Nature-based environmental education of children: Environmental knowledge and connectedness to nature, together, are related to ecological behaviour

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A B S T R A C T

The promotion of environmental knowledge is viewed as a fundamental component of environmental education and a necessary prerequisite to ecological behaviour; however, it has little effect on actual behaviour. Nature-based environmental education, which combines the acquisition of environmental knowledge with the promotion of an intrinsic driver, namely connectedness to nature, is proposed as a holistic approach to increase ecological behaviour. This paper evaluates the effect of participation in nature-based environmental education in 4th to 6th graders ($N = 255$). As expected, increased participation in nature-based environmental education was related to greater ecological behaviour, mediated by increases in environmental knowledge and connectedness to nature. While both factors were similarly predicted by participation in nature-based environmental education, connectedness to nature explained 69% and environmental knowledge 2% of the variance in ecological behaviour. However, the design of our data do not evidence the causality of these relations, which are solely based on theoretical assumptions supported by literature. Nevertheless, the importance of fostering both environmental knowledge and connectedness to nature as complementary drivers of ecological behaviour, as offered by nature-based environmental education, should be researched further as a highly promising approach to fostering ecologically-motivated individuals.

1. Introduction

It is widely agreed that current human behaviour has detrimental impacts on the planet's environment (e.g., IPCC, 2014); thus, avenues for understanding and ultimately increasing the ecological behaviour of individuals are required. Environmental education can serve as a critical tool in countering environmental problems as it strives toward the goal of environmental protection and conservation (e.g., Potter, 2009; Palmer, 1998). Environmental education aims to impact not only an individual's internal representations and understandings of the world, but ultimately to intrinsically motivate people to perform appropriate real-life behaviours (Mcclelland, 1973). Indeed, education is regarded as an indispensable requirement if we want to promote sustainable development successfully (Michelsen and Fischer, 2017).

Intrinsic motivation to behave ecologically, as Otto et al. (2014) explain, is a crucial requirement to reduce humanity's detrimental effect on the planet, as extrinsic motivations (e.g., incentives, punishments) are often met with opposition and have only temporary effects (De Young, 2000). Thus, to authentically mitigate anthropogenic environmental problems, fostering intrinsic motivation to behave ecologically is essential (Otto et al., 2014). Numerous scholars have argued for environmental education to promote intrinsic motivation in addition to providing appropriate information (e.g., Kollmuss and Agyeman, 2002; Kaiser et al., 2008; Monroe, 2003). As in childhood the motivation to be ecologically friendly is formed and probably has a lifelong effect (Evans et al., 2007), the environmental education of children is thus especially important.

This paper investigates the correlates of participation in nature-based environmental education on children's ecological behaviour. In doing so, the competence model of environmental education (Kaiser et al., 2008; Roczen et al., 2014) is examined. This model proposes that the development of an intrinsic motivation by way of feeling connected to nature, in combination with the acquisition of environmental knowledge, are required to authentically produce ecological behaviour. Conducting environmental education directly in nature or close to nature, as offered by nature-based environmental education institutions, such as forest schools or conservation centres, addresses environmental knowledge while also fostering nature connectedness. We

will be the first to show that the frequency of children's visits to nature-based environmental education institutions is related to ecological behaviour through the acquisition of environmental knowledge and connectedness to nature.

1.1. Environmental knowledge

Environmental knowledge is important in producing ecological behaviours because an individual must know what type of actions to take. Thus, environmental knowledge is an intellectual prerequisite to performing ecological behaviour (Frick et al., 2004; Gardner and Stern, 2002; Otto and Kaiser, 2014). Although participation in environmental education programs commonly has positive effects on environmental knowledge (Rickinson, 2001; Liefländer et al., 2015), the relation between environmental knowledge and ecological behaviour has been disputed (e.g., Geiger et al., 2014; Frick et al., 2004), and may be influenced by several factors, such as motivational components in the form of personal values and attitudes (e.g., Gatersleben et al., 2002).Previous research investigating the relationship between environmental knowledge and ecological behaviour shows that environmental knowledge, more often than not, fails to directly influence ecological behaviour (e.g., Kals et al., 1999; Hines et al., 1986/87, Steg and Vlek, 2009), or does so only weakly (e.g., Frick et al., 2004). In fact, fostering singular knowledge, even directly related to a specific ecological behaviour, seems to have – if at all – one of the lowest effects (e.g., Abrahamse et al., 2005; Otto et al., 2016). What is missing in knowledge approaches not just with respect to ecological behaviour is a motivational component.

1.2. The motivational component in education

Motivation as an important educational component has been recently acknowledged in several educational-related fields. Especially in the fields of education for sustainable development (which originated from environmental education), and global learning, knowledge is but one part of their conception of education. Global learning clearly defines the promotion of motivation as one core component beside the acquisition of knowledge, and ethical guidelines (Michelsen and Fischer, 2017). Within this line of argumentation falls the call for deeper learning and education for sustainable development (Warburton, 2003), because holistic insight and the ability to manage contrasting types of information is central to sustainable development and also to ecological behaviour. Deeper learning fosters the comprehension of underlying meaning, cross-referencing, and independent thinking, which are all highly relevant to ecological and sustainability issues. But most importantly, in the case of deeper learning students are internally motivated and have an intention to understand – in contrast to simply pass a test. Therefore, an educational setting has to be provided where students develop a strong personal motivation in sustainability issues (Warburton, 2003). Also in Science Technology Engineering and Mathematics (STEM) fields, both knowledge in combination with sufficient motivation are seen as essential prerequisites for the mastery of related behaviour (e.g., OECD, 2015). Based on the insight regarding the necessity of a motivational component, a more holistic competence model is promoted (see e.g., NATIONAL RESEARCH COUNCIL, 2012; OECD, 2015). With specific respect to environmental education, Kaiser et al. (2008) similarly propose a competence model that incorporates both environmental knowledge and a specific motivational component, that is, connectedness to nature.

1.3. Connectedness to nature

Connectedness to nature refers to the perceived closeness in the relationship between an individual and nature (Brügger et al., 2011; Mayer and Frantz, 2004; Clayton, 2003; Schultz, 2001; Nisbet et al.,
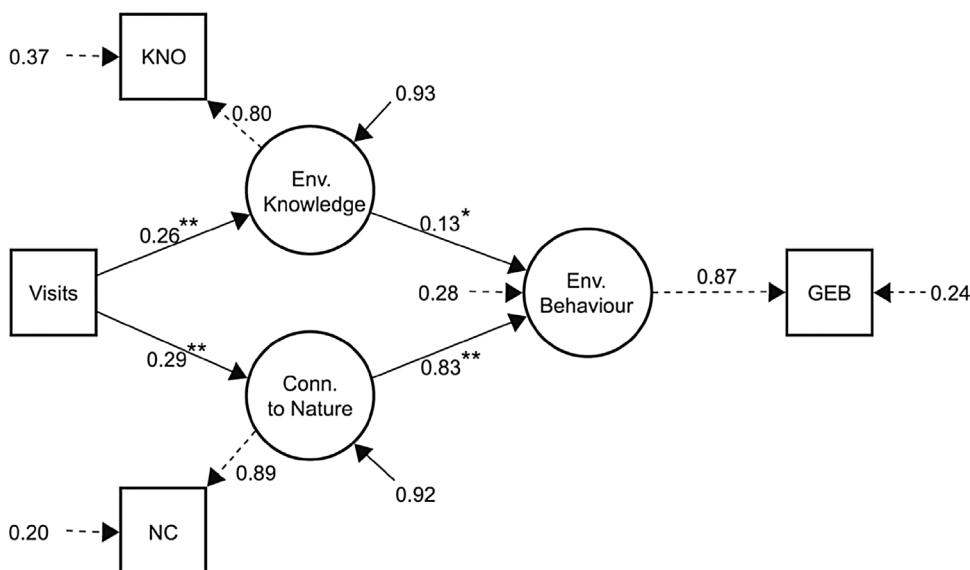
2009), and has been found in a multitude of studies to have a positive relationship to ecological intention and behaviour (e.g., Pensini et al., 2016; Barbaro and Pickett, 2016). Indeed, connectedness to nature seems to be the strongest predictor of (or at least does have the strongest relation to) ecological behaviour. That connectedness to nature and ecological behaviour share up to 60% of common variance has been shown across different studies and with different measures (e.g., Roczen et al., 2014; Brügger et al., 2011; Pensini et al., 2016). The strength of this relation is important for approaches to foster ecological behaviour, because it outperforms all other variables' (e.g., moral and normative concern) relations to ecological behaviour and even models (e.g., the norm activation model) that include a number of such variables do not explain more variance in ecological behaviour than connectedness to nature does (for a comprehensive review see Steg and Vlek, 2009). Even more so, the relation between connectedness to nature and ecological behaviour seems to be robust throughout all life stages as it holds for children (e.g., Cheng and Monroe, 2012), adolescents (e.g., Roczen et al., 2014), and adults (e.g., Mayer and Frantz, 2004; Tam et al., 2013).

Connectedness to nature is reasoned to be a necessary prerequisite for engagement in ecological behaviours (e.g., Kossack and Bogner, 2012; Roczen et al., 2014; Frantz and Mayer, 2014). It provides an intrinsic motivation for adopting a more ecological lifestyle as, when one is more connected to nature, knowingly causing harm to the natural environment impacts the self more directly (e.g., Schultz, 2002a; Metzner, 1999). Considering that connectedness to nature is an indication of the closeness between the individual and nature, like other relationships, this can be fostered by contact and experiences (Pensini et al., 2016). For instance, exposure to nature as opposed to an urban environment (Mayer et al., 2009), repeated visits to natural areas (Schultz and Tabanico, 2007), and also having nature close to home (Cheng and Monroe, 2012) are all positively related to connectedness to nature.

1.4. Environmental knowledge and connectedness to nature – related but independent constructs

The combination of environmental knowledge and connectedness to nature serve as the drivers of individual's ecological behaviour (Kaiser et al., 2008). Considering the interrelatedness of these constructs, acquiring knowledge of the functioning of the natural environment may, for example, confront individuals with the interconnectedness of all life, impacting their connectedness to nature. Increases in environmental knowledge may also follow from connectedness to nature. With connectedness to nature an individual may become more interested in learning about the natural environment and how to protect it. Empirical findings suggest that environmental knowledge and connectedness to nature are only weakly interrelated (Kaiser et al., 2008; Roczen et al., 2014; Bamberg and Moser, 2007). This is most reasonably due to the extremely low levels of environmental knowledge demonstrated in the sample. Very low levels of environmental knowledge are, in fact, not uncommon, and were similarly found in other studies (e.g., Frick et al., 2004). Thus, connectedness to nature demonstrated to be a much stronger predictor of ecological behaviour than environmental knowledge, and explained approximately one third of the variance in ecological behaviours (Roczen et al., 2014).

Even though environmental knowledge and connectedness to nature go hand-in-hand conceptually in promoting ecological behaviour, they relate only weakly as their common variance is only about 1% (Roczen et al., 2014). Furthermore, it is not clear which of the two, if either, comes first. While their weak relation speaks of some mutual effect upon each other on the basis of an individual's past, we propose that in a nature-based environmental educational setting these two components are addressed simultaneously and their effect on each other cannot be analysed in such settings.

1.5. Fostering environmental competence through nature-based environmental education

As explained, the environmental competence model (Roczen et al., 2014) states that environmental knowledge and connectedness to nature in combination affect ecological behaviour. While providing environmental knowledge in an educational setting is the standard component of environmental education, fostering connectedness to nature is not a common feature of educational settings. Fortunately, educational settings exist that combine the promotion of environmental knowledge and connectedness to nature via their embeddedness in natural settings. In Germany, for instance, a variety of such settings exist: farms, where children can participate in farming life; urban gardening projects such as community gardens in abandoned urban allotments; botanical gardens; zoos; forest schools; inclusive gardening-schooling concepts; classical conservation centres; and other centres for environmental education such as outdoor labs or ecoworks (both centres for environmental education and protection), all of which provide environmental education outdoors, or at least partially outdoors, in the setting of the natural environment. Conducting environmental education in such a nature-based setting enables environmental knowledge acquisition as well as simultaneously fostering connectedness to nature by providing nature contact and experiences.

More specifically, nature-based environmental education – through personal experiences – aims to and does foster students' affective relationship to nature, their attention to ecological issues, as well as their social relationships (e.g., Palmberg and Kuru, 2000; Ballantyne and Packer, 2002). For instance, Palmberg and Kuru (2000) found that nature experiences developed the students' self-confidence and feelings of safety, which in turn increased their willingness to participate in future outdoor activities. Students experienced in outdoor activities seemed to have a strong empathic relationship to nature, showed more prosocial behaviour and expressed higher moral standards. Similarly, Ballantyne and Packer (2002) found that students find natural environment learning settings attractive and that it impacts their attitudes towards the environment, related desire and behaviour. Overall, nature-based environmental education is an effective teaching strategy, especially when it includes the understanding of the ecological impact of human action. In this way, nature will develop new meanings for the students individually.

Furthermore, the empirical association between connectedness to nature and environmentally-relevant measures (e.g., environmental concern, ecological behaviour) has been shown to be substantial. Research suggests that connectedness to nature is related to greater

concern for the environment, and higher rates of ecological behaviour (Schultz, 2002b). Correlations between connectedness to nature and measures of, for instance, biospheric values, environmentalism, and ecological behaviour are as high as .45, .61, and .45, respectively (Mayer and Frantz, 2004).

As connectedness to nature can be fostered via contact with nature (e.g., Mayer et al., 2009; Pensini et al., 2016; Schultz, 2002a), longer-lasting or more frequent nature-based environmental education programs are more likely to have impacts on ecological behaviour than shorter or less frequent ones (Chawla and Cushing, 2007). Indeed, the length of the environmental education program is an important and positive determinant on the outcomes of such programs on connectedness to nature (Rickinson, 2001, Zelezny, 1999). Sellmann and Bogner (2013) also found that initial increases in connectedness to nature resulting from shorter (1-day) programs do not last, at least not to 4 to 6 weeks later. This has led these scholars to go so far to state that "repeated or long-term implementation may ensure persistent effects which eventually may last for life" (p.1079). Similar conclusions were reached by Stern et al. (2008). Thus, to the extent that environmental education programs operate in the setting of the natural environment, the frequency in which individuals participate in such a program is expected to have a positive impact on ecological behaviour.

Nature-based environmental education settings address connectedness to nature and environmental knowledge concurrently. In other words, the effect of these educational settings on connectedness to nature and environmental knowledge cannot be temporally separated. Any acquisition of environmental knowledge happens within a nature-based setting and also based on natural illustrative objects such as soil, plants, and animals. At the same time environmental knowledge and connectedness to nature affect ecological behaviour. Thus, we assume that the two components mediate the effect of nature-based environmental education on ecological behaviour. Furthermore, the simultaneous effect of nature-based environmental education on knowledge and connectedness precludes any analysis of the covariance of the two. For these reasons, and because the relation between environmental knowledge and connectedness to nature has been found to be rather weak, we will omit this relation from our model (see Fig. 1).

1.6. Research goal

The current paper investigates the relation of participation in nature-based environmental education to ecological behaviour. Ecological behaviour is expected to be positively related to participation in nature-based environmental education. We theoretically assume

that the embeddedness of the educational setting in or close to nature fosters connectedness to nature, while the educational institution also fosters the acquisition of environmental knowledge. Participation in nature-based environmental education is expected to simultaneously have a positive relation to environmental knowledge and connectedness to nature. In line with the competence model of environmental education (Roczen et al., 2014), the relation between participation in nature-based environmental education and ecological behaviour is predicted to be mediated by connectedness to nature and environmental knowledge.

2. Method

2.1. Participants and procedure

A total of 358 4th to 6th grade students at 5 schools in the city of Berlin participated in our study. Written consent was obtained from the Senate Office of Education, Youth, and Science of Berlin, the schools' headmasters, and the students' parents. 53% of the parents at the 5 schools consented to the request, and 255 students answered the crucial question about how often they visited nature-based environmental educational facilities or programs. The responses of these 255 students, that is, 38% of all 4th to 6th graders of the 5 selected schools, were used in the analysis. The data were collected via a questionnaire completed by the students during class hours. This occurred under the supervision of the same researcher who gave a standardised oral introduction and explanations in addition to the written instructions on the questionnaire.

2.2. Measures

Participation in nature-based environmental education was assessed by an item in which the children indicated the number of times they attended a nature-based environmental education centre. The item read "Have you visited a nature-based environmental education centre (e.g., outdoor labs, ecoworks, conservation centres, or forest schools)." Participants indicated if they visited such centres 'never', "once", or "several times". The researcher who introduced the questionnaire to the students put special emphasis in explaining what was meant by "nature-based environmental education centres". For instance he gave several examples of the most renowned and most frequently visited local institutions such as outdoor labs or ecoworks but also botanical gardens, forest schools, and conservation centres. He put special emphasis on the fact that only institutions that provide environmental education outdoors in the setting of the natural environment should be counted. One of the most prominent institutions in Berlin, the "Naturschutzzentrum Ökowerk" (see http://www.oekowerk.de/), provides a variety of nature-based environmental education programs that are mainly outdoors and last more than an hour, but more typically half a day. In order to measure the components of the environmental competence model central to our study, we utilised (a) an ecological behaviour scale for children, (b) a connectedness to nature scale for children, and (c) an environmental knowledge measure for children.

Ecological behaviour was measured based on the Campbell paradigm (Kaiser et al., 2010), which, instead of focusing on specific behavioural domains, addresses the extent to which individuals generally embrace an environmentally-friendly lifestyle. Such an approach is informative because focusing on one particular behavioural domain and ignoring others neglects the fact that individuals perform a vast multitude of behaviours, all of which have some environmental impact. Thus, the broader environmental impact of an individual may not be adequately captured unless a similarly broad approach to assessing ecological behaviour is utilised. Further, in the assessment of children's ecological behaviour, it is important to consider that their behavioural alternatives are relatively limited (Evans et al., 2007). In this respect, we selected and adapted the most suitable behaviours of the behaviour-based

environmental attitude scale (Kaiser et al., 2007) resulting in 19 behavioural items addressing six domains: *energy conservation, mobility and transportation, waste avoidance, recycling, consumerism,* and *vicarious behaviours toward conservation.* Example items are "When I leave a room as the last person, I switch of the light" and "I keep gift wrapping paper for reuse." 3 of the 19 behaviours were unecological behaviours and reverse coded. The items were answered on a five-point scale ranging from 1 (not at all) to 5 (absolutely). As suggested by Kaiser et al. (2007) in order to increase measurement reliability, responses to the polytomous self-report items were recoded into a dichotomous format by collapsing 1, 2, and 3 into an unecological propensity, while 5 and 4 were combined into an ecological propensity.

Connectedness to nature was assessed with a 20-item shortened version of the Disposition to Connect to Nature scale (DCN) developed by Brügger et al. (2011). Unlike other measures of connectedness to nature, such as the Connectedness to Nature Scale (Mayer and Frantz, 2004), or the Environmental Identity Scale (Clayton, 2003), which rely on the individual to answer abstract items regarding their relationship to nature, the DCN assesses specific bonding behaviours that indicate the closeness of one's relationship to the natural world. As such, this measure is particularly suitable for use with children. While largely converging with other measures of connectedness to nature, the DCN measure also has a higher incremental validity than the other measures (Brügger et al., 2011). Based on the difficulty distribution of the items reported by Brügger et al. (2011), 20 items were selected to form an equally-broad distribution as the original scale. Example items are 'Watching animals is exciting' and "The noise of crickets gets on my nerves" (reversed). All 20 items were answered on a five-point scale ranging from 1 (not at all) to 5 (absolutely). As suggested by Kaiser et al. (2007), responses to the polytomous self-report items were recoded into a dichotomous format by collapsing 1, 2, and 3 into a disconnected propensity, while 5 and 4 were combined into a connectedness propensity.

Environmental knowledge is commonly assessed by an individual's ability to correctly solve tasks specific to the age range of participants. In order to differentiate between individuals within a wide range of a certain ability, they are confronted with differentially demanding tasks which can be analysed with the Rasch model in order to form an intransitive scale (e.g., Wilson, 2004). One – and to our knowledge the only – Rasch based environmental knowledge measure was developed by Frick et al. (2004). This measure includes not just action related knowledge as, for instance, how to separate waste, but also knowledge on the environmental system in general, as well as effectiveness knowledge (i.e., the impact of certain behaviours on the environment). To develop a set of questions that sufficiently match the range of the potential test taker's knowledge, fitting with the theoretical approach of Rasch based measurements, we selected and adapted items from Frick et al. (2004) to match the knowledge level of 4th to 6th graders. Based on insights from a pre-study, environmental knowledge was assessed with 8 items, of which 3 items could be answered either incorrectly or correctly, and 5 items whose answers could be incorrect, partially correct or fully correct. Unanswered questions were rated as incorrect. The content of these items reflects a wide range of environmental knowledge from biology, environmental systems knowledge, to environmental action knowledge (i.e., how to behave in an environmentally-friendly way). Item examples are: "How many legs does a spider have?" or "Which of the following waste belongs in the recycle bin?" Multiple choice options of the two questions were a) *8/*b) *6/*c) *4,* and a) *shampoo bottles, spray cans, and toothpaste tubes/*b) *paint and household chemicals/*c) *small furniture,* respectively.

Socially desirable responses might potentially bias self-reported measures of ecological behaviour and connectedness to nature. We did not include a social desirability measure. However, in a previous study (Oerke and Bogner, 2013) social desirability only had a minor impact on a measure of ecological behaviour (Kaiser et al., 2010). Thus, we also assume no significant impact of social desirability on our measure

of ecological behaviour nor on our measure of connectedness to nature, both of which are based on the same behaviour based measurement approach, the Campbell paradigm (Kaiser et al., 2010).

2.3. Statistical analysis

We calibrated the measures assessing ecological behaviour and connectedness to nature with the simple Rasch model (Rasch, 1980) because these two scales consisted exclusively of dichotomous items [after collapsing them as suggested by Kaiser et al. (2007)]. The environmental knowledge scale was calibrated with the partial-credit Rasch model (Masters, 1982) in order to account for the polytomous items (i.e., multiple choice items with partially-correct answers). For Rasch models, a common estimation procedure is the conditional maximum likelihood estimation which we used in our analysis. After the conditional maximum likelihood estimation of the item parameters, person parameters were estimated in a second step with an unconditional maximum likelihood method (for computational details see Mair and Hatzinger, 2007).

Based on the person estimates of the three scales and their variance we confirmatorily tested our theoretically-derived structural equation model using a maximum-likelihood approach (for more details see Rosseel, 2012). Because we used the person ability score of the Rasch model (i.e., for environmental knowledge, nature connectedness, and ecological behaviour) as single indicator for the manifest variable, we fixed the error term based on the indicator's variance (e.g., Hayduk and Littvay, 2012). In order to assess the model fit we computed the χ^2 statistic and the most commonly used fit indices, that is, the root mean square error of approximation (RMSEA), the root mean square residual (SRMR), and the comparative fit index (CFI). Hu and Bentler (1999) consider a RMSEA < .06, a SRMR < .08, and a CFI around or above .98 as acceptable based on their widely-recognised simulation study.

3. Results

First we present the details of the calibration of the three scales assessing ecological behaviour, connectedness to nature, and environmental knowledge. Next, we report the details of our structural equation model that tests our prediction that the number of visits to nature-based environmental education institutions positively effects ecological behaviour, mediated by increased environmental knowledge and connectedness to nature.

The item fit for all three measurement instruments was satisfactorily within the commonly-suggested range. In order to assess this model fit we used infit (i.e., weighted) mean square (MS) values to check how well the item response data fit the model (e.g., Wu and Adams, 2013). The optimum value for an item's MS is 1, and values below 1 represent overfit while values over 1 indicate underfit. For instance, a MS value of 1.2 expresses 20% excess variation (underfit), and a value of .8 indicates 20% less variation (overfit). In order to check model fit, guidelines and rules-of-thumb are offered by researchers that suggest different ranges as acceptable (Wright et al., 1994). A MS ranging from .7 to 1.3 is one of the commonly used rules-of-thumb. As a common procedure in Rasch modelling, we anchored the resulting logit scale with the overall mean of the item estimates at 0 (e.g., Bond and Fox, 2007).

For the ecological behaviour measure, MS values of the items ranged between .81 and 1.31, and the mean of all items' MS was M $(MS) = .98$ $(SD = .11)$, indicating a good overall fit of the items. Furthermore, only 2% of children had a statistically significant poor fit, which is well below the recommended 5%. The separation reliability (i.e., the proportion of person variance that is not due to error) was $r = .76$, and thus, acceptable. The individuals' mean score for ecological behaviour was $M = .12$ $(SD = 1.18)$ which is close to the mean of the items and thus shows a good match of item difficulty and individual motivation to behave ecologically. Also the items of the connectedness

to nature measure fell within the suggested range with MS values ranging from .82 – 1.31 with an overall mean of $M(MS) = .99$ $(SD = .11)$ and only 1% of the children's answer patterns could not be fitted with the model. Separation reliability was acceptable as well with $r = .80$. The individuals' average connectedness to nature was $M = .02$ $(SD = 1.30)$, almost perfectly matching the scale's difficulty. For the environmental knowledge measure, items had MS values ranging from .63 to 1.16 with an overall mean of $M(MS) = .90$ $(SD = .18)$, and only 2% of children had a statistically significant poor fit. Separation reliability was also acceptable, $r = .64$, especially when considering the relatively short length of the scale. The children's mean score for environmental knowledge was $M = .76$ $(SD = 1.26)$ and thus above 0. However, in any knowledge test with multiple choice items, the participants' measured score is necessarily higher due to the chance of guessing. As a rule-of-thumb in the PISA study (see OECD, 2009), it is assumed that a student dependably possesses the knowledge assessed by a certain item if its response probability exceeds $p = .62$. In our sample the response probability was close to this value of $p = .62$ with $p = .66$ on average.

The test of our structural equation model revealed a good match of our unaltered theoretical model-implied figures with the observed figures ($\chi^2 = 2.4$, $df = 2$, $p = .31$). All three model fit indices unanimously indicated a good fit: RMSEA = .03, 90% CI [0,0.12]; SRMR = .03; and CFI = .99. All four theoretically-anticipated paths were significant. The effects of visits to nature-based environmental education on environmental knowledge and connectedness to nature were positive and approximately equal, β = .26 ($p = .001$) and β = .29 ($p < .001$), respectively. The effect of connectedness to nature and environmental knowledge on ecological behaviour were β = .83 ($p < .001$) and β = .13 ($p = .035$; see Fig. 1), respectively. Thus, connectedness to nature explained 69% of variance, and environmental knowledge 2% of variance in ecological behaviour. Environmental knowledge and connectedness to nature scores were also correlated, albeit weakly, $r = .13$ ($p < .05$).

4. Discussion

This study contributes to understanding the role of environmental education in promoting an ecological lifestyle. To our knowledge this study is the first to show a substantial effect of nature-based environmental education on ecological behaviour mediated by both connectedness to nature and environmental knowledge. This effect relies on nature-based environmental education, offered by institutions that focus on the promotion of environmental knowledge about flora, fauna, and the ecosystem, through real contact with nature.

The effects in our competence model that had been researched previously (i.e., the effects of connectedness to nature and environmental knowledge on ecological behaviour; Roczen et al., 2014), are not just significant in the expected direction, they are also well within the expected magnitude. The effect of connectedness to nature on ecological behaviour was considerably stronger (β = .83; $p < .001$) than the effect of environmental knowledge on ecological behaviour (β = .13; $p = .035$). Connectedness to nature explained 69% while environmental knowledge determined only 2% of the variance in ecological behaviour. Similar to other work (e.g., Frick et al., 2004), the relation between environmental knowledge and ecological behaviour was significant but rather weak. It was suggested that this effect might be due to a mismatch of environmental knowledge level (too low) and the difficulty of questions (too difficult). However, in our study this was not the case. Thus, even with a suitably fitting knowledge measure, the relation between environmental knowledge and ecological behaviour remained relatively low at $r = .19$ ($p < .01$).

Also in our study, environmental knowledge and connectedness to nature were weakly related with $r = .13$ ($p < .05$), a finding very similar to other studies (e.g., Roczen et al., 2014). Nevertheless, we assumed that visits to nature-based environmental education facilities

directly and simultaneously influence environmental knowledge and connectedness to nature, and thus, omitted their relation from our structural equation model. The good fit of our model on all fit-indices empirically supports this omission in favour of our more parsimonious model in Fig. 1.

While we found promising effects of nature-based environmental education for institutions in and around Berlin, before it may be suitable to generalise to all such settings, our approach should be applied to other regions and institutions in order to test the robustness of our findings. By doing so, the effectiveness of different educational settings could be compared and improved. Based on our model, new educational concepts might be derived and tested before their large scale application. In sum, the empirical evaluation of environmental education programs will benefit environmental education in theory and practice. So far we only rudimentarily showed that children's increased participation in nature-based environmental education relates to more environmental knowledge and connectedness to nature, which in turn relates to increased ecological behaviour. A lot is still unknown, such as which amount of time in nature and which frequency is most efficient for achieving the most sustained effects – over the course of a person's life. Future work would benefit to track the changes in these variables over the life course to understand how nature-based environmental education can be most effective. Also, the implied causality of our model is only inferred from literature and has not been demonstrated empirically. Thus, a more elaborate testing of the causal direction would help to strengthen the scientific base for the effects of nature-based environmental education. Furthermore, retrospective monitoring is a conflicting approach especially for the chosen age-group and, thus, the measure of the independent variable (i.e., the recall of the frequency of visits to nature-based environmental educational institutions) could be replaced or substituted with other indicators to test the validity of our findings. However, the effect of retrospective monitoring as a source of measurement error (most likely unrelated to our tests) would work against our hypothesis.

It has been shown that environmental knowledge and connectedness to nature positively affect ecological behaviour and that educational programs can lead to more ecological behaviour (e.g., Liefländer et al., 2015; Roczen et al., 2014). We were able to show that nature-based environmental education effectively increases ecological behaviour by fostering both connectedness to nature and environmental knowledge. In doing so, nature-based environmental education seems to be a highly effective way of promoting the development of an ecological lifestyle that affects a broad range of ecological behaviours. Considering the relative strength of the effect on ecological behaviour, connectedness to nature clearly outperforms environmental knowledge, even though the effects of nature-based environmental education on environmental knowledge and connectedness to nature were approximately equal.

In addition, there might be other routes through which nature-based environmental education affects knowledge and ecological behaviour. Environmental attitudes, which are highly relevant for the motivational components of education, interact with knowledge acquisition, even in a classroom setting (Schumm and Bogner, 2016). Thus, even if knowledge acquisition is not at the focus of nature-based environmental education and only the motivational component (i.e., connectedness to nature) is addressed, it is likely that the increase in motivation will foster knowledge acquisition even in other settings.

Another important issue is the stability of the effects of education on knowledge and behaviour which most likely depends largely on the frequency and length of the programme (Chawla and Cushing, 2007). For instance, after a 1-day environmental education intervention in an ecological-botanical garden at least some of the initial effects on environmental attitude persisted for 4–6 weeks after the program (Sellmann and Bogner, 2013). Thus, even short-term nature-based environmental education may positively influence participants' environmental attitudes and behaviour, and it is likely that more frequent and long-term programs would ensure life lasting effects (e.g., Stern et al., 2008; Sellmann and Bogner, 2013). With respect to the frequency of nature-based environmental education and its relation to connectedness to nature and to ecological behaviour, our study provides some evidence.

Overall, nature-based environmental education seems to be a promising approach to increasing ecological behaviour without extrinsic drivers such as material or social enticements. However, it is still unclear which kind of nature-based environmental education leads to this effect. The causality of this effect needs further support through other, preferably longitudinal, studies. One of the most advisable next steps would be to test the additional benefit of nature exposure by comparing environmental education units with and without nature exposure. In addition to fostering environmental knowledge, nature-based environmental education's fostering of connectedness to nature provides intrinsic motivation to behave ecologically, thereby offering an enduring approach to ecological behaviour.

Acknowledgements

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.gloenvcha.2017.09.009.

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