# Symbiosis Between EE and SE

*The Combined Effect of Environmental Values and Fascination with Biology on Biodiversity-Related Learning*


## Jennifer Schneiderhan-Opel[a] and Franz X. Bogner[a]

[a]*Centre for Mathematics and Science Education (Z-MNU), Department of Biology Education, University of Bayreuth, Bayreuth, Germany*

Correspondence concerning this article should be addressed to Jennifer Schneiderhan-Opel, University of Bayreuth, Department of Biology Education, Centre for Mathematics and Science Education (Z-MNU), Universitaetsstraße 30, 95447 Bayreuth, Germany, Jennifer.Schneiderhan@uni-bayreuth.de

Franz X. Bogner is a full Professor at the University of Bayreuth, director of the Centre of Mathematics and Science Education (Z-MNU) and head of Department of Biology Education at the University of Bayreuth, Germany.

Jennifer Schneiderhan-Opel is a postdoctoral fellow in the research group of Franz X. Bogner.


## Symbiosis between EE and SE: the combined effect of environmental values and fascination with biology on biodiversity-related learning


Cognitive learning in 'green' education modules feeds its success from a host of predictor variables. In our present study, we focused on the relation between environmental attitude sets and fascination with biology and their impact on biodiversity-related learning within a sample of 205 Bavarian 10th graders (Mage = 15.3, SD = ±0.64). We engaged the participants in an innovative environmental learning module situated in biology lessons and including student-centered, hands-on learning experiences, such as, for instance, a species identification exercise, interactive multimedia-based elearning activities, or a role-play to explore a future scenario for sustainable forestry. Central element of our module was a citizen science activity in which students collected forest soil samples that contributed to the DNA barcoding project Barcoding Fauna Bavarica, which aims to complete a comprehensive inventory of biodiversity at the state and national level. Using a pre-post-retention-test design (T0, T1, T2), we monitored cognitive achievement, environmental values, and fascination with biology by applying a module-dependent knowledge test, the 2-MEV scale and the Fascination with Science scale. Pro-environmental values (preservation, PRE) showed a strong positive correlation with fascination with biology (FB), whereas preferences of nature utilization (UTL) revealed the reverse trend. The effects of PRE attitudes and FB on biodiversity-related learning were analyzed via structural equation modeling (SEM): both variables positively predicted cognitive learning achieved through module participation. The results underline the relevance of developing a symbiotic relationship between environmental education (EE) and science education (SE), which is up to now underresearched and underrepresented in practice.

Keywords: fascination; environmental attitudes; environmental values; 2-MEV; biodiversity education; citizen science

# Introduction

Exploitative use of natural resources, environmental pollution, climate change and insertion of invasive species have led to irrevocable habitat destruction and severe biodiversity loss (Díaz et al., 2006). The main drivers of environmental degradation are the demands and consumer behavior of a steadily growing world population (Kitzes et al., 2016). Efforts to halt further human-driven biodiversity decline and to minimize the human impact on the environment, therefore, rely heavily on public involvement and commitment to sustainable consumption. The reduction of global biodiversity loss cannot be solely achieved through political top-down decisions. Education provides the basis for preparing young adults for conscious consumer decisions as well as an active and responsible citizenship (Grace, 2006). The overarching goals of environmental education (EE) and education for sustainable development (ESD) approaches are to foster informed decision making in socio-ecological issues, problem-solving skills as well as sustainable, eco-friendly and pro-environmental (‘green’) behavior (Lee & Grace, 2010; McKeown & Hopkins, 2005). In formal education, both approaches are implemented in science education, primarily in biology and geography classes.

# Knowledge-Acquisition in Relation to Environmental Attitudes

Environmental education research primarily focuses on factors that have been identified as highly important for achieving the goals of environmental education programs: environmental knowledge and attitudes and their relation to eco-friendly behavior. Limited or missing knowledge has been repeatedly described as a crucial obstacle to pro-environmental behavior (Gifford, 2011) and studies point towards a positive association between environmental knowledge and behavior (e.g. Frick et al., 2004; Kaiser & Fuhrer, 2003). Bord et al. (2000), for example, determined an in-depth understanding of the main drivers of global climate change as an major prerequisite for the development of ecofriendly behavior towards a mitigation of climate change. Even though knowledge might not be the major influencing variable, it still plays an important role for 'going green', i.e. to engage in eco-friendly behavior (Moss et al., 2017).

The acquisition of knowledge and individual pro-environmental attitudes are regarded as key indicators for successful environmental education approaches (e.g. Fančovičová & Prokop, 2011). While a lasting change in environmental values (in terms of attitude-sets) requires longer-term or repeated participation in educational programs, cognitive achievement can already be affected by short-term environmental learning modules (Bogner, 1998). Using a pre-, post and retention test design, Schumm and Bogner (2016a) monitored adolescents' knowledge acquisition within a three-lesson classroom-module about renewable energies and reported a short-term as well as a long-term knowledge gain six weeks after participation. Similarly, within a one-day education program about honeybees, Schönfelder and Bogner (2017) reported a gain in students' environmentally relevant knowledge on the conservational issues. Moreover, Thorn and Bogner (2018) examined cognitive learning within an adolescent 10th grade sample participating in a three-lesson, inquiry-based program on the topic of the forest ecosystem and confirmed that the short-term intervention effectively fostered students' long-term knowledge acquisition after six months. Finally, what is more, even a one-year period proved to keep an acquired knowledge gain when 6th graders follow an outreach bionics module within a zoological garden (Marth & Bogner, 2017).

In all these studies, students' environmental learning was positively related to pro-environmental values. Numerous further correlative studies have proven a relation between knowledge acquisition and environmental values within the context of environmental education programs (e.g., Fremerey & Bogner, 2015). Pro-environmental values are considered as an important predictor and trigger of 'green' behavior (Roczen et al., 2014). The investigation of the environmental knowledge acquisition and environmental values, their relation, and the underlying interrelations with other factors are therefore of high importance for successful environmental education approaches. In our present study we focused on motivational abilities as well as environmental values and their role for biodiversity-related learning.

An instrument that is regarded to monitor environmental attitude sets reliably and validly, is the 2-MEV scale (MEV: Two Major Environmental Values; Bogner & Wiseman, 1999). Both environmental values are based on two underlying higher-order factors: preservation and utilization. As higher-order factors, they are defined as values, consisting of a set of primary factors, defined as attitude sets (Bogner & Wiseman, 2006). preservation represents an ecocentric perspective that assigns an inherent value to nature worthy of protection. In contrast, utilization reflects a rather anthropocentric view in which nature is regarded as an exploitable resource exclusively valued on the basis of its benefit to human welfare. The particular advantage of the 2-MEV lies not only in its confirmation by various bi-national studies (e.g.; DE-DK: Bogner & Wiseman, 1997; DE-CH: Bogner & Wiseman, 1998; DE-FR: Bogner & Wiseman, 2002) or internal cross validation studies (e.g. Wiseman et al., 2012) but also in its repeated independent confirmation by different groups (Borchers et al., 2014; Braun et al., 2018; Johnson & Manoli, 2010; Milfont & Duckitt, 2004).

## Motivational Abilities: Fascination with Science

In a recent study, Schönfelder and Bogner (2020) have investigated the relationship between environmental values and general science motivation. The study sheds light on a so far unconsidered relationship between the two variables. Especially intrinsic science motivation turned out to be a strong predictor of pro-environmental attitudes. In general, motivational abilities play a major role in educational contexts and have been shown to determine, among other factors, students' effort, engagement, learning success and self-monitoring (Schunk & Zimmerman, 2012). In the context of science education, studies are indicating a decline in students' motivation towards scientific topics (Potvin & Hasni, 2014). Accordingly, ongoing research efforts are focused on the relation between motivation and learning, how to foster motivation for science in educational settings and how to appropriately measure motivational abilities. A fairly new approach is the description and investigation of the construct fascination with science. Bonnette et al. (2019) referred to fascination with science as to be in love with science by summarizing three motivational aspects under the concept of fascination: curiosity, interest, and mastery goal orientation. Similarly, Otto et al. (2020) included the concepts participation, interest and excitement, and identification with the scientific enterprise in the construct of fascination. These concepts are subject of intensive psychological and educational research and will only be described very briefly here.

Markey and Loewenstein (2014) defined curiosity as "a desire for specific information in the absence of extrinsic reward". According to their definition, curiosity emerges when a person encounters a specific information or knowledge gap, which he or she wants to bridge. In contrast to the concept of curiosity, they define an interest as a desire to expand one's general knowledge about an object or to engage in an activity. Although, interest is a content-specific motivational state, its development does not necessarily require a person to encounter a specific gap of knowledge or information. Following the person-object-theory of interest, which is widely used in educational research, an interest arises from an interaction between a person and their environment (Krapp, 1993). Two forms of interest have been of particular importance for science education research: situational interest, which represents a temporary psychological state and individual interest, which means a permanent motivational disposition (Hidi & Renninger, 2006). Repeated preoccupation with the object or re-engagement with the activity can induce a deepening and development of situational interest into persistent individual interest. Mastery goal orientation in science describes the pursuit to gain scientific knowledge and to achieve mastery of scientific skills (Elliot & McGregor, 2001). The goal of science mastery in and beyond school is closely related to the identification with the nature of the scientific enterprise (Carey & Smith, 1993). Comprehension of the way scientific knowledge is acquired and understanding how scientific methods are used is, in turn, a key aspect of scientific literacy (Dass, 2005).

In the present study, we measured fascination with biology (fascination with biology) using a subscale of the recently developed Fascination with Science Scale by Otto et al. (2020). The instrument conceptually draws upon the Campbell paradigm (Kaiser & Wilson, 2019) as a new variation of the tripartite model of attitudes (Rosenberg & Hovland, 1960), which proposes an attitude to be based on three dimensions: an affective, a cognitive and a behavioral component. The affective dimension is characterized by positive feelings and emotions towards a subject area, here science in general or certain scientific fields (Otto et al., 2020). The learning topic “aquatic ecosystems”, for example, is supposed to trigger positive emotional reactions in a person who is fascinated with biology and who would enjoy learning more about marine wildlife. The cognitive component is reflected in willingness to solve even complex scientific problems as well as to develop necessary skills, knowledge, and competences. The behavioral dimension manifests itself in the repeated and voluntary exercise of extracurricular activities and experiences. For example, students fascinated with biology will frequently watch TV documentaries about animal behavior or observe garden birds. Like environmental values, fascination is a latent construct, which is not directly observable but becomes measurable based on its three dimensions (Otto et al., 2020).

## Purpose

In recent correlative studies, we have already identified a positive relation between pro-environmental attitudes and knowledge and have provided first insights into the relation between fascination with biology and cognitive learning (Schneiderhan-Opel & Bogner, 2020b, 2020c). The present study aimed to shed light on an expected relation between both variables and their combined effect on environmental learning. We examined the following research questions and hypotheses:

RQ 1: To what extent is fascination with biology with biology related to environmental values?

H1: preservation attitudes and fascination with biology are positively correlated.

H2: utilization attitudes and fascination with biology are negatively correlated.

RQ 2: Do fascination with biology and environmental values have a relevant impact on content knowledge acquisition?

H3: preservation and fascination with biology are positive predictors of knowledge at all three test times.

## Methodology

### *Sample and Research Design*

Our sample consisted of 205 tenth graders from 14 secondary school classes of seven grammar schools (German ‘Gymnasium’; note that Gymnasium students receive a university entrance qualification) in Bavaria, Southern Germany ($M_{age}$ = 15.3, SD = ±0.64; 46.8% female). In accordance with the national guidelines, participation required parents' written consent and we guaranteed anonymity as well as confidentiality of the data. The study was approved by the Bavarian State Ministry of Education and Cultural Affairs (StMUK; reference number X.7-BO5106/160/12).

Our study followed a quasi-experimental research design. Students completed a pre-, post- and follow-up questionnaire (T0: one or two weeks before project participation, T1: directly after the lesson, T2: six weeks after participation) distributed in a paper-and-pencil version. Module participation as well as the evaluation took place during regular school hours.

### *Content and Design of the Educational Module*

Within the framework of the present study, we developed and evaluated an educational module on the topic of biodiversity at the example of the forest ecosystem. The overall goal of our intervention, called FutureForest, was twofold. First, we intended to increase environmentally relevant knowledge on the topic of biodiversity and second, the module aimed to raise awareness for environmental conservation. The module took 180 min and was held during four regular biology lessons. It was divided into four sub-modules that covered different aspects of the issue:

1. Sub-module one focused on the ecosystem services of forests that contribute to human wellbeing (supporting, cultural, provisioning, and regulating services, e.g., sequestration of carbon and provision of oxygen). The students worked with an interactive website.
2. Sub-module two dealt with the method of DNA barcoding for species identification and demonstrated how environmental monitoring relates to biodiversity conservation. The participants worked with an interactive, digital learning tool.
3. Sub-module three focused on the relevance of a diverse composition of forest soil organisms for forest ecosystem functioning. Students observed organisms under the microscope and trained their species determination skills with a simple identification key.
4. Sub-module four dealt with the human-induced impact on forests and biodiversity, e.g., the cultivation of monocultures or the consequences of climate change. The participants were involved in a role-play that included the perspectives of different stakeholders on organic forest conversion.

Our approach followed the self-determination theory (Deci et al., 1991). Consequently, the participants completed the sub-modules autonomously in small groups of three to four students. The groups completed the whole module self-responsibly within a given time frame. They were provided with all the necessary material and each student got a workbook that contained information texts and task descriptions. Only the final wrap-up phase was teacher-guided. Here, the students were able to compare their results and to improve them where applicable

(for a detailed description of the modules' tasks see Schneiderhan-Opel & Bogner, 2020a)

In addition to the activities in the classroom, we involved the students in a collaborative citizen science project. They collected forest soil samples for our project partner at the Bavarian State Collection of Zoology. To ensure correct sampling, the students were instructed by their teachers. Additionally, they were provided with a protocol that contained necessary tasks and information on how to take the sample, how to collect the GPS location data of the sampling site and how to prevent the sample from drying out. The scientists received the samples together with the protocols, which provided necessary information on the sampling site (e.g., plant and tree composition of the respective forest). The soil organisms extracted from the samples were determined through DNA barcoding, which is a method for species identification through the use of species-specific genetic markers, the so-called DNA Barcodes (Hebert et al., 2003). To determine an unknown specimen, its genetic marker is amplified and subsequently compared to reference species within a database. Thus, the determination process heavily relies on the establishment of reference databases that contain information on morphologically and genetically determined species. The data collected by the participants supported the work of the scientists at the Bavarian State Collection of Zoology, who aim to further expand the national DNA barcoding database and to identify previously unknown species within the framework of their project Barcoding Fauna Bavarica.

*Instruments*

Knowledge was measured at all test times using a program-specific multiple-choice test, which comprised 25 items on the lesson content. Each item had four possible answers, only one of which was correct. For statistical analyses, correct answers were coded as "1" and incorrect answers as "0". In the post- and retention test, we reordered the items randomly to prevent response bias.

To measure the environmental values, we used the 2-MEV scale as outlined in Bogner (2018), which measured the two higher order factors utilization, and preservation by 13 items. The items required approval of rejection on a 5-point Likert-Scale ranging from 1 "strongly disagree" to 5 "strongly agree".

To measure fascination with biology, we used a subscale of the Fascination with Science scale by Otto, et al. (2020). The scale has its roots in the Campbell-paradigm, which "describes individual behavior as a function of a person's attitude level and the costs of the specific behavior involved" (Kaiser et al., 2010). In consequence, the more difficult a statement a person agrees with, the higher is their fascination level. The scale is comprised of 84 items related to seven scientific fields: science in general, biology, chemistry, physics, astronomy, geology, and technology. Each of these subscales consists of 12 items covering the three attitudinal dimensions behavior, cognition, and affection. We applied 12 items referring to the field of biology. The items were measured on a 5-point Likert-type scale ranging from 1 "strongly disagree" to 5 "strongly agree" for affective and cognitive items and covering 1 "never" to 5 "very often" for behavioral items.

*Statistical Analyses and procedure*

For reliability analysis of the ad-hoc knowledge test, Cronbach`s alpha was calculated. Except for T0, internal consistency was acceptable (T0: $\alpha = 0.654$; T1: $\alpha = 0.745$; T2: $\alpha = 0.796$). Item difficulties between 0.15 and 0.96 represent a suitable range between easy and difficult questions. An insignificant Shapiro-Wilk test ($p = 0.31$) confirmed normal distribution of the item difficulties.

In accordance with Otto et al. (2020), we analyzed the quality of the Fascination with Biology Scale by using the Rasch model approach (for an overview of how to use Rasch analysis in science education research see Boone, 2016). Rasch analysis is based on the assumption that the probability of a respondent correctly answering an item depends on the difference between the person's ability (measured by the number of correctly answered items) and the item difficulty (measured by the number of respondents who gave a correct answer) (Bond & Fox, 2010). We used data of all three testing points (T0, T1, T2), with $N = 736$ for the calibration procedure. The Likert-Type answers were dichotomized (agree, strongly agree = 1; partially agree, disagree, strongly disagree = 0; often, very often = 1; sometimes, seldom, never = 0). The item separation reliability was $r_i = 1.0$; $SD = 2.26$. The person separation reliability was $r_p = 0.69$; $SD = 1.53$.

> Person separation indicates how efficiently a set of items is able to separate those persons measured. Item separation indicates how well a sample of people is able to separate those items used in the test. Where these statistics are expressed as reliabilities, they range from 0.0 to 1.0. The higher the value the better the separation that exists and the more precise the measurement (Wright & Stone, 1999, p. 151).

For further evaluating of the instrument quality, we used the item fit statistics (Boone, 2016). They indicate how well the observed data fits to the predicted Rasch model (Bond & Fox, 2010). Items show infit mean square values (wMNSQ) in the range between wMNSQ = 0.79 and wMNSQ = 1.18 with a mean value of MNSQ = 0.98 and SD = 0.13. The infits lie within the acceptable limits between 0.70 and 1.30 (Bond & Fox, 2010). 25 students scored 0 and seven students reached the maximum score. There are no maximum or zero score items. Item difficulties show a suitable range from $\delta = -2.92$ to $\delta = 3.71$ with $SD = 2.27$. Confirming the results of Otto et al. (2020), items belonging to the behavioral dimension are the most difficult whereas the easiest items belong to the cognitive dimension.

We examined the relation between environmental values and fascination with biology via correlation analysis. Second, we performed confirmatory factor analyses (CFA) to assess the discriminant validity of the scales. We proceeded with analyzing the effects of environmental attitude-sets and fascination with biology on biodiversity-related learning by means of structural equation modeling (SEM). We decided to test two alternative models to investigate the relation of fascination with biology and preservation and their combined impact on cognitive achievement. In a first model (A), we measured the predictive ability of fascination with biology on preservation and the impact of their relation on knowledge acquisition at all three test times. In a second model (B), we tested the opposite scenario: the predictive ability of preservation on fascination with biology and the mediated impact on students' cognitive performance. We evaluated the model fit with the following conventionally used indices (Kline, 2016): relative Chi-square (χ2/df), comparative fit index (CFI), root mean square error of approximation (RMSEA) and the standardized root mean square residual (SRMR). A good fit is indicated by $\chi 2/df < 2$, $RMSEA < 0.07$, $SRMR < 0.08$, and $CFI > 0.9$ (for an overview on structural equation modeling fit indices see Hooper et al., 2008). Due to non-normality of the data, we used robust procedures (spearman-rho coefficient for correlation analyses and maximum-likelihood estimator for model calculations). We used IBM SPSS 24 for descriptive statistics and correlation analyses, IBM SPSS AMOS for the CFA and SEM and ACER ConQuest 3 for Rasch analysis.

# Results

### *Descriptive Statistics and Correlation Analysis*

Preservation showed a strong positive correlation with fascination with biology ($r_s = 0.436$, $p \leq 0.001$), whereas preferences of nature utilization revealed the reverse trend ($r_s = -0.313$, $p \leq 0.001$). Gender showed a negative correlation with utilization but positive correlations with preservation as well as fascination with biology. Knowledge variables did not correlate with gender. At all test times, knowledge was positively related to both preservation and fascination with biology. The latter consistently showed higher effect sizes, which increased from pre-test to retention test. utilization correlated negatively with knowledge, with decreasing effect sizes from T0 to T2. As expected, the knowledge variables were positively correlated throughout all test times. All bivariate Spearman-rho correlation coefficients are depicted in Table 1.

Table 1:

Descriptive statistics and bivariate Spearman-rho correlations between the variables. $^*p \leq 0.05$, $^{**}p \leq 0.01$, $^{***}p \leq 0.001$. KN = knowledge, UTL = utilization, PRE= preservation, FB = fascination with biology, SD = standard deviation.

| variable | 1. gender | 2. KN T0 | 3. KN T1 | 4. KN T2 | 5. UTL | 6. PRE | 7. FB |
|---|---|---|---|---|---|---|---|
| 1. gender | - | 0.076 | 0.104 | 0.135 | $-0.244^{***}$ | $0.355^{***}$ | $0.244^{***}$ |
| 2. KN T0 | 0.076 | - | $0.592^{***}$ | $0.540^{***}$ | $-0.254^{***}$ | $0.198^{**}$ | $0.275^{***}$ |
| 3. KN T1 | 0.104 | $0.592^{***}$ | - | $0.658^{***}$ | $-0.218^{**}$ | $0.265^{***}$ | $0.318^{***}$ |
| 4. KN T2 | 0.135 | $0.540^{***}$ | $0.658^{***}$ | - | $-0.179^{*}$ | $0.267^{***}$ | $0.416^{***}$ |
| 5. UTL | $-0.244^{***}$ | $-0.254^{***}$ | $-0.218^{**}$ | $-0.179^{*}$ | - | $-0.381^{***}$ | $-0.313^{***}$ |
| 6. PRE | $0.355^{***}$ | $0.198^{**}$ | $0.265^{***}$ | $0.267^{**}$ | $-0.381^{***}$ | - | $0.436^{***}$ |
| 7. FB | $0.244^{***}$ | $0.275^{***}$ | $0.318^{***}$ | $0.416^{***}$ | $-0.313^{***}$ | $0.436^{***}$ | - |
| number of items | - | 25 | 25 | 25 | 7 | 6 | 12 |
| mean | - | 11.48 | 15.21 | 14.13 | 1.81 | 3.70 | 3.10 |
| SD | - | 3.45 | 3.66 | 4.41 | 0.43 | 0.56 | 0.58 |

*Confirmatory Factor Analysis Results*

The estimated CFA of the fascination with biology scale showed overall good model fit (chi2 = 93.39, df = 45, chi2/df = 2.08, p > 0.001, CFI = 0.93, RMSEA = 0.07, SRMR = 0.07). There was a strong positive relation between the affective and the cognitive (r = 0.73, p < 0.001) as well as the affective and the behavioral factor (r = 0.67, p < 0.001). The cognitive and behavioral factor were not significantly correlated (r = 0.17).

The CFA of the 2-MEV data verifies the two-dimensional factor structure of the instrument (Fig. 2.). Chi-Square is low relative to the degrees of freedom and with an insignificant p-value (chi2 = 82.56, df = 64, chi2/df = 1.29, p = 0.059). The CFI with 0.91 is acceptable and the RMSEA with 0.038 as well as the SRMR value with 0.06 lie below the acceptable thresholds of RMSEA < 0.07 and SRMR < 0.08. We additionally conducted an exploratory factor analysis in SPSS. Among the factor solutions, the varimax-rotated two-factor solution yielded the most interpretable solution with overall good factor loadings above the threshold of 0.3. Kaiser-Meyer-Olkin measure was 0.7 with a significant Bartlett's test (p > 0.001) and eigenvalues were above 1.

Figure 1.

CFA of the fascination with biology scale. Model fit indices: chi2/df = 2.08, CFI = 0.93, RMSEA = 0.07, SRMR = 0.07.

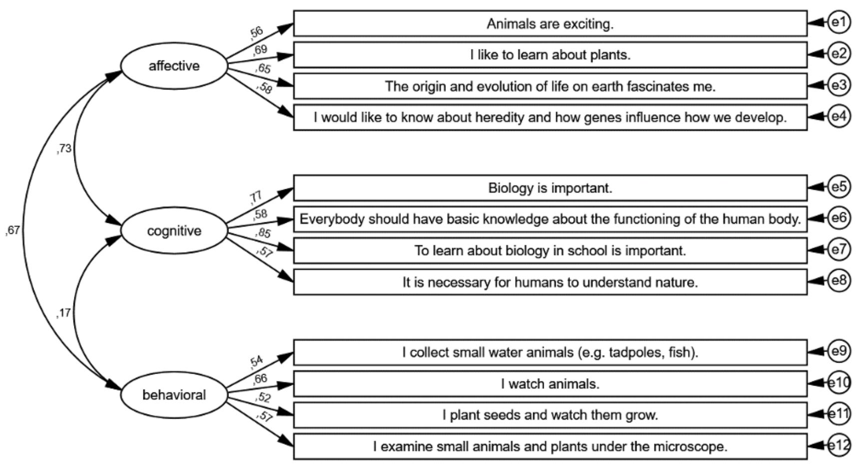
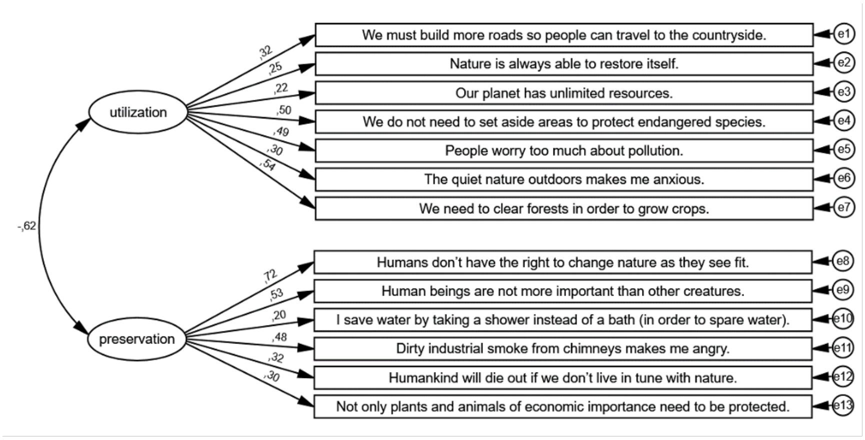


Figure 2.

CFA of the 2-MEV. Model fit indices: chi2/df = 1.29, CFI = 0.91, RMSEA = 0.038, SRMR = 0.06.

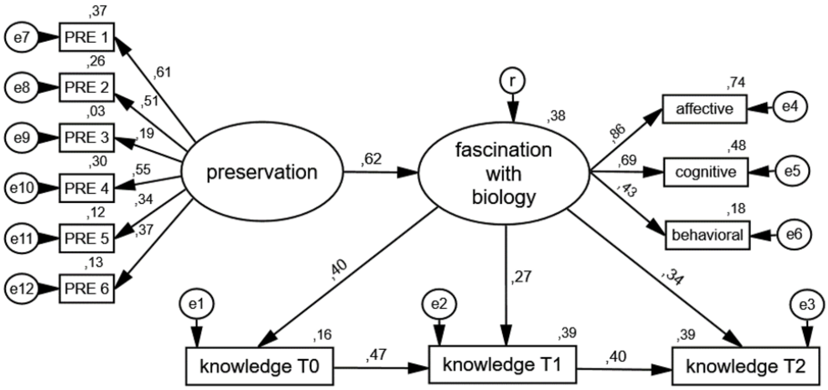



*Structural Equation Modeling*

Due to the negative correlation between utilization and preservation and their opposite association with fascination with biology and knowledge, we only inserted preservation to avoid suppression effects (Kline, 2016). The results of the two structural equation models and model fit indices are shown in Figure 3 and Figure 4.

Figure 3.

Model A: fascination as the mediator χ2/df = 1.53, CFI = 0.94, RMSEA = 0.051, SRMR = 0.05.

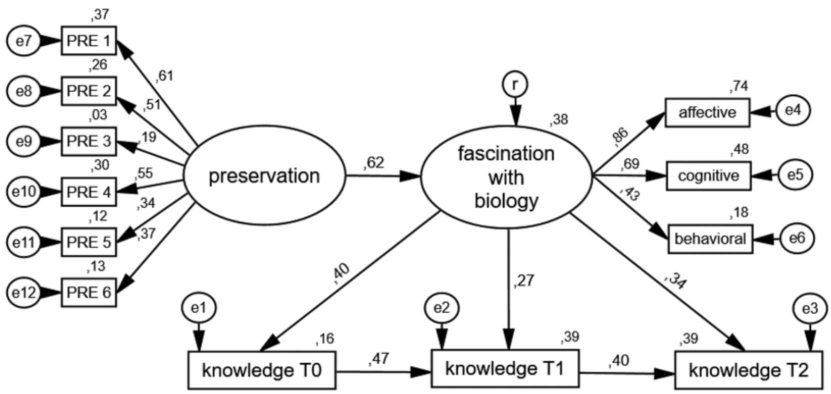


In model A, preservation was a positive predictor of fascination with biology ($ß = 0.62$, $p \leq 0.001$). In relation with preservation, fascination with biology was a positive predictor of knowledge at all three test times ($ßT0 = 0.40$, $p \leq 0.001$; $ßT1= 0.27$, $p \leq 0.001$; $ßT2 = 0.34$, $p \leq 0.001$) and explained 16% of the variance in pre-knowledge at T0. 39% of the shared variance in post-knowledge was predicted by fascination with biology and pre-knowledge. Accordingly, 39% of the variance in knowledge retention was explained by fascination with biology with biology and the previous cognitive performance.

In our model B, fascination with biology was a positive predictor of preservation ($ß = 0.72$, $p \leq 0.001$). preservation, in turn, positively predicted knowledge ($ßT0 = 0.44$, $p \leq 0.001$, $ßT1= 0.29$, $p \leq 0.001$; $ßT2 = 0.40$, $p \leq 0.001$) and explained 19% in the variance of pre-knowledge. Both, pre-knowledge at T0 and preservation explained 40% in the variance of knowledge at T1. 42% of the variance in retention knowledge was explained by preservation and knowledge at T0 and T1.

Figure 4.

Model B: preservation as the mediator variable. $\chi 2/df = 1.66$, CFI = 0.93, RMSEA = 0.057, SRMR = 0.06.




# Discussion

The main outcome of our study is the positive relation between environmental values and fascination with biology and their combined impact on environmental learning. The positive relationship between preservation and fascination with biology is in line with recent research on the relation between environmental values and general science motivation (Schönfelder & Bogner, 2020) and we will discuss our findings especially regarding the largely unconsidered potential of a mutualistic relationship between science education and environmental learning (Gough, 2002).

### *Measuring Environmental Values and Fascination with Biology*

As stated above, the factor structure of the 2-MEV has been repeatedly and independently confirmed (for an overview see Bogner, 2018). Initially developed for measuring German adolescent secondary school students' environmental preferences, the model proved its reliability and validity within samples of different age groups as well as for various countries. To our knowledge, up to now, the 2-MEV has been successfully applied in 33 languages. Starting in the late 1990s with a high number of items, the item set was successively reduced to a 14-item battery validly reproducing the two-factor structure (Bogner, 2018). Even a reduction to 12 (Schneller et al., 2015) or 10 items (Schönfelder & Bogner, 2020), still leads to the expected factor structure. Shorter scales offer a clear advantage for the evaluation of education programs: in most cases, the research questions require the application of several instruments but, at the same time, it is necessary to take into account that the participants' attention span is not unlimited. In the present study, we, thus, decided on using the short version of the 2-MEV scale (as displayed in Bogner, 2018).

An estimation of our 2-MEV data led to an acceptable CFA model with overall good model fit indices passing the criteria defined. However, as our sample size was limited to 205, we preferred to additionally conduct an explanatory factor analysis to assure the factor structure. Kaiser's criteria, the scree-plot, eigenvalues above 1 and factor loadings above 0.3 give empirical justification for maintaining the two-factor solution of the 2-MEV (Field, 2009). In accordance with previous studies, the CFA and the correlation analysis revealed a significant negative relation between the higher-order factors preservation and utilization (e.g. Milfont & Duckitt, 2004; Schneller et al., 2015; Schönfelder & Bogner, 2020).

The results of the Rasch analysis and the CFA prove the reliability of the fascination with biology scale. Our results confirm the scale as a ready-to-use instrument to measure the fascination with biology (Otto et al., 2020). Overall, item difficulties showed a suitable range between easy and difficult items ($\delta = -2.92$ to $\delta = 3.71$). Behavioral items were most difficult whereas cognitive items were fairly easy. The item separation reliability of $r = 1.0$ verifies the item hierarchy (construct validity). In comparison, the person separation reliability of $r = 0.69$ as well as the number of 25 zero and seven maximum scores indicates, that the test did not sensitively enough distinguish between very high and low performing students. One reason could be the low item number since we did only apply eight items for the scientific field biology. Increasing the number of items for the specific science subject areas would most probably enhance the ability of the test to classify different levels of fascination. Additionally, our confirmatory factor analysis results of the fascination with biology items are in line with two recent studies that report a three-factor structure for the fascination with the field science in general, biology and technology (e.g. Baierl & Bogner, 2020). Comparable to their results, we found the strongest correlation between the affective and the cognitive domain of fascination and a less but still strong effect between the factors affect and behavior. While they found a small but significant correlation between the factors behavior and cognition, our results show no statistically significant relation. We agree with the assumption of Baierl & Bogner (2020) that this finding is probably related to an attitude-behavior gap. The positive intentions represented by the cognitive and affective domain are not necessarily translated into actions or behaviors. Further, the behavior items are the most difficult items. High approval ratings to those items represent high fascination because the greater the actual effort or cost the greater is the estimated fascination (Otto et al., 2020).

*Relation between environmental values and fascination (H1 & H2)*

Fostering pro-environmental values is one of the major aims of ESD (Rieckmann et al., 2017). It is therefore of high importance for the development of educational measures to investigate relevant factors influencing environmental values. In our present study, we focused on fascination with biology. Since assessing fascination with scientific fields is a new approach to measure motivational abilities related to science, most assumptions are drawn from related research on interest and motivation.

Preservation is clearly positively related to fascination: the higher the pro-environmental value score, the higher is the fascination with biology and vice versa. Further, in our model A, preservation showed a strong, positive impact on fascination with biology (ß = 0.62) and in model B, fascination with biology revealed a positive effect on preservation (ß = 0.72). Learners with high pro-environmental preferences seem to be more interested in biology, more willing and motivated to learn subject-specific content and methods and more open to identify with the nature of the scientific enterprise. Conversely, our findings indicate that higher fascination levels will positively affect pro-environmental attitudes, i.e., students' preferences and willingness to protect the environment. Comparable results have been found for the relation between environmental attitudes and motivational abilities or concepts that are comprised by fascination, e.g., interest. In two correlational studies with Finnish secondary school students, interest in environmental issues has shown to be positively correlated with pro-environmental, biocentric attitudes and attitudes towards sustainability (Uitto et al., 2011; Uitto & Saloranta, 2010). Le Hebel et al. (2014) measured adolescents' environmental values and their interest in learning socio-scientific topics, e.g. the greenhouse effect. Students with higher pro-environmental attitudes showed greater willingness to learn. Additionally, in an adult sample and within a structural equation modeling approach, interest in scientific issues positively predicted attitudes towards sustainability (Wang et al., 2020). Further, in a study of Schönfelder and Bogner (2020) biocentric attitudes had a positive impact on general science motivation and vice versa. The observed interconnection between environmental values and motivational abilities is of high relevance for educators, in this case especially biology teachers. From our results we conclude that students holding low pro-environmental attitudes will not be enthusiastic about learning biology or willing to master scientific skills. On the other hand, students with low fascination, i.e., with low interest in biological topics and curiosity to learn more about biology or willingness for science mastery, will have less intentions to preserve the environment. This interdependence indicates that fascination with biology is conducive for the development of pro-environmental values and vice versa, preservation attitudes can be beneficial for generating fascination. This would also mean that the manifestation of the motivational abilities curiosity, interest, and science mastery can positively contribute to the promotion of pro-environmental attitudes. During the last decades, we encounter an ongoing decline in students' interest in STEM (Osborne & Dillon, 2008). At the same time, we observe an increase in environmental concern (Gough, 2002), which became visible very recently in the global Fridays For Future movement. As proposed by Dillon (2012), "focusing on issues of health and the environment might motivate more students to appreciate the value of science and to consider studying it for longer either at school or elsewhere". From our findings, we support the call for developing stronger synergies between EE/ESD approaches and formal science education (Schönfelder & Bogner, 2020). The probability for students to develop pro-environmental attitudes increases if they are fascinated with biology. Taking the other perspective, interest, curiosity, and mastery goals are thus most probably required for the development of intentions to protect the environment. The interconnection found between fascination with biology and environmental values suggests that biology lessons in formal education provide a suitable platform for EE/ESD approaches and consequently for simultaneously fostering environmental values and fascination.

### *Combined Impact on Environmental Knowledge (H3)*

Fascination and preservation attitudes positively predicted pre-knowledge and cognitive learning achieved through module participation. In Model A, fascination with biology mediated by preservation, positively predicted knowledge at all three test times with medium effect sizes. fascination with biology had the highest impact on pre-knowledge scores, the second highest effect on retention knowledge scores and the least impact on post-knowledge directly after module participation. From the second perspective in Model B reveals a similar picture. Mediated by fascination with biology, preservation predicted cognitive achievement with medium effect sizes and the highest impact on pre-knowledge scores. These findings confirm correlative analyses for the relation between environmental values and knowledge as well as fascination with biology and knowledge (e.g.Schneiderhan-Opel & Bogner, 2020b, 2020c).

We see two possible reasons for the highest influence of fascination on students' pre-knowledge scores. First, as indicated above, learners already holding higher fascination levels and pro-environmental values have probably already benefitted from former science lessons and were able to successfully gain respective knowledge. This conclusion is supported by the fact that the participating 10th graders have already attended biology lessons on environmental topics in previous school years. Secondly, students with pro-environmental attitudes and high fascination scores may have achieved higher pre-knowledge scores due to frequent nature experiences or practice of extra-curricular activities as well as informal learning opportunities related to environmental learning. In terms of environmental values, this assumption is supported by Le Hebel et al. (2014), who report a positive correlation between learners' extracurricular activities and their preservation attitudes. Thus, students with high preservation attitudes do more likely deal with science-related activities outside the classroom and they will most probably gain respective pre-knowledge. Regarding the influence of fascination with biology, findings of Uitto et al. (2006) on the positive correlation between interest in biology and students' nature experience confirm our assumption. Frequent exposure to nature presumably enhances learners' fascination with biology. In a study of Prokop et al. (2007), a one-day field trip increased students' knowledge and positively affected learners' attitudes towards biology and nature as well as their intention towards choosing a future biologist career.

Additionally, we assume that students scoring high on preservation will outperform students with low pro-environmental preferences leading to a performance gap. This assumption has also been made for the impact of science motivation on environmental knowledge acquisition and is supported by our results on fascination (Schumm & Bogner, 2016b). The differences in knowledge between learners with high or low fascination with biology and preservation attitudes, respectively, may increase over time and become obvious in the long-term view. When it comes to new environmental topics during their school career, low performing students will lack the pre-knowledge required for cumulative learning. Students with low motivation to learn biological or environmental topics will not successfully acquire knowledge as well as scientific skills and will, thus, lack scientific and environmental literacy (Bryan et al., 2011). In the future those students will most probably not persist in science and will not choose a scientific career. The connection between fascination and environmental values found in this study might further increase this effect leading to less environmentally responsible citizens.

## Conclusion

In view of combating major global environmental challenges, it has never been more important to develop successful EE and ESD approaches. Our study contributes to this need by supporting EE/ESD practitioners and science teachers. To our knowledge, this is the first study investigating the relation between environmental values and fascination with biology and their combined impact on environmental content knowledge. Keeping in mind the multitude of variables that intervene with cognitive achievement (pre-conceptions, emotions, creativity, etc.), both fascination as well as positive environmental values need specific attention when planning and implementing successful EE/ESD modules. Students with preferences to nature protection and higher levels of fascination with the subject biology will benefit the most from such approaches. The aim must therefore be to foster pro-environmental values as well as the intrinsic motivation towards science.

However, further investigation of the unresearched and under-pursued relationship between environmental education and science education is needed (Dillon, 2012). Given a positive relation between environmental values, fascination with biology and cognitive learning, we support the demand for greater synergy between EE/ESD and formal science education (Gough, 2002). As a prerequisite for this, further analysis and understanding of the interdependence between motivational abilities and environmental values are needed to enable the development of successful EE/ESD approaches within formal science education. Studies with different age groups should simultaneously assess motivational abilities and environmental attitudes to broaden the results of the present study. If science education and environmental education form a symbiotic relationship, they can mutually benefit from each other. Simultaneously fostering interest towards science as well as providing the required knowledge and skills can set the course to become responsible citizens who take action for nature protection.

### *Ethics and Consent*

The proposed study and consent processes have been approved by the Bavarian-Ministry of Education (StMUK; X.7-BO5106/160/12).

Participating schools were informed about the research conducted and all participants and legal guardians provided written consent to participate in this study. Data privacy laws were respected because the data was recorded pseudo-anonymously: only a specific identification code, based on sex, birth month and year allowed conclusions on sex and age. Withdrawal from participation was possible at any time.

*Funding Information*

This study was supported by the STORIES Project funded by the European Unions' Horizon 2020 research and innovation program under grant agreement no. 731872 and by the 'Qualitätsoffensive Lehrerbildung' program funded by the German Federal Ministry of Education and Research (BMBF) under grant agreement no. 01JA160. This publication was funded by the German Research Foundation (DFG) and the University of Bayreuth in the funding program Open Access Publishing (grant agreement no. LA 2159/8-6). The funders had no role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results. This article reflects only the authors' views.

## References

Baierl, T.-M., & Bogner, F., X. (2020). *Biosphere 2 as an Informal Learning Platform to Assess Motivation, Fascination, and Cognitive Achievement for Sustainable Development*, [submitted].

Bogner, F., X. (1998). The Influence of Short-Term Outdoor Ecology Education on Long-Term Variables of Environmental Perspective. *The Journal of Environmental Education*, 29(4), 17–29. https://doi.org/10.1080/00958969809599124

Bogner, F., X. (2018). Environmental Values (2-MEV) and Appreciation of Nature. *Sustainability*, 10(2), 350. https://doi.org/10.3390/su10020350

Bogner, F., X., & Wiseman, M. (1997). Environmental Perspectives of Danish and Bavarian Pupils: towards a methodological framework. *Scandinavian Journal of Educational Research*, 41(1), 53–71. https://doi.org/10.1080/0031383970410104

Bogner, F., X., & Wiseman, M. (1998). Environmental perception of Swiss and Bavarian pupils. *Schweizerische Zeitschrift Für Soziologie*, 24(3), 547–566.

Bogner, F., X., & Wiseman, M. (1999). Toward Measuring Adolescent Environmental Perception. *European Psychologist*, 4(3), 139–151.

Bogner, F., X., & Wiseman, M. (2002). Environmental perception of French and some Western European secondary school students. *European Journal of Psychology of Education*, 17(1), 3–18. https://doi.org/10.1007/BF03173201

Bogner, F., X., & Wiseman, M. (2006). Adolescents' attitudes towards nature and environment: Quantifying the 2-MEV model. *Environmentalist*, 26, 247–254. https://doi.org/10.1007/s10669-006-8660-9

Bond, T. G., & Fox, C. M. (2010). *Applying the Rasch model: Fundamental measurement in the human sciences* (2. ed.). Lawrence Erlbaum.

Bonnette, R. N., Crowley, K., & Schunn, C. D. (2019). Falling in love and staying in love with science: ongoing informal science experiences support fascination for all children. *International Journal of Science Education*, 0(0), 1–18. https://doi.org/10.1080/09500693.2019.1623431

Boone, W. J. (2016). Rasch Analysis for Instrument Development: Why, When, and How? *CBE Life Sciences Education*, 15(4). https://doi.org/10.1187/cbe.16-04-0148

Borchers, C., Boesch, C., Riedel, J., Guilahoux, H., Ouattara, D., & Randler, C. (2014). Environmental Education in Côte d'Ivoire/West Africa: Extra-Curricular Primary School Teaching Shows Positive Impact on Environmental Knowledge and Attitudes. *International Journal of Science Education*, Part B, 4(3), 240–259. https://doi.org/10.1080/21548455.2013.803632

Bord, R. J., O'Connor, R. E., & Fisher, A. (2000). In what sense does the public need to understand global climate change? *Public Understanding of Science*, 9(3), 205–218. https://doi.org/10.1088/0963-6625/9/3/301

Braun, T., Cottrell, R., & Dierkes, P. (2018). Fostering changes in attitude, knowledge and behavior: demographic variation in environmental education effects. Environmental Education Research, 24(6), 899–920. https://doi.org/10.1080/13504622.2017.1343279

Bryan, R. R., Glynn, S. M., & Kittleson, J. M. (2011). Motivation, achievement, and advanced placement intent of high school students learning science. *Science Education*, 95(6), 1049–1065. https://doi.org/10.1002/sce.20462

Carey, S., & Smith, C. (1993). On understanding the nature of scientific knowledge. *Educational Psychologist*, 28(3), 235–251. https://doi.org/10.1207/s15326985ep2803_4

Dass, P. M. (2005). Understanding the Nature of Scientific Enterprise (NOSE) through a Discourse with Its History: The Influence of an Undergraduate 'History of Science' Course. *International Journal of Science and Mathematics Education*, 3(1), 87–115. https://doi.org/10.1007/s10763-004-3225-1

Díaz, S., Fargione, J., Chapin, F. S., & Tilman, D. (2006). Biodiversity loss threatens human well-being. *PLoS Biology*, 4(8), e277. https://doi.org/10.1371/journal.pbio.0040277

Dillon, J. (2012). Science, the Environment and Education Beyond the Classroom. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 1081–1095). Springer. https://doi.org/10.1007/978-1-4020-9041-7_71

Elliot, A. J., & McGregor, H. A. (2001). A 2 X 2 achievement goal framework. *Journal of Personality and Social Psychology*, 80(3), 501–519. https://doi.org/10.1037/0022-3514.80.3.501

Fančovičová, J., & Prokop, P. (2011). Plants have a chance: outdoor educational programmes alter students' knowledge and attitudes towards plants. *Environmental Education Research*, 17(4), 537–551. https://doi.org/10.1080/13504622.2010.545874

Field, A. (2009). *Discovering Statistics Using SPSS* (3rd ed.). SAGE Publications, Inc.

Fremerey, C., & Bogner, F., X. (2015). Cognitive learning in authentic environments in relation to green attitude preferences. *Studies in Educational Evaluation*, 44, 9–15. https://doi.org/10.1016/j.stueduc.2014.11.002

Frick, J., Kaiser, F. G., & Wilson, M. (2004). Environmental knowledge and conservation behavior: exploring prevalence and structure in a representative sample. *Personality and Individual Differences*, 37(8), 1597–1613. https://doi.org/10.1016/j.paid.2004.02.015

Gifford, R. (2011). The dragons of inaction: Psychological barriers that limit climate change mitigation and adaptation. *The American Psychologist*, 66(4), 290–302. https://doi.org/10.1037/a0023566

Gough, A. (2002). Mutualism: A different agenda for environmental and science education. *International Journal of Science Education*, 24(11), 1201–1215. https://doi.org/10.1080/09500690210136611 (International Journal of Science Education, 24(11), 1201-1215).

Grace, M. (2006). Teaching citizenship through science: socio-scientific issues as an important component of citizenship. *Prospero*, 12(3), 42–53.

Hebert, P. D. N., Cywinska, A., Ball, S. L., & DeWaard, J. R. (2003). Biological identifications through DNA barcodes. *Proceedings of the Royal Society B. Biological Sciences*, 270(1512), 313–321. https://doi.org/10.1098/rspb.2002.2218

Hidi, S., & Renninger, K. A. (2006). The Four-Phase Model of Interest Development. *Educational Psychologist*, 41(2), 111–127. https://doi.org/10.1207/s15326985ep4102_4

Hooper, D., Coughlan, J., & Mullen, M. (2008). Structural Equation Modelling: Guidelines for Determining Model Fit. Electron. J. Bus. Res. *Method*s, 6, 53–60. https://doi.org/10.21427/D7CF7R

Johnson, B., & Manoli, C. C. (2010). The 2-MEV scale in the United States: a measure of children's environmental attitudes based on the theory of ecological attitude. *The Journal of Environmental Education*, 42(2), 84–97. https://doi.org/10.1080/00958964.2010.503716

Kaiser, F. G., Byrka, K., & Hartig, T. (2010). Reviving Campbell's Paradigm for Attitude Research. *Personality and Social Psychology Review*, 14(4), 351–367. https://doi.org/10.1177/1088868310366452

Kaiser, F. G., & Fuhrer, U. (2003). Ecological Behavior's Dependency on Different Forms of Knowledge. *Applied Psychology*, 52(4), 598–613. https://doi.org/10.1111/1464-0597.00153

Kaiser, F. G., & Wilson, M. (2019). The Campbell Paradigm as a Behavior-Predictive Reinterpretation of the Classical Tripartite Model of Attitudes. *European Psychologist*, 24(4), 359–374. https://doi.org/10.1027/1016-9040/a000364

Kitzes, J., Berlow, E., Conlisk, E., Erb, K., Iha, K., Martinez, N., Newman, E. A., Plutzar, C., Smith, A. B., & Harte, J. (2016). Consumption-Based Conservation Targeting: Linking Biodiversity Loss to Upstream Demand through a Global Wildlife Footprint. *Conservation Letters*, 10(5), 531–538. https://doi.org/10.1111/con4.12321

Kline, R. B. (Ed.). (2016). M*ethodology in the social sciences. Principles and practice of structural equation modeling* (4th edition). The Guilford Press.

Krapp, A. (1993). The construct of interest: Characteristics of individual interests and interest related actions from the perspective of a person object theory. *Studies in Educational Psychology*, 4, 1-18.

Le Hebel, F., Montpied, P., & Fontanieu, V. (2014). What Can Influence Students' Environmental Attitudes? Results from a Study of 15-year-old Students in France. *International Journal of Environmental and Science Education*, 9(3), 329–345.

Lee, Y. C., & Grace, M. (2010). Students' reasoning processes in making decisions about an authentic, local socio-scientific issue: bat conservation. *Journal of Biological Education*, 44(4), 156–165. https://doi.org/10.1080/00219266.2010.9656216

Markey, A., & Loewenstein, G. (2014). *Curiosity. In International handbook of emotions in education* (pp. 238–255). Routledge.

Marth, M., & Bogner, F., X. (2017). Does the issue of bionics within a student-centered module generate long-term knowledge? *Studies in Educational Evaluation*, 55, 117–124. https://doi.org/10.1016/j.stueduc.2017.09.001

McKeown, R., & Hopkins, C. (2005). EE and ESD: Two Paradigms, One Crucial Goal. *Applied Environmental Education & Communication*, 4(3), 221–224. https://doi.org/10.1080/15330150591004616

Milfont, T. L., & Duckitt, J. (2004). The structure of environmental attitudes: A first- and second-order confirmatory factor analysis. *Journal of Environmental Psychology*, 24, 289–303. https://doi.org/10.1016/j.jenvp.2004.09.001

Moss, A., Jensen, E., & Gusset, M. (2017). Probing the Link between Biodiversity-Related Knowledge and Self-Reported Proconservation Behavior in a Global Survey of Zoo Visitors. *Conservation Letters*, 10(1), 33–40. https://doi.org/10.1111/conl.12233

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections* (Vol. 13). The Nuffield Foundation.

Otto, S., Körner, F., Marschke, B. A., Merten, M. J., Brandt, S., Sotiriou, S., & Bogner, F., X. (2020). Deeper learning as integrated knowledge and fascination for Science. *International Journal of Science Education*, 42(5), 807–834. https://doi.org/10.1080/09500693.2020.1730476

Potvin, P., & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at K-12 levels: a systematic review of 12 years of educational research. *Studies in Science Education*, 50(August 2016), 85–129. https://doi.org/10.1080/03057267.2014.881626

Prokop, P., Tuncer, G., & Kvasničák, R. (2007). Short-Term Effects of Field Programme on Students' Knowledge and Attitude Toward Biology: A Slovak Experience. *Journal of Science Education and Technology*, 16(3), 247–255. https://doi.org/10.1007/s10956-007-9044-8

Rieckmann, M., Mindt, L., & Gardiner, S. (2017). *Education for sustainable development goals: Learning objectives*. UNESCO.

Roczen, N., Kaiser, F. G., Bogner, F., X., & Wilson, M. (2014). A Competence Model for Environmental Education. *Environment and Behavior*, 46(8), 972–992. https://doi.org/10.1177/0013916513492416

Rosenberg, M. J., & Hovland, C. I. (1960). Cognitive, affective, and behavioral components of attitudes. In M. J. Rosenberg (Ed.), *Attitude organization and change: an analysis of consistency among attitude components* (Yale studi, pp. 1–14). Yale University Press.

Schneiderhan-Opel, J., & Bogner, F. X. (2020a). FutureForest: Promoting Biodiversity Literacy by Implementing Citizen Science in the Classroom. *The American Biology Teacher*, 82(4), 234–240. https://doi.org/10.1525/abt.2020.82.4.234

Schneiderhan-Opel, J., & Bogner, F., X. (2020b). How fascination for biology is associated with students' learning in a biodiversity citizen science project. *Studies in Educational Evaluation*, 66, 100892. https://doi.org/10.1016/j.stueduc.2020.100892

Schneiderhan-Opel, J., & Bogner, F., X. (2020c). The Relation between Knowledge Acquisition and Environmental Values within the Scope of a Biodiversity Learning Module. *Sustainability*, 12(5), 2036. https://doi.org/10.3390/su12052036

Schneller, A. J., Johnson, B., & Bogner, F., X. (2015). Measuring children's environmental attitudes and values in northwest Mexico: validating a modified version of measures to test the Model of Ecological Values (2-MEV). *Environmental Education Research*, 21(1), 61–75. https://doi.org/10.1080/13504622.2013.843648

Schönfelder, M. L., & Bogner, F., X. (2017). Two ways of acquiring environmental knowledge: by encountering living animals at a beehive and by observing bees via digital tools. *International Journal of Science Education*, 39(6), 723–741. https://doi.org/10.1080/09500693.2017.1304670

Schönfelder, M. L., & Bogner, F., X. (2020). Between Science Education and Environmental Education: How Science Motivation Relates to Environmental Values. *Sustainability*, 12(5), 1968. https://doi.org/10.3390/su12051968

Schumm, M. F., & Bogner, F., X. (2016a). How Environmental Attitudes Interact with Cognitive Learning in a Science Lesson Module. *Education Research International*, 2016(4), 1–7. https://doi.org/10.1155/2016/6136527

Schumm, M. F., & Bogner, F., X. (2016b). The impact of science motivation on cognitive achievement within a 3-lesson unit about renewable energies. *Studies in Educational Evaluation*, 50, 14–21. https://doi.org/10.1016/j.stueduc.2016.06.002

Schunk, D. H., & Zimmerman, B. J. (2012). *Motivation and self-regulated learning: Theory, research, and applications*. Routledge.

Thorn, C., & Bogner, F., X. (2018). How Environmental Values Predict Acquisition of Different Cognitive Knowledge Types with Regard to Forest Conservation. *Sustainability*, 10(7), 2188. https://doi.org/10.3390/su10072188

Uitto, A., Juuti, K., Lavonen, J., Byman, R., & Meisalo, V. (2011). Secondary school students' interests, attitudes and values concerning school science related to environmental issues in Finland. *Environmental Education Research*, 17(2), 167–186. https://doi.org/10.1080/13504622.2010.522703

Uitto, A., Juuti, K., Lavonen, J., & Meisalo, V. (2006). Students' interest in biology and their out-of-school experiences. *Journal of Biological Education*, 40(3), 124–129. https://doi.org/10.1080/00219266.2006.9656029

Uitto, A., & Saloranta, S. (2010). The relationship between secondary school students' environmental and human values, attitudes, interests and motivations. *Procedia-Social and Behavioral Sciences*, 9, 1866–1872.

Wang, H.-H., Hong, Z.-R., Lin, H.-s., & Tsai, C.-Y. (2020). The relationships among adult sustainability attitudes, psychological well-being, nature relatedness, and interest in scientific issues. *Current Psychology*. https://doi.org/10.1007/S12144-020-00708-1

Wiseman, M., Wilson, G., & Bogner, F., X. (2012). Environmental values and authoritarianism. *Psychology Research*, 2(1), 25–31.

Wright, B., & Stone, M. (1999). *Measurement essentials* (2nd ed.). Wide Range.