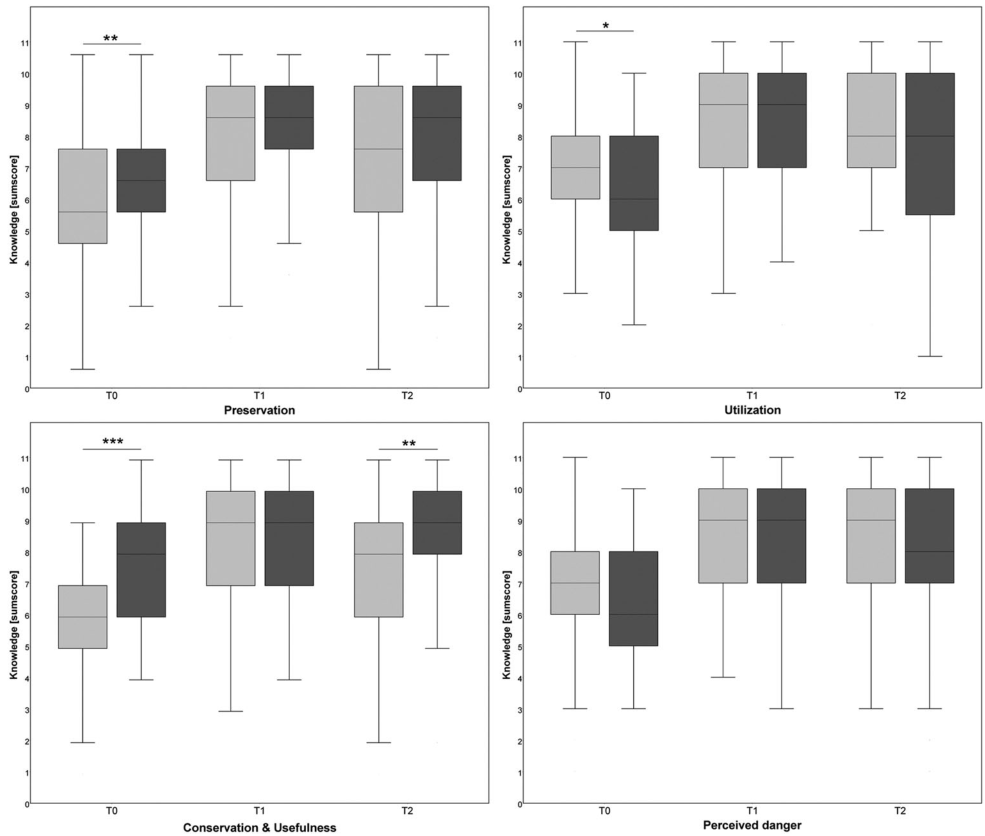

Figure 3. *Study 2*: Sum score of environmentally relevant knowledge of the three test times classified into their attitudinal preference. Note: low scorer (light grey) and high scorer (dark grey); T0 = pre-test, T1 = post-test, T2 = retention test.

In *Study 1*, we combined our workstations with a visit to a beehive at the school grounds. The opportunity to experience the bees directly, to observe them in their natural habitat and to conduct measurements at the beehive seems to be supportive. The use of living animals in biology classes is common practice in order to acquire knowledge (Hummel & Randler, 2012), but also to reduce disgust and/or fear (Randler, Hummel, & Prokop, 2012) as well as to support positive attitudes towards the respective organism (Ballouard et al., 2012). There are only a few studies in the context of environmental education on cognitive success using living animals. The point is that most research followed a more holistic approach to encountering nature in general (e.g. Bogner, 1998), or implemented field trips to a zoo (e.g. Sattler & Bogner, 2016) without focusing on selected species or taxonomic groups. However, Randler et al. (2005) reported a cognitive learning outcome after an indoor class programme and encountering five selected amphibian species during a field trip with conservational purpose; their programme reported a knowledge increase, which remained stable after four weeks, as did our approach. However, as Randler et al. (2005) rather focused their knowledge instrument on species identification knowledge, we validated a knowledge scale focusing on conservational issues of a species. Future studies may need to combine both species identification skills and specific conservational knowledge.

As the use of living animals in educational settings sometimes depends on season, weather and appearance, we evaluated an approach using living bees via eLearning within *Study 2*. The use of eLearning in environmental education is already in place, but its extensive success has been poorly studied (Fauville et al., 2014). Our approach integrating eLearning into an environmental education programme yielded positive results concerning the acquisition of environmentally relevant knowledge in the short term and medium term. Using high school students, Fauville and colleagues (2011) used a virtual laboratory in order to lead students to understand ocean acidification in the context of global climate change. The evaluation of the programme using a pre–post-test design showed significantly increased knowledge due to integration of appropriate ICT tools. A similar large-scale study using the same tool yielded positive results concerning newly acquired knowledge (Petersson, Lantz-Andersson, & Saljö, 2013). Further studies focusing on cognitive learning due to ICT have produced very different results (Fauville et al., 2014). However, we can hardly draw any comparisons because in this domain, data collection on environmentally relevant knowledge has to date been neglected.

Besides using different methods in order to encounter bees, our programme has been structured in workstations including experiments, further hands-on material as well as information about honeybees. Over and above our studies, learning at workstations seems to be a successful approach to teaching biological content as various interventions have also yielded positive learning outcomes in environmental context (e.g. Sattler & Bogner, 2016; Sellmann & Bogner, 2013).

Effects of environmental attitudes on knowledge acquisition

Our second research question asks whether environmental attitudes in general and perception of bees in particular have an influence on students' knowledge gain. Overall, *Study 1* differed from *Study 2* which is quite in line with the literature, as there are no consistent findings in regard to environmental attitudes and knowledge (e.g. Boeve-de Pauw & Van Petegem, 2011; Liefländer & Bogner, 2016). In *Study, 1* no relationship between preference for preservation and environmental knowledge about bees appeared. Although we expected this value as acting as a predictor for knowledge, similar results have been found in recent studies (Liefländer & Bogner, 2016). In *Study 2,* a relationship between knowledge and preservation was found, but only before participating in our programme and 2–3 months after, perhaps because of measurement constraints, such as ceiling effect or social desirability involvement (Oerke & Bogner, 2013). However, as previous studies applying the 2-MEV consisted of samples of younger children up to 12 years (e.g. Boeve-de Pauw & Van Petegem, 2011; Fremerey & Bogner, 2015), a possible explanation for the difference before programme participation (*Study 1* vs. *Study 2*) could also be an effect which comes with higher age. Our deviating sample (*Study 2*) consisted of students aged 13–14 years. Since adolescents in this age range obtain and acquire less pro-environmental attitudes compared to younger counterparts (Liefländer & Bogner, 2014), let us assume that differences in environmentally relevant knowledge may appear during the intervening years. Nevertheless, students with low preservation scores attending our HOBOS programme caught up with the knowledge level of the high scorer. An eLearning tool like HOBOS may therefore support students with lower preservation values to acquire conservational knowledge. Although we have to keep in mind that high scorers are possibly limited in their potential for cognitive improvement (ceiling effect), it is still encouraging to find a tool helping adolescents to acquire knowledge, especially those with lower preference for preservation.

Focusing on the second 'green' attitude value (utilization), the pre-knowledge is related to participants' utilization score in both studies. The lower the preference for exploitative utili, the more the students already knew about conservational issues with bees. This negative correlation remained stable at all three test times within *Study 1*, while in *Study 2,* we detected no significant correlations after the intervention. We conclude that students with higher utili scores, thus having less 'green' attitudes, could also catch up on the knowledge level of the low scorer in T1 by using the eLearning tool. Later on, an effect of utilitarian preferences emerges again, maybe due to high utili scorers failing to retain knowledge as well as the low utili scorers. The effect of students' utili values on environmentally relevant knowledge about bees seems to be parallel to the finding in regard to preservation preferences. Unlike *Study 2*, the use of living animals addresses students equally concerning their knowledge acquisition unbiased of their preference for utili. This was unexpected considering recent research of Liefländer and Bogner (2016), who implemented an environmental education programme encountering nature directly. Although they also found correlations between students' utili scores and their environmental knowledge, the authors arrived at a different conclusion: Children who tend less to (ab)use nature would benefit more concerning acquiring environmental knowledge. In future research, the relationship and causality between environmental attitude variables and knowledge needs to be considered more closely by focusing on different age groups and extreme groups regarding attitudes with a larger sample sizes.

Effects of perception of bees

Not only do environmental attitudes in general need consideration, as the content of our educational programme is really narrow in the broad field of environmental education. It remains open to what extent individual perception of bees has an influence on students' increase on environmentally relevant knowledge. We focused on participants' perception of bee conservation and dangerousness, as these two factors are relevant in this context (Schönfelder, 2016).

As expected, in both studies, the perception of bee conservation is related to pre-knowledge, but also to knowledge 6–9 weeks after attending the programme. It is not surprising that students with positive perceptions and substantial willingness to protect also have more conservational knowledge about bees or that students with more knowledge about bee conservation are more willing to protect the species. Since we compared two statistical groups, high and low scorers, the convergence concerning their knowledge level in short term and in medium term was notable. Within both educational approaches, students showed cognitive achievement, regardless of their initial perception of bee conservation. These findings are encouraging even though we must take into account that the intervention itself predicts a change of their perception of bees (Schönfelder & Bogner, 2017).

Moreover, it was astounding that we detected no effects at all of students' perceived danger towards bees on their knowledge level. This result is in contrast to the current literature which describes emotions such as disgust or fear as barriers for effective environmental learning (Bixler & Floyd, 1999). Outside the context of environmental education, Hummel and Randler (2010) used living animals in science class and found students showing less cognitive achievement when they felt disgusted. However, in comparison to other organisms (e.g. woodlouse, earthworm, snail), honeybees were less attributed to disgust (Randler, Hummel, & Wüst-Ackermann, 2013). There is a lack of studies examining the influence of fear and perceived danger on students' cognitive learning outcomes, as far as we are aware. Future research needs to focus on this issue taking our findings into account, and examining the influences of anxiety and fear on effective environmental education.

Educational implications

Our findings clearly show the potential of educational modules to foster environmental knowledge. Teachers and educators should consider student-centred methods when preparing environment-related classes or programmes. We have shown that initiatives including direct or virtual encounters with living animals lead to cognitive achievement in the short and medium term. Experiencing nature directly provides further benefits such as students' high motivation (Hummel & Randler, 2012) or positive situational emotions (Schönfelder & Bogner, 2017). Our findings, however, show additionally that cognitive achievement may be expected. Nevertheless, sometimes, changes in method are desired or needed depending upon external circumstances like weather, time, availability and so on. In these cases, the use of eLearning constitutes a great opportunity in general and the use of HOBOS in the case of pollinators or bees in particular. Especially when targeting adolescents with low 'green' attitudes, eLearning tools seem to be appropriate to address them in order to yield an environmentally relevant cognitive achievement.

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Appendix 1. Description of the educational programme 'Let it Bee' (*Study 1*).

Duration (min)	Name of activity	Content	Student activity
10	Introduction	Introduction by instructor: general information about the workstations, distribution of workbooks Instructions and behavioural rules for the visit of the beehive	Paying attention, working with the introductory pages
Learning at workstations			
20	*Wax Factory*	Construction of honeycombs, hexagon shape, mathematic considerations	Visual examination of a honeycomb, conducting two experiments on the hexagon shape of a honey cell with marbles (room volume) and with modelling clay (round vs. angular), sorting of different info- and figure-cards on the wax production and honeycomb construction process
20	*Direct Me!*	Communication in the dark hive, wagging dance	Conducting a playful experiment: testing different coding (movements, noises, odours) explaining his/her classmates a hiding place, deriving the waggle dance from learning poster
20	*Bee products*	Bee products and pollination service	Exploring a basket of bee products and info-cards, sorting of the products into categories, calculation the bees' collection rate of nectar and their honey production
20	*Bye Bye Bee*	Human impact, action options for society, economy and policy	Deriving information on human impact on bee mortality from text and dictionary, deriving information on bee mortality and its effects in China from a magazine article, discussion with role cards viewpoints of different stakeholders, concluding action options
Visiting the beehive			
45	Visit of the beehive	Introduction to the beehive	General explanations about the beehive
		Observing the hive	Measuring temperature (air, inside, outside) and comparing, observing the bees' outgoing rate and calculating the pollination rate per day
		Interviewing the beekeeper	One interview question for each student on and protections against heat and cold in the beehive and on bees' natural causes of death
		Conclusion	Exchange forum on the interview questions, recording information

Appendix 2. Description of the educational programme 'HOBOS – The flying classroom' (Study 2).

Duration (min)	Name of activity	Content	Student activity
15	Introduction to HOBOS	Introduction by instructor: general information about the workstations, distribution of workbooks Instructions for use of HOBOS (step-by-step explanations, login details, testing live streams and chart tool)	Paying attention, working with the introductory pages and instructions for use of HOBOS, testing selected tools at the HOBOS platform
Learning at workstations			
30	'Bee-onics' – Learning from honeybees	(1) *Wax Factory* Construction of honeycombs, hexagon shape, mathematic considerations	Working with a learning pathway at HOBOS (*eLearning*), sorting of different info- and figure-cards
		(2) *Honeybees as Engineers* Bionics, usage of honeycombs in technology and architecture	Conducting experiment: testing paper tubes of different shapes for stability and material consumption, sorting of info-cards
30	Life in the dark bee hive	(1) *Direct Me!* Communication in the dark hive, wagging dance	Conducting a playful experiment: testing different coding (movements, noises, odours) explaining his/her classmates a hiding place, deriving the waggle dance from learning poster
		(2) *Air-condition Beehive* Thermoregulation, risks and protection against heat and cold	Deriving information on the hive temperature from the HOBOS graphs, drawing new graphs with different variables (*eLearning*), answering questions about risks and protections against heat and cold in the beehive with info text
30	Economic & ecological importance of honeybees	(1) *Bee products* Different direct and indirect bee products	Exploring a basket of bee products and info-cards and sorting them into categories, calculation the bees' collection rate of nectar and their honey production
		(2) *Pollination* Calculation and projection of the achievement of the pollination	Observing the bees' outgoing rate via livestream of the HOBOS beehive (*eLearning*), calculation of the pollination rate per day, deriving information on pollination rate of diverse insects from tables and charts
30	'Bye Bye Bee' – Bee mortality	(1) *Honeybees in Danger* Natural causes of death, human impact	Watching an interview with a beekeeper explaining bees' natural causes of death, deriving information on the incoming and outgoing rate during prescribed time periods from the HOBOS graphs (*eLearning*), working with text and an online dictionary on human impact on bee mortality
		(2) *Rescue for the Honeybee?* Action options for society, economy and policy	Deriving information on bee mortality and its effects in China from a magazine article, discussion with role cards viewpoints of different stakeholders, concluding action options