Universität Bayreuth

Lehrstuhl Didaktik der Biologie

Unterricht in nachhaltiger Entwicklung: Vorstellungen und Wirkungsmessungen

Dissertation

zur Erlangung des akademischen Grades

- Dr. rer. nat. -

der Fakultät Biologie, Chemie und Geowissenschaften
an der Universität Bayreuth

vorgelegt von

Michaela Maurer

aus Lörrach

Master of Science in Biologie der Tiere

Diplomierte Lehrerin für Maturitätsschulen (EDK)

März 2020

Die vorliegende Arbeit wurde von Dezember 2016 bis März 2020 in Bayreuth am Lehrstuhl Didaktik der Biologie unter der Betreuung von Herrn Professor Dr. Franz X. Bogner angefertigt.

Vollständiger Abdruck der von der Fakultät für Biologie, Chemie und Geowissenschaften der Universität Bayreuth genehmigten Dissertation zur Erlangung des akademischen Grades einer Doktorin der Naturwissenschaften (Dr. rer. nat.).

Dissertation eingereicht am: 10. März 2020

Zulassung durch die Promotionskommission: 18. März 2020

Wissenschaftliches Kolloquium: 18. Juni 2020

Amtierender Dekan: Prof. Dr. Matthias Breuning

Prüfungsausschuss:

Prof. Dr. Franz X. Bogner (Gutachter)

Prof. Dr. Volker Ulm (Gutachter)

Prof. Dr. Stefan Schuster (Vorsitz)

Prof. Dr. Thomas Köllner

Danksagung

Mein erster Dank geht an meinem Doktorvater Prof. Dr. Franz X. Bogner, der mir die Möglichkeit gegeben hat an seinem Lehrstuhl promovieren zu dürfen. Vielen Dank für die Hilfestellungen bei der Anleitung zum selbstständigen wissenschaftlichen Arbeiten, sowie bei Fragen und Problemen auch außerhalb seiner Verfügbarkeit im Ausland oder an den Wochenenden.

Ein besonderes Dankeschön geht an Pavlos Koulouris. Durch seine Unterstützung und gute Zusammenarbeit konnte ich im Rahmen des EU-Projektes GAIA Datenerhebungen in Griechenland durchzuführen lassen.

Bei Petra Feuerstein und Sabine Hübner möchte ich mich ebenfalls bedanken, welche stets für mich ein offenes Ohr gehabt haben und mir bei organisatorischen Angelegenheiten geholfen haben. Für die statistischen Beratungen und konstruktive Kritik möchte ich mich ganz herzlich bei Dr. Franz J. Scharfenberg und Prof. Dr. Florian G. Kaiser bedanken.

Ein weiterer Dank gilt allen anderen Mitarbeitern des Lehrstuhls Didaktik der Biologie, die mich während der Promotionszeit unterstützt, motiviert und konstruktive Kritik gegeben haben. Vielen Dank für die gemeinsame schöne Zeit beim Mittagessen, an den nationalen und internationalen Konferenzen und zu guter Letzt auch bei unseren gemeinsamen Lehrstuhltreffen außerhalb der Arbeitszeiten.

Außerdem möchte ich mich bei meinen Eltern und meinen Freunden aus meiner Heimat bedanken, die mich in den letzten Jahren ebenfalls unterstützt und somit zum Gelingen dieser Arbeit beigetragen haben. Fürs Korrekturlesen möchte mich bei Markus Kachel ebenfalls bedanken.

Besten Dank an alle Studierende und Schüler, welche an den Studien teilgenommen haben. Ein weiterer Dank geht auch an alle Dozenten und Lehrer, die ermöglicht haben, die Studien durchzuführen.

Zu Guter Letzt möchte ich mich für die finanzielle Unterstützung bedanken, welche mir das Projekt Qualitätsoffensive Lehrerbildung zur Verfügung gestellt hat.

Inhaltsverzeichnis

Aus Gründen der besseren Lesbarkeit wird an einigen Stellen im Text auf die gleichzeitige Verwendung männlicher und weiblicher Sprachformen verzichtet. In diesem Fall gelten die Personenbezeichnungen gleichwohl für beiderlei Geschlecht.

A Summary

The world's population of almost eight billion and their increasing demand for natural resources is pushing the limits of the planet's capacities. Counteraction is mandatory, so schools are facing an enormous challenge. Agenda 2021 and 2030, for instance, developed keystones in education to work on the consistent implementation of *Education for Sustainable Developments* (ESD). Ever since, empirical data of human perceptions and activities regarding environmental awareness has been collected. The competency model developed by Roczen and colleagues was a turning point to relate the variables *Knowledge*, *Attitude* and *Behaviour* into a theoretical framework. In contrast, the effectiveness of sustainable teaching modules (according to ESD) has not yet been sufficiently assessed, which consequently, results in few reliable recommendations.

The present thesis's objective was to monitor students' perception regarding different terms of environmental education. **Study A** provided data of the conceptions of Environmental Education and ESD, which are often still used as synonyms. Yet both terms were perceived differently, and they do not follow an equally balanced three-pillar model of ecology, economy and social aspects. The term *Environment* evolved in **study B** as the sum of different environmental-ethical perspectives. The participants often equated the term to nature and associated it with positive feelings or emotions. Regardless of the concept, humans were perceived as the greatest environmental threat. In contrast, recommendations to reduce environmental footprints regarding mobility & transport, waste avoidance and consumption differ. Such ideas are shaped by experiences and scientific expertise and that is where schools come into play. The classic example – *Green Awareness in Action* (GAIA), saving energy in classrooms – aimed at improving the CO_2-balance of a school. The goal was to encourage environmentally friendly behaviour without impacting the quality of everyday school life. **Study C** incorporated the already described competency model which relates the extended environmental awareness scale with its variables *Preservation, Utilisation* and *Appreciation* (Bogner, 2018; Wiseman & Bogner, 2003)to the General Ecological Behaviour-scale (GEB-scale including the variables *Consumerism, Energy, Mobility & Transport, Recycling, Vicarious behaviour and Waste avoidance* (Kaiser, Oerke, & Bogner, 2007); it also includes the three dimensions of knowledge (including the variables *System knowledge, Action-related knowledge* and *Effectiveness knowledge*) developed by Liefländer, Fröhlich, Bogner, &

Schultz (2013). A path analysis showed the causal relationship between the three latent dimensions and sub-scales environmental knowledge and values (ξ = 0.69, p > 0.001), values and (reported) behaviour (ξ = 0.80, p > 0.001), as well as environmental knowledge and (reported) behaviour (ξ = 0.37, p = 0.001). In a practical framework, the classroom module of **study D** has proven effective if implemented regularly. The in-class contest of the sixth graders achieved to reduce energy consumption by 50% within a ten-week intervention. Action-related knowledge and effectiveness knowledge increased whereas environmental values showed no impact on environmental knowledge. Implying environmental behaviour as a moderator, students of lower person parameters learnt most.

To sum up, the transformation into ESD took place in the student's minds; and implementation of the sustainable teaching module. An ecological mind-set is essential, and it requires persistent integration in everyday life.

B Zusammenfassung

Eine Weltbevölkerung von knapp acht Milliarden und deren stetig steigende Nachfrage an natürlichen Ressourcen bringen die planetare Belastbarkeit zunehmend an ihre Grenzen. Ein Gegensteuern ist unerlässlich, auch auf Schulen kommt daher eine enorme Aufgabe zu. Meilensteine bei Bildungsvereinbarungen waren beispielsweise durch die globalen Abkommen der Agenda 2021 und 2030 beschlossen worden, um weltweit eine konsequente Umsetzung der *Bildung für eine Nachhaltige Entwicklung* (BNE) einzufordern. Empirische Erhebungen zu Vorstellungen menschlichen Handelns zum Umweltbewusstseins werden seither durchgeführt. Eine Wende brachte das Kompetenzmodel nach Roczen und Kollegen (2014), das die Variablen Wissen, Einstellung und Verhalten theoretisch fundiert zusammenführte. Konkrete Handlungsbeispiele in Form von nachhaltigem Unterricht sind dagegen in ihrer Praxis-Wirksamkeit noch kaum vorhanden, auch im Hinblick auf belastbare Empfehlungen.

Die vorliegende Arbeit zielt darauf ab, Vorstellungen verschiedener Begrifflichkeiten im Umweltbildungssektor von Studierende zu eruieren. **Teilstudie A** erfasst die allgemeine Wahrnehmung von Umweltbildung und BNE, welche bis heute oft noch als Synonyme verwendet werden. Beide Terminologien wurden unterschiedlich wahrgenommen und folgten bezüglich des Drei-Säulen-Modells keiner gleich gewichteten Einheit von Ökologie, Ökonomie und Soziales. Der Zugang zum *Umweltbegriff* kristallisierte sich in **Teilstudie B** als eine Summe verschiedener umweltethischer Sichtweisen heraus. Der Begriff wurde oft mit der Natur gleichgesetzt, welche vorwiegend mit positiven Gefühlen/ Emotionen assoziiert werden. Die Einsicht, dass der Mensch die größte Bedrohung der Umwelt darstellt, erstreckt sich gleichwertig über alle Wertevorstellungen. Dagegen gehen die Vorstellungen hinsichtlich einer Reduktion des eigenen ökologischen Fußabdrucks in puncto Mobilität & Transport, Müllvermeidung und Konsum weit auseinander. Die Wahrnehmungen resultieren vorwiegend aus Erfahrungen und wissenschaftlichen Erklärungen, die der Schule einen erheblichen Beitrag zuweisen. Das Schulbeispiel – Green Awareness in Action (GAIA), Energiesparen im Klassenzimmer – sollte dabei die CO_2-Bilanz einer ganzen Schule einbeziehen und verbessern. Individuelles Verhalten sollte dabei gefördert werden, ohne die Qualität des Schullebens beeinträchtigen. In **Teilstudie C** wurde angelehnt an das Kompetenzmodel die erweiterte Umweltbewusstseins-Skala mit den Variablen *Preservation*, *Utilisation* und *Appreciation*) (Bogner, 2018; Wiseman & Bogner, 2003), zusammen mit der Allgemeinen ökologischen Verhalten-Skala (GEB-Skala

mit den Variablen *Konsum*, *Energiesparen*, *Mobilität & Transpor*t, *Recycling*, *Vikariierende Verhalten* in Bezug auf Umweltschutz und Abfallvermeidung) (Kaiser, Oerke, & Bogner, 2007) und den drei individuell entwickelten Wissensdimensionen (mit den Variablen *Systemwissen*, *Handlungswissen* und *Effektivitätswissen*) nach Liefländer, Fröhlich, Bogner, & Schultz (2013), eingesetzt. In einem Pfadmodell konnten die Zusammenhänge der drei latenten Dimensionen mit den jeweiligen Unterskalen veranschaulicht werden [Umweltwissen und Umweltverhalten (ξ = 0.69, p > 0.001), Umwelteinstellungen und Umweltverhalten (ξ = 0.80, p > 0.001), Umweltwissen und Umweltverhalten (ξ = 0.37, p = 0.001]. In der Praxis erwies sich das Unterrichtsmodul in **Teilstudie D** als effektiv im Rahmen der konsequenten Umsetzung im Schulalltag. Durch den internen Wettbewerb aller sechsten Jahrgangsstufen konnte der Stromverbrauch beispielsweise während einer zehnwöchigen Interventionseinheit um die Hälfte gesenkt werden. Handlungswissen und Effektivitätswissen wurden über diesen Zeitraum gesteigert, während Umwelteinstellungspräferenzen gegenüber dem Wissenserwerb keinen Einfluss ausübten. Unter Einbezug des Umweltverhaltens lernen insbesondere Schüler mit einem niedrigen Personen-Schätzer-Wert dazu.

Zusammenfassend bleibt demnach festzuhalten, dass die Transformation in einer *Bildung für Nachhaltige Entwicklung* sowohl in den Vorstellungen der Studierenden als auch in der Umsetzung von nachhaltigem Unterricht vonseiten der Schüler bereits stattfindet. Es bedarf jedoch einer konsequenten Umsetzung im Alltag, bei der eine ökologische Einstellung unerlässlich bleibt.

C Synopsis

C.1 Einleitung

> *„Wir können die erste Generation sein, der es gelingt, die Armut zu beseitigen, ebenso wie wir die letzte sein könnten, die die Chance hat, unseren Planeten zu retten.“*
>
> *(Ban-Ki Moon, UN-Generalsekretär von 2007 bis 2016, in Kontext der Agenda 2030)*

Während vor vierzig Jahren der sogenannten „Earth Overshoot Day“ auf Ende Dezember datiert wurde, überschritt der weltweite Bedarf an natürlichen Ressourcen der Weltbevölkerung im vergangenen Jahr schon Ende Juli (Earth Day Overshoot, 2020). Für europäische Länder wie beispielsweise die Schweiz oder Deutschland waren die Ressourcen schon im Mai aufgebraucht. Im Jahr 2018 lebten in der Schweiz laut Schätzung etwa 215 Menschen pro km² Fläche. In Deutschland waren es sogar 237 Menschen (‘Worldbank’, 2020). Vorbildlich haushalten hingegen u. a. asiatische Länder wie beispielsweise Indonesien, die trotz ihrer hohen tragfähigen Bevölkerungsdichte von 147 Menschen pro km^2 Fläche deutlich weniger Ressourcen über das Jahr hinweg verbrauchen, als nachwächst. Das dennoch in den meisten Ländern sehr prävalente Problem wurde erstmals mit der Publikation „Club of Rome – über die Grenzen des Wachstums“ (Meadows und Kollegen, 1972) in den 1970ern Jahren adressiert. Im Sinne der Nachhaltigkeit sollte dabei das anthropozentrische Ausschöpfen der planetaren Ressourcen bis an die Grenzen der Belastbarkeit aufgezeigt werden. Als besonders kritisch galten schon damals die Übernutzung von Boden und Wasser, das Verpesten der Luft und die Gefährdung der Artenvielfalt (Boylan, 2013). Seitdem hat sich diese Pionierstudie immer mehr zum Leitbild ökologischer Probleme entwickelt (Gardner & Stern, 1996). Im Fokus der Kritik standen demnach vorwiegend der ausufernde Konsum und die steigende Mobilität. In Kooperation mit dem Brundtland-Bericht (UNWCED, 1987) wurde so das erste Konzept zu einer nachhaltigen Entwicklung herausgearbeitet: „Nachhaltige Entwicklung ist eine Entwicklung, die den Bedürfnissen der heutigen Generation entspricht, ohne die Möglichkeiten künftiger Generationen zu gefährden, ihre eigenen Bedürfnisse zu befriedigen“. Ihre Legitimation erhielten diese Bestrebungen nicht zuletzt durch den „Silent spring“ (Carson, 1962), wobei die Anklage auf kontrollierte Freisetzung von Umweltgiften eine der frühesten Umweltbewegungen auslöste. Denn die Erkenntnis,

dass Dichlordiphenyltrichlorethan (DDT) und andere Pestizide in Körpern von Weddellrobben (*Leptonychotes weddellii*) und Kaiserpinguinen (*Aptenodytes forsteri*) fernab des eigentlichen Ortes der Verwendung gefunden wurden (George & Frear, 1966), war schockierend. Die daraus resultierende Protestwelle führte Jahre später zu einem weltweiten Verbot von DDT.

Verschiedenste Abkommen von globaler und historischer Bedeutung (u. a. UNESCO-UNEP, 1975; UNESCO UNEP, 1978) sprachen sich schließlich vehement für strikte Umweltbildung aus. Neben den kognitiven Fähigkeiten sollten besonders affektive und psychomotorische Aspekte des Lernens in den formellen und informellen Unterricht integriert werden (UNESCO-IEEP, 1985; UNESCO-UNEP, 1975), wodurch man eine breitere Methodenvielfalt anstrebte (Palmer, 1998; Prince & Felder, 2006). Mit der Konferenz von Rio de Janeiro wurde die Agenda 21 verabschiedet, welche den Umweltbildungsbegriff in eine Bildung für eine Nachhaltige Entwicklung (BNE) erweiterte (United Nation, 1992). Lokales Engagement sollte die Möglichkeit für Nachhaltigkeitsprozesse vorantreiben. Dabei sollen die sowie drei Säulen der Nachhaltigkeit, nämlich Ökologie, Ökonomie und Soziales, gleichwertig behandelt werden. Insbesondere wollte man dadurch eine neue Bewusstseinsbildung im Hinblick auf die Auswirkungen des aktuellen Handelns auf heutige und zukünftige Generationen in den Fokus rücken. Nachdem die Ziele der ersten UN Dekade (2005-2014) nicht vollständig erfüllt wurden, haben die Vereinten Nationen im Jahre 2015 die Agenda 2030 unter Einbindung von Schwellenländern und Drittweltländern erweitert. Das Augenmerk lag dabei auf Kollaboration und Frieden (UN SDG, 2016). Die Gesellschaftspolitik ist seit jeher auf das Beobachten von und Reagieren auf gesellschaftliche Diskurse ausgelegt. Umweltbewegungen könnten somit aktuell für den notwendigen Sinneswandel der Verbraucher und Politiker in Bezug auf die Energiewende gesorgt haben. Zugang zu bezahlbarer, sauberer, verlässlicher und nachhaltiger Energie – so lautet das siebte Nachhaltigkeitsziel (Rieckmann, 2017). So wird gerade ein Übergang von nicht nachhaltiger Nutzung fossiler Energieträger und Kernenergie zu einer nachhaltigen Energieversorgung geschaffen. Denn einen ständig steigenden Bedarf an Energie durch nukleare Energieträger zu lösen, mag sich zwar als wirtschaftlich äußerst profitabel herausgestellt haben, doch ist dies auf Dauer für den Planeten auch nicht tragbar. Heute ist daher zu überlegen, wie die globale Energieversorgung aussehen kann, dass sie nachhaltig ist und nicht sofort zahlreiche Protestaktionen von unterschiedlichen Seiten nach sich zieht. Trotz Jahrzehntelanger Bemühungen von Bildungsinitiativen und politischen Maßnahmen ist jüngst eine neue Umweltbewegung -„Fridays for Future“- entstanden. Schüler und Studierende engagieren sich

aktiv als Umweltaktivisten und drängen die Politik zur Einhaltung ihrer auf der Weltklimakonferenz in Paris 2015 beschlossenen Ziele. Besonders eine Vermeidung der Erderwärmung um mehr als zwei Grad Celsius gilt es zu realisieren. Dazu wird in regelmäßigen Abständen der Unterricht an bestimmten Freitagen weltweit geschwänzt, um auf den Straßen zu protestieren. Wohin diese Bewegung noch führt, wird sich zeigen. Doch sind nicht von jeher Umweltbewegungen Zeugen stummer Impulse aus der Bevölkerung gewesen, eine bessere Zukunft zu fordern?

Die vorliegende Arbeit besteht aus zwei Schwerpunkten. Bei Teilstudie A + B liegt der Fokus bei der Erfassung von Studierenden-Vorstellungen im Kontext Umweltbildung, Umwelt und Natur. Bei Teilstudie C + D liegt der Fokus bei der Evaluation eines EU-Projekts in Theorie und Praxis. Das Unterrichtsmodul GAIA (Green Awareness in Action) – Energiesparen im Klassenzimmer – steht dabei im Zentrum, inwiefern diese Schulmaßnahme zum Umweltbewusstsein der Schüler beitragen kann.

C.2 Theoretischer Hintergrund

Vorstellungen

Lernen ist ein lebenslanger und altersabhängiger Prozess, welcher an zwei Wirklichkeitszugängen anknüpft: persönliche Erfahrungen und wissenschaftliche Erklärungen (Andresen, Boud, & Cohen, 1999). Individuen rekonstruieren ihr Wissen immer wieder neu (Piaget, 1964), das sich im Laufe ihres Lebens durch Erfahrungen akkumuliert (Driver, 1989). Durch Annäherung (Subjektivierung) und Distanzierung (fachliche Objektivierung) werden individuelle Vorstellungen zu objektiven und systematischen Wahrnehmungen und Realitäten (Kaiser und Kollegen, 2011). Mit der Einführung der Alltagsphantasien nach Gebhard (2009) werden Assoziationen, Gefühle und Vorstellungen zusammen mit einem bestimmten Thema assoziiert. Sie greifen beim Lernprozess im Ansatz auf Aspekte der Tiefendimension ein (Selbst-, Menschen- und Weltbild). Grundsätzlich entstehen neben den individuellen Vorstellungen auch Formen verschiedener Assoziationen, Intuitionen, Ängste oder emotionaler Reaktionen. Emotionen sind mehrdimensionale Konstrukte, die aus affektiven (subjektive Zugänge), physiologischen, kognitiven (Interpretation, Erinnerung und Erwartungen), expressiven und motivationalen Komponenten bestehen. Sie helfen uns mit der Fülle an Informationen im Alltag umzugehen (Holodynski & Oerter, 2012) und können positiv oder negativ erlebt werden.

Wissen baut auf Vorwissen auf, welches zusammen mit der Einstellungsebene (Werte) und Handlungsebene die drei Bereiche der Bildung für eine Nachhaltige Entwicklung (BNE) abbildet (UNGA, 2015; United Nation, 1992). Inwiefern diese Bereiche in Form von Vorstellungen erfasst werden können, wird sich exemplarisch an einer westeuropäischen Bevölkerungsgruppe von Studienanfängern (i.d.R. Schulabgänger) in dieser Arbeit zeigen. Die aus der Literatur bekannten (Schüler)Vorstellungen im Kontext Umwelt und Natur sind inzwischen überholt. Des Weiteren liegen keine größeren Studien im Kontext BNE vor, da sie in der Regel themenspezifisch sind. Natur und Naturbegriffe unterliegen keiner Konstante und sind meist biografisch und kulturell geprägt. Sie nehmen Einfluss auf die jeweiligen Werthaltungen, Interessen und Verhaltensweisen des Individuums (Gebhard, 2013). Durch Bildungsarbeit, insbesondere in der Umweltbildung können Lern- und Denkerfahrungen unterstützen. Die Entscheidung bleibt jedoch beim Individuum selbst.

Umweltwissen, Umwelteinstellung und Umweltverhalten

Umweltbewusstsein wird heutzutage oft in Zusammenhang mit ökologischem Wissen, ökologischen Einstellungen (einschließlich Werthaltungen) und ökologischem Verhalten/ Handeln gebracht (Grob, 1995; Kollmuss & Agyeman, 2002). Der Begriff wurde erstmals durch Maloney & Ward (1973) erwähnt und durch Urban (1986) in die Bestandteile umweltrelevante Wertorientierung, umweltbezogene Einstellungen und umweltorientierte Handlungsbereitschaften klassifiziert. Man der heutzutage der Ansicht, dass anthropozentrische Eingriffe die natürliche Umwelt zunehmend bedrohen oder schädigen (Boylan, 2013). Bei der Frage, welche Rechte Menschen im Umgang mit Tieren, Pflanzen und der nicht belebten Natur haben, respektive wie sich der Mensch demgegenüber verhalten soll, versucht die Umweltethik (bekannt auch unter dem Begriff Naturethik) zu vermitteln. Dieser Begriff wird auf die 1970er Jahre zurückdatiert, als die ersten Umweltkrisen publik wurden (z. B. Waldsterben, Luftverschmutzung, saurer Regen). Dabei wird die ethische Disziplin in zwei Ansichten unterteilt: (i) die der anthropozentrischen Sichtweise, bei welchem der Mensch den Schutz der Honigbienen beispielsweise nur zum Zwecke der Bestäubung oder der Honiggewinnung um seiner selbst willen nutzt (instrumentellen Wert) (Cedillo, 2016) und (ii) die der physiozentrischen (Oberbegriff für pathozentrische, biozentrische und ökozentrische) Sichtweise, bei dem der Wert der jeweiligen Ansicht der Natur zugesprochen wird (moralischer Wert) (Taylor, 2013; Thompson & Barton, 1994).

In den 1970er Jahren stellten sich Pädagogen, Psychologen und Soziologen zurecht die Frage, warum ein breiteres öffentliches Verständnis im puncto Umweltwissen über die

Umweltgefahren nicht automatisch zum Handeln führt. Zusammenhänge von Umweltwissen, Umwelteinstellungen und Umweltverhalten waren bis dato weitgehend unerforscht. Ursprünglich ging man von einer kontinuierlichen Linearität von Wissen (Kombination aus Faktenwissen) über Einstellung (Bedenken) zur Handlung aus, was inzwischen schon mehrfach revidiert wurde (z. B. Roczen und Kollegen, 2014). Die politische Entscheidung, die Umweltbildung als festen Bestandteil in den Lehrplan zu verankern (United Nation, 1992), hatte zum Ziel, den Schülern einen verantwortungsbewussten Umgang mit der Umwelt und den natürlichen Ressourcen zu lehren. Unabhängig von halb- bis mehrwöchigen Interventionen konnten Wissenszuwächse psychometrisch erfasst werden (Bogner, 1998; Zelezny, 1999). Mit dem Wandel in eine BNE (UN, 1992) nahm der Begriff des Umweltwissens eine neue Dimension an. Zu einer erweiterten Erkenntnis von kognitivem Wissen haben Frick, Kaiser und Wilson (2004) wesentlich beigetragen. Sie nahmen eine Einteilung in drei unterschiedliche Dimensionen vor: (i) Systemwissen, bekannt auch unter dem Begriff Faktenwissen, (ii) Handlungswissen und (iii) Effektivitätswissen, populär auch unter der Bezeichnung Wirksamkeitswissen. Systemwissen, welches auch als Basiswissen bezeichnet wird, deckt das Wissen über einfache Zusammenhänge oder Ursachen von Umweltproblemen ab. Handlungswissen ist komplexer einzuordnen als Systemwissen. Beim Kochen (mit/ohne Deckel) oder durch den Einkauf von Milch (Glas- oder Plastikflaschen, Tetrapack oder durch ein selbst mitgebrachte Flasche direkt beim Bauern) sind konkrete Handlungsführungen erforderlich. Frick und Kollegen (2004) nahmen an, dass Systemwissen mit Handlungswissen zusammen das Fundament von Effektivitätswissen bildet. Diese beinhalten Kenntnisse des Schutzpotentials der Umwelt, welche verschiedene Verhaltensweisen (Kaiser, Roczen, & Bogner, 2008) integrieren (Vicente-Molina, Fernandez-Sainz, & Izagirre-Olaizola, 2013). Beim Kauf einer neuen Lampe (Glühlampe, Energiesparlampe, Fluoreszenzlampen oder LED Lampen) oder eines neuen Autos (Elektroauto, Benziner oder Diesel) wird die Kaufentscheidung der individuellen Beurteilung mit Bezug auf das eigene Wissen beeinflusst. Die Beziehungen der drei Wissensdimensionen wurden durch Roczen und Kollegen (2014) in einem empirisch fundierten Kompetenzmodell bestätigt, wodurch ein tieferes Verständnis in puncto Umweltwissen möglich wurde. Die Erforschung in der Praxis erfolgte erstmals im Rahmen einer einwöchigen außerschulischen Interventionsstudie von Viert- und Sechstklässler im Kontext Wasser (Liefländer und Kollegen, 2015). Bisher noch wenige Studien wie die nachfolgenden, konnten zeigen, dass es bezüglich der drei Wissensdimensionen

Unterschiede in puncto Vorwissen und Wissenszuwachs gibt (z. B. Braun, Cottrell, & Diekers, 2018; Fremerey & Bogner, 2014; Schumm & Bogner., 2016; Thorn & Bogner, 2018). Die drei Wissensdimensionen werden in der Regel durch Multiple Choice Fragen mit nur einer richtigen Antwortmöglichkeit abgefragt. Die Überprüfung der Reliabilität (Zuverlässigkeit, Genauigkeit) und Validität (Gültigkeit) in einem Rasch-Modell dient dazu, grünen Bildungsinitiative statistisch besser zu beleuchten und fundierter argumentieren zu können.

Umwelteinstellungen und Umweltverhalten spielen eine wichtige Rolle, wenn es um den Zusammenhang mit Umweltwissen geht (Meinhold & Malkus, 2005). Nach Stern & Dietz (1994) werden Einstellungen zur Umwelt in drei verschiedene Einstellungskomponenten aufgeteilt (egoistisch, altruistisch und biospherisch), worauf in den 1990er Jahren das Messinstrument der New Environmental Paradigm (NEP)-Skala nach Dunlap & Van Liere (1978) für Erwachsene entstanden ist. Gleichzeitig haben Bogner und Kollegen eine Umweltbewusstseins-Skala (2-MEV-Skala, engl. 2-Major Environmental Values) erforscht, mit welcher man mithilfe von zwei orthogonalen Skalen, den sogenannten Ecological Values, Naturschutzpräferenz (engl. preservation PRE) und Natur(aus)nutzungspräferenz (engl. utilisation UTL) auf Basis einer 5-stufigen Likert-Skala erfassen konnte (Bogner, 2002; Bogner & Wiseman, 1999; Wiseman & Bogner, 2003). PRE gruppiert man eher der bio- als ökozentrischen Sichtweise zu, da diese auch die Wertschätzung der Natur berücksichtigt (Thompson & Barton, 1994). Bei Biozentrismus stehen die Natur und alle lebenden Organismen im Mittelpunkt (Botar, 2017). Beim Ökozentrismus dagegen werden alle Elemente der Natur (biotisch und abiotisch) einen eigenen Wert zugeschrieben. Tier- und Pflanzenarten, Flüsse und Berge, sogar Ökosysteme sind Elemente von immanentem Wert (Thompson & Barton, 1994). UTL dagegen präferiert natürliche Ressourcen auszubeuten (Wiseman & Bogner, 2003), bevorzugt also eine anthropozentrische Sichtweise. Das stellt den Menschen ins Zentrum, der Ressourcen wie Wasser, Boden und Luft um seiner selbst willen nutzen kann (Bogner, Brengelmann, & Wiseman, 2000; Hargrove, 1992). Die Umwelt zu schützen wird nur dann für sinnvoll erachtet, wenn es einen Nutzen gibt (Cedillo, 2016). Nichtmenschliche Organismen oder Naturphänomene haben stattdessen einen instrumentellen oder ästhetischen Wert (Cedillo, 2016). Beide Sekundärfaktoren werden auch als Werte (*engl. values*) definiert (Wiseman & Bogner, 2003). Ursprünglich wurden 60 Items für das Instrument im Rahmen von binationalen Studien mehrfach getestet (z. B. Bogner & Wiseman, 1997) und im Laufe der Zeit mit anderen Skalen (z. B. individuellen Risikopräferenz) weiter validiert (Bogner und Kollegen, 2000). Schließlich ergab sich eine Version mit 20 Items, die um eine weitere Skala

– Wertschätzung (engl. Appreciation APR) – ergänzt wurde (Bogner, 2018). Insgesamt hat sich die 2-MEV-Skala hinsichtlich unterschiedlicher Sprachen und Altersgruppen im nationalen und internationalen Raum gut etabliert (Boeve-de Pauw & Van Petegem, 2011; Borchers und Kollegen, 2014; Braun und Kollegen, 2018; Johnson & Manoli, 2010; Milfont & Duckitt, 2004). Insgesamt haben fünf westeuropäische binationale Studien die Gültigkeit des Modells bestätigt, wie beispielsweise die Studie des deutsch-schweizer Vergleiches mit nahezu eintausend Teilnehmern (Bogner, 1999). Die Effektivität grüner Bildungsinitiativen konnte durch dieses Modell daher schon mehrfach ausgesprochen werden (Boeve-de Pauw & Van Petegem, 2013; Schmitz & Rocha, 2018). Aus der Literatur ist bereits mehrfach bestätigt worden, dass Umwelteinstellungen hinsichtlich des Umweltwissens einander bedingen (Marcinkowski & Reid, 2019; Yoon & Sirisena, 2014; Zelenika und Kollegen, 2018). Hinsichtlich der Wirkung der drei Wissensdimensionen auf Umwelteinstellungen ist aber noch wenig bekannt.

Mit der Einführung der Umweltbildung in den 1970er Jahren glaubte man, durch Wissensvermittlung und Betroffenheitserzeugung menschliches Verhalten formen zu können (Hungerford & Volk, 1990). Seit dem Wandel in eine Bildung für eine Nachhaltige Entwicklung distanziert man sich zunehmend von diesem Erziehungsgedanken (Marcinkowski & Reid, 2019). Unter einer Vielzahl von Messinstrumenten ist es bis heute schwierig, Umweltverhalten zuverlässig zu messen. Mitte der 1990er Jahre etablierte sich ein Messinstrument, welches sich auf spezifische, dafür leichter erfassbare Verhaltensweisen (berichtetem Verhalten) spezialisiere (Kaiser, 1998). Ursprünglich für Erwachsene konzipiert, wurde das probabilistische Messinstrument der allgemeinen ökologischen Verhalten-Skala (engl. the General Ecological Behavior-GEB) später durch die sogenannten self-reports für Jugendliche von Kaiser, Oerke, & Bogner (2007) adaptiert. Mit nur 40 Items werden sechs Verhaltenspräferenzen (Konsum, Energiesparen, Mobilität und Transport, Recycling, Vikariierende Verhalten in Bezug auf Umweltschutz und Abfallvermeidung) auf Basis einer 5-stufigen Likert-Skala valide und reliabel abgefragt. Andere Studien untersuchten zur gleichen Zeit ähnliche Verhaltenspräferenzen (Konsum, Energiesparen und Verhalten im Straßenverkehr) (Diekmann & Preisendörfer, 1998), ohne weitere Erkenntnisse zu liefern, ob eine Person ein Verhalten aus Überzeugung zeigt (Umweltschutz durch Fahrrad statt Auto nehmen) oder um Geld zu sparen.

Vonseiten der drei beschriebenen Messinstrumente ist es bereits mehrfach gelungen, den Mehrwert von grünen Bildungsinitiativen (Interventionen) einzeln oder in Kombination zu messen. Geiger, Dombois, und Funke (2018) konnten beispielsweise

zeigen, dass sich Umweltverhalten sowohl durch positive Umwelteinstellungen als auch durch den Wissenszuwachs verbessern lässt. Andere Studien zeigen wiederum, dass es durch grüne Bildungsinitiativen zu keinen signifikanten Veränderungen von Umweltverhalten gekommen ist (Braun und Kollegen, 2018). Über die drei Bereiche von Bildung für eine Nachhaltige Entwicklung (Wissens-, Einstellungs- und Handlungsebene) ist in Anlehnung an das Kompetenzmodell nach Roczen und Kollegen (2014) noch wenig bekannt. Ein Pfadmodell könnte helfen, nachhaltigen Unterricht im Sinne von BNE genauer zu untersuchen.

C.3 Ziele und Fragestellungen der Arbeit

Mit der Verabschiedung der Agenda 2030 wurde auf dem Gipfel der Vereinten Nationen von allen 193 Mitgliedsstaaten beschlossen, dass die globalen wirtschaftlichen Herausforderungen vonseiten der Wirtschaft nur im Einklang mit der sozialen Gerechtigkeit und unter Berücksichtigung von ökologischen Grenzen gemeinsam zu schaffen sind (UN SDG, 2016). 17 gemeinsame Nachhaltigkeitsziele wurden dabei auf fünf Kernbotschaften verteilt (Mensch, Planet, Wohlstand, Frieden und Partnerschaft). Bildung für eine Nachhaltige Entwicklung (BNE) widmet sich der Aufgabe, das Bewusstsein der Bevölkerung zu stärken. Weg von der Idee, Einstellungen oder Verhaltensänderungen zu erzwingen (Grønhøj & Thøgersen, 2017), möchte man in diesem Sinne durch die drei Bereiche (Wissens-, Einstellungs- und Handlungsebene) eine gemeinsame und lebenswerte Zukunft schaffen. Hierbei stellen sich zwei grundlegende Fragen, welche das Fundament der vorliegenden Arbeit bilden: (i) Inwieweit wird der Wandel und die Bereitschaft in Richtung BNE vonseiten der Bevölkerung wahrgenommen und (ii) inwiefern sind Wirkungsmessungen von nachhaltigem Unterricht im Sinne von BNE am Beispiel GAIA empirisch in Theorie und Praxis erfassbar.

Teilstudien A + B beziehen sich exemplarisch auf 464 Studienanfänger, deren Vorstellungen im Kontext Umweltbildung, Umwelt und Natur erfasst wurden. Insgesamt sind daraus zwei Teilstudien entstanden. Die konkreten Fragestellungen der Teilstudie A lauten:

1. Unterscheiden oder ähneln sich die Wahrnehmungen von Studierenden bezüglich der drei Dimensionen Ökologie, Ökonomie und Soziales in puncto Umweltbildung versus BNE?
2. Zu welchen Themengebieten in der Umweltbildung hätten sich die Studierenden mehr Informationen gewünscht und gehen diese mit der Wahrnehmung des Umweltbildungsbegriffs auseinander?
3. Inwiefern haben unterschiedlich Informationsquellen zur Aufklärung in der

Umweltbildung beigetragen?

4. Wie unterscheiden sich die Selbst- und Fremdwahrnehmung bezüglich der Naturverbundenheit?

Für die Teilstudie B wurde die Skala der Naturverbundenheit aus Teilstudie A als erklärende Variable herangezogen, um Beziehungen zu den einzelnen Fragen herzustellen. Die konkreten Fragestellungen lauten:

1. Unterscheiden sich die ethischen Sichtweisen (ökologisch, biozentrisch und anthropozentrisch) in Bezug auf Umwelt?
2. Werden Emotionen/Gefühle in Bezug auf die Natur unterschiedlich von Studierenden empfunden?
3. Klaffen Vorstellungen bezüglich der größten Umweltgefährdung mit der persönlichen Wahrnehmung des eigenen ökologischen Fußabdrucks auseinander?

Teilstudien C + D beziehen sich auf eine Schulmaßnahme innerhalb eines dreijährigen EU-Projekts zum Energiesparen im Klassenzimmer, welche auf zwei individuellen Datensätzen basieren. Teilstudie C schließt auf die Wirkungsmessungen der Faktoren (Umweltwissen, Umwelteinstellungen und Umweltverhalten) und Zusammenhänge mit den verschiedenen Unterkategorien in einem Pfadmodell. 223 Schüler nahmen – größtenteils aus der sechsten Jahrgangsstufe – im Schuljahr 2017/2018 an dieser Studie teil. Die konkreten Fragestellungen dieser Teilstudie lauten:

1. Sind die neu entwickelten Wissensitems psychometrisch reliabel und valide?
2. Können die vorliegenden Daten die orthogonale Struktur der 2-MEV-Skala von Bogner (2018) bestätigen?
3. Welche Beziehungen bestehen zwischen Umweltwissen, Umwelteinstellungen, Umweltverhalten und deren Unterskalen in einem Pfadmodell?

In Teilstudie D lag der Hauptschwerpunkt in der Erfassung eines möglichen kognitiven Wissenserwerbs, sowie dessen Beziehungen zu Umwelteinstellungen und Umweltverhalten (Verhaltenspräferenzen) in einem quasi-experimentellen Design. Insgesamt wurde diese Studie mit 132 Schülern aus sieben Klassen der sechsten Jahrgangsstufe im Schuljahr 2018/2019 durchgeführt. Die konkreten Fragestellungen dieser Teilstudie lauten:

1. Nimmt Umweltwissen bezüglich der drei Dimensionen durch die Teilnahme am Unterrichtsmodul – Energiesparen im Klassenzimmer – gleichermaßen zu?
2. Haben Umweltpräferenzen bezüglich der Umwelteinstellung (Umweltschutz und Umweltausnutzung) einen Einfluss auf den kognitiven Wissenszuwachs und

Verhaltenspräferenzen?

3. Inwiefern hängen Umweltwissen und Umwelteinstellungen in einem quasi-experimentellen Design zusammen?
4. Wie verhält sich der zu erwartende kognitive Wissenszuwachs in Abhängigkeit von Umweltverhalten (Verhaltenspräferenzen)?

C.4 Material und Methoden

Teilnehmer und Studiendesign

Auf Grundlage der unterschiedlichen Ziele und Fragestellungen wurde für beide Schwerpunkte der vorliegenden Arbeit ein eigenes Design entwickelt und unterschiedliche Zielgruppen befragt.

Die Daten der beiden **Teilstudien A + B** wurden mit Studienanfängern unterschiedlicher Fakultäten an der Universität Basel durchgeführt. Die insgesamt 86 Teilnehmer von der Uni Bayreuth, welche an der Vorstudie teilgenommen haben, sind in dieser Stichprobe durch die Ähnlichkeit beider Nachbarländer integriert. Alle Teilnehmer haben einmalig einen Fragebogen (Papier-und-Bleistift-Test) schriftlich am Ende der Vorlesung ausgefüllt ($N = 464$; $M = 21{,}3$; $SD = \pm 3{,}1$; Frauen = 66.5 %). Der Kern dieser beiden Teilstudien lag darin, studentische Vorstellungen im Kontext Umweltbildung, Umwelt und Natur qualitativ und quantitativ auszuwerten (Abb., 1).

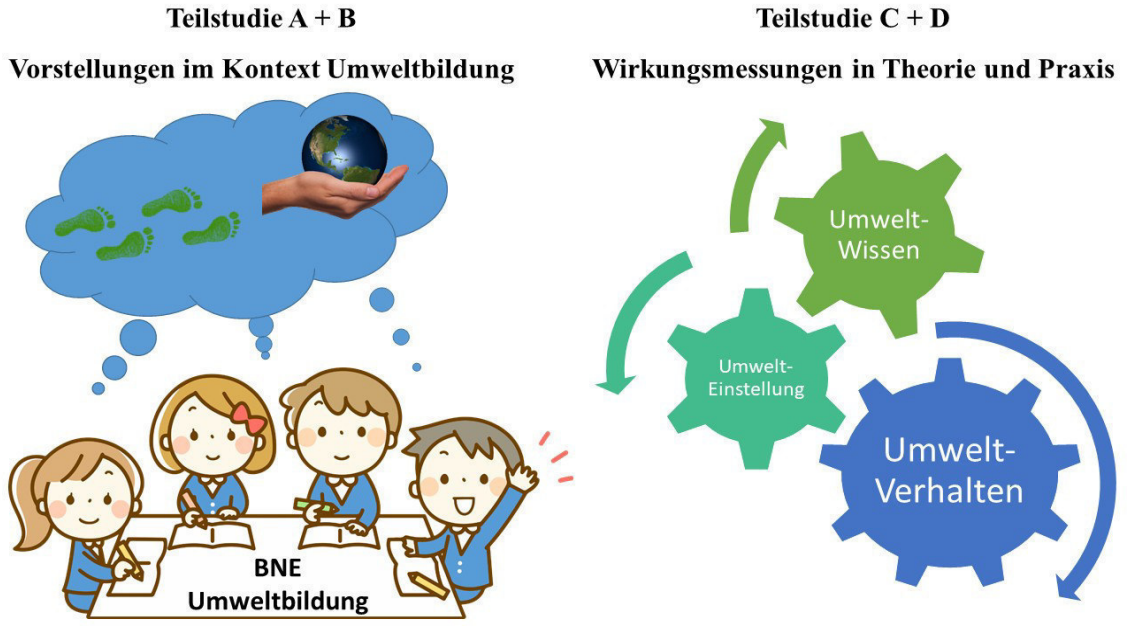


Abbildung 1: Verzahnung von Unterricht in nachhaltiger Entwicklung: Vorstellungen und Wirkungsmessungen in der Umweltbildung.

Die Datenerhebung der beiden **Teilstudien C + D** beziehen sich auf Schülern der sechsten Jahrgangsstufe, welche in Griechenland erhoben wurden. Ziel war es, die Schulmaßnahme – Energiesparen im Klassenzimmer – auf deren Wirksamkeit in Bezug auf Umweltwissen, Umwelteinstellungen und Umweltverhalten (Verhaltenspräferenzen) zu überprüfen (Abbildung 1). Der erste Teil (Teilstudie C) fungierte als Pilotstudie und bezieht sich auf die Theorie der drei Bereiche in einem theoretischen Pfadmodell. 223 Schüler wurden in dieser Studie berücksichtigt (N = 245), welche für die Vergleichbarkeit alle Teilbereichen des Fragebogens (Papier-und-Bleistift-Test) ausgefüllt haben (M = 11,7, SD ± 1,3; 49,8 % Mädchen). In einem quasi-experimentellen Design wurde dieser Fragebogen um ein Drittel gekürzt und für den zweiten Teil (Teilstudie D) in einem quasi-experimentellen Design auf Zusammenhänge überprüft. Items aus den Wissens- und Verhaltensfragen, welche sich in der ersten Studie für nicht brauchbar erwiesen haben, wurden nicht erhoben. Für diese Studie wurden 132 von 155 Schüler aus sieben Klassen der sechsten Jahrgangsstufe an der Schule *Ellinogermaniki Agogi* berücksichtigt, welche den Fragebogen zu beiden Testzeitpunkte ausgefüllt haben (M = 11,03; SD ± 0,23; 53.4 % Mädchen).

Erhebungsinstrumente und Datenauswertung

Alle statistischen Auswertungen wurden mit R (R Stiftung für Statistische Berechnungen für Windows; Version 2.14.2 und 3.6.0; www.r-project.org) ausgeführt. Bei der Erfassung studentischer Vorstellungen (N = 464) wurden alle offenen Fragen der Teilstudien A + B mittels einer qualitativen Inhaltsanalyse nach Mayring (2000) induktiv und deduktiv kategorisiert. Durch die manifeste Datenebene (tatsächlich gesagte) lassen sich latente Informationen (Beobachtungen) zuordnen (Merkmal, Konstrukte) (Arbuckle, 1997). Die Beobachtungen innerhalb jeder Hauptkategorie hatten einen Maximalwert von „eins“ pro Person, unabhängig davon wie viele Aussagen die jeweilige Person zu den Unterkategorien gemacht hat. Beobachtungen zu den jeweiligen Aussagen wurden nur dann gewertet, wenn deren Eigenname nicht enthalten war (z. B. Umwelt bei Umweltbildung). Synonyme wurden hingegen berücksichtigt (z. B. Natur bei Umweltbildung). Für beide Teilstudien wurde ein Teil der Stichprobe Re-kategorisiert. Das Kriterium der Reliabilität wurde mittels des Cohen´s Kappa Koeffizienten durch den Inter- versus Intra-rater ermittelt, welches die Objektivität (Untersuchungsunabhängigkeit) gewährleistet. Nach Literaturangaben lassen Werte über 0,75 auf eine sehr gute Übereinstimmung schließen, bei 0 führt der Wert auf eine zufällige und unter 0 ist die Übereinstimmung geringer als die

erwartete zufällige (Cohen, 1960). Für C_{cor} wurden alle Werte über 0,2 akzeptiert ($\alpha = 0{,}001$). Alle geschlossenen Fragen wurden aufgrund der Normalverteilung (Überprüfung durch ein Q-Q Diagramm und einen Shapiro-Test) mit einem zweistufigen T-Test ausgewertet.

Für die Teilstudie A wurden die offenen Fragen wie folgt erhoben: 1. Bildung für eine nachhaltige Entwicklung (BNE) – was verstehen Sie darunter? 2. Umweltbildung – was verstehen Sie darunter? 3. Zu welchem Themengebiet in der Umweltbildung wünschen Sie sich mehr Informationen? Anhand der Antworten der Studierenden haben sich fünf Hauptkategorien induktiv (Ökologie, Ökonomie, Soziales, Ökologische Problemstellungen und Bildung) und zwei deduktiv (Umwelteinstellungen und Umweltverhalten) ergeben. Für die ersten beiden Fragen wurden insgesamt 28 identische Unterkategorien gebildet, wobei Vorstellungen der Unterkategorie „nächste Generation“ nur bei der zweiten Frage zu beobachten war. Bei der dritten Frage haben sich 70 Unterkategorien deduktiv herauskristallisiert. Zur statistischen Auswertung wurden jeweils die Gesamtsummen aller Beobachtungen der jeweiligen Kategorien aus der ersten und zweiten Frage versus der ersten und dritten Frage mithilfe einer Kontingenzanalyse analysiert. Diese basieren auf einer Validierung des Ansatzes einer Kontingenztabelle. Für die Frage, „wie stark trugen in Ihrem Fall die folgenden Kategorien zur Umweltbildung bei“, wurden fünf Antwortmöglichkeiten (Werbung, Politik, Medien, Schule, Außerschulischer Lernort und Familie) als vierstufige Likert-Skala mit den Werten „schwach“, „mittelmäßig“, „stark“ und „sehr stark“ angeboten. Ein zweiseitiger Test ergab Aufschluss über die Intensität der jeweiligen Kategorie. Zu guter Letzt wurden die Studierenden seitens der Inclusion of Nature in Self (INS)-Skala (Schultz, 2002) zu ihrer Selbst- und Fremdeinschätzung der Naturverbundenheit befragt, welche aus zwei Fragen resultiert: Betrachten Sie folgende Kreise. 1. Wie eng sollte Ihrer Meinung nach der Mensch mit der Natur verbunden sein? Kreuzen Sie nur ein Kästchen an. 2. Wie eng sehen Sie sich mit der Natur verbunden? Kreuzen Sie nur ein Kästchen an.

Für die Teilstudie B wurden die offenen Fragen wie folgt erhoben: 1. Umwelt: Wofür steht für Sie der Begriff Umwelt? 2. Natur: Welche persönlichen Gefühle/Emotionen verbinden Sie damit? 3. Wodurch wird Ihrer Meinung nach die Umwelt am stärksten gefährdet? 4. Ökologischer Fußabdruck: Was können Sie dazu beitragen, um Ihren ökologischen Fußabdruck zu verringern? Für die Kategorisierung der ersten Frage wurden drei ethische Ansätze (anthropozentrisch, biozentrisch und ökozentrisch) induktiv miteinbezogen, welche aus 14 Unterkategorien aller Beobachtungen hervorgegangen sind. Bei der zweiten Frage wurden zehn Hauptkategorien von Emotionen und Gefühlen induktiv aus 43 Unterkategorien verwendet (Ästhetische Wertschätzung, Bewunderung, Freude, Ruhe,

Angst, Besorgnis, Ekel, Scham, Traurigkeit und Wut). Für die dritte und vierte Frage wurde eine Kontingenzanalyse durchgeführt. Dabei wurden die Wahrnehmung von der stärksten Umweltgefährdung und der Reduktion den eigenen ökologischen Fußabdruck zu reduzieren von Studierenden gegenübergestellt. Die Zusammenhänge der einzelnen Unterkategorien aus der ersten Frage und der Hauptkategorien aus Frage drei und vier wurden mittels einer hierarchischen Clusteranalyse [Paket *pvclust*, Methode nach Suzuki & Shimodaira (2006)] nach Ward überprüft, um visuelle Strukturentdeckungen im Datenbestand zu beleuchten. Im Sinne der Konstruktvalidität (Messick, 1995), wurden die Ergebnisse der Inclusion of Nature in Self (INS)-Skala (Schultz, 2002) – Selbsteinschätzung auf deren Zusammenhänge (Gruppenunterschiede) – als erklärende Variable herangezogen, um einzelne Fragen per binärer Regressionsanalyse zu analysieren.

In Teilstudie C wurden im ersten Schritt die verwendeten Messinstrumente (Umweltwissen, Umwelteinstellungen und Umweltverhalten) auf deren Qualität getestet. Der zweite Schritt diente der Überprüfung einer konfirmatorischen Faktorenanalyse [Paket *lavaan*, Methode nach Rosseel (2012); *semPlot,* Methode nach Epskamp, Eskamp, & MplusAutomation (2019)] um deren Effekte in einem Pfadmodel zu überprüfen. Mithilfe der Skala der drei Wissensdimensionen (Systemwissen, Handlungswissen und Effektivitätswissen) (Frick und Kollegen, 2004) wurde das Umweltwissen durch ein dichotome Rasch Modell [Paket *eRM*, Methode nach Mair, Hatzinger, & Maier (2009)] auf dessen Reliabilität, Validität, Personenfähigkeit und Itemschwierigkeit untersucht. Insgesamt wurden zehn Multiple-Choice-Fragen pro Wissensdimension zu je vier Antwortmöglichkeiten entwickelt, welche jeweils mit 1 (richtig) oder 0 (falsch) codiert wurden. Nach Bond & Fox (2007) liegen alle Items für Multiple-Choice Fragen in einen akzeptablen Wertebereich, dem sogenannten gewichteten Effektivwert (*engl. weighted fit mean square (wMNSQ)*, wenn dieser zwischen 0.80 und 1.20 liegt. Die Bestätigung der drei Faktorenstrukturen (homogene Itemgruppen von PRE, APR und UTL) der 2-MEV Skala (Bogner, 2018) erfolgte mittels einer explorativen Faktorenanalyse [Paket *psych*, Methode nach (Revelle 2012)]. Der Kaiser-Meyer-Olkin (KMO) Test galt dabei als Qualitätsmerkmal (> 0,6 schlecht, > 0,7 fragwürdig, > 0,8 gut > 0,9 exzellent) (Kaiser, 1974), ebenso die Reliabilität der Cronbach alpha Werte. Diese dienten ebenfalls der Überprüfung der sechs Verhaltenspräferenzen als Qualitätsmerkmal, welche auf Basis der Skala des Allgemeinen Ökologischen Verhaltens (Kaiser und Kollegen (2007) für Jugendliche diente. Die Ergebnisse der zu überprüfenden Faktoren des 2-MEV-Skala und GEB-Skala und deren zugrundeliegenden Theorien wurden zusammen mit den

Ergebnissen der Rasch Analyse als gültig ermittelt und mittels einer konfirmatorischen Faktorenanalyse auf deren Zusammenhänge untersucht. Diese wurden zuvor mithilfe von Mittelwerten jedes einzelnen Schülers ermittelt und in einem Pfadmodel grafisch dargestellt. Mittels des Vergleichsindex (*engl. Comparative Fit Index* – CFI), dem Effektivwert (standardisiert) (*engl. Standardized Root Mean Square Residual* – SRMR) und der Approximationsdiskrepanzwurzel (*engl. Root Mean Square Error of Approximation* – RMSEA) wurde das Modell mittels eines Strukturgleichungsmodells überprüft. Laut Literatur gelten Werte wie folgt als valide: RMSEA < 0,08; SRMR < 0,08 und CFI ≥ 0,90 (Browne & Cudeck, 1993; Hooper, Coughlan, & Mullen, 2008).

In Teilstudie D wurden aussagekräftige Rasch-Personenschätzer (Einheit: Logits, natürlicher Logarithmus des Verhältnisses von richtigen zu falschen Antworten) als Input-Werte für Umweltwissen und Umweltverhalten für jeden einzelnen Schüler ebenfalls durch eine Rasch Analyse ermittelt [Paket *eRM*, Methode nach (Mair und Kollegen (2009)]. Mithilfe dieser Werte wurden Regressionsanalysen des Umweltwissens zwischen dem Vor-Test (T0) und Nach-Test (T1) durchgeführt, um den Wissenszuwachs zwischen beiden Testzeitpunkten zu analysieren. Bei der moderierten Regressionsanalyse fungierte die Variable „Umweltverhalten“ als Moderator mit der Frage, inwiefern dieser einen möglichen Wissenszuwachs zwischen beiden Testzeitpunkten beeinflussen konnte. Die ANCOVA (Typ III) Analysen [Paket *effects*, Methode nach (Fox und Kollegen (2016)], welche auf Mittelwerten basieren, gaben Aufschluss über die Beziehungen zwischen den drei Dimensionen von Umweltwissen zwischen T0 und T1 an, sowie deren mögliche Beziehungen zur Umwelteinstellung. Der Levene-Test diente als Gütekriterium [Paket *car*, Methode nach (Fox und Kollegen (2012)].

Unterrichtsmodul – Energiesparen im Klassenzimmer

Im Rahmen des Unterrichtsmoduls GAIA - wurde an einer griechischen Schule eine zehnwöchige Interventionsstudie mit insgesamt 19 Unterrichtsstunden zum Thema Energiekonsum im Klassenzimmer entwickelt und durchgeführt. Durch den technischen Einsatz des *Internet of Things (IoT)* wurde eine Internetplattform errichtet, welche die Daten von dem Schulgebäude empfangen und aufgezeichnet hat (u.a. Temperatur, relative Luftfeuchtigkeit, Beleuchtung, Bewegungserkennung, Geräuschpegel und Stromverbrauch). Alle sieben Klassenräume waren mit der entsprechenden Technik ausgerüstet (Sensoren und Messgeräte), wodurch die Schüler Daten auf der Gebäude-App (GAIA Building Manager app) beobachten konnten. Mit Unterstützung von modernen Unterrichtsmodulen durch

computergestütztes Lernen, konnten die Schüler beispielsweise deren Energieverbrauch überwachen und diskutieren. Zwischen den Parallelklassen gab es einen Wettbewerb untereinander, welches Klassenzimmer am meisten Energie einsparen konnte (Abb., 2).

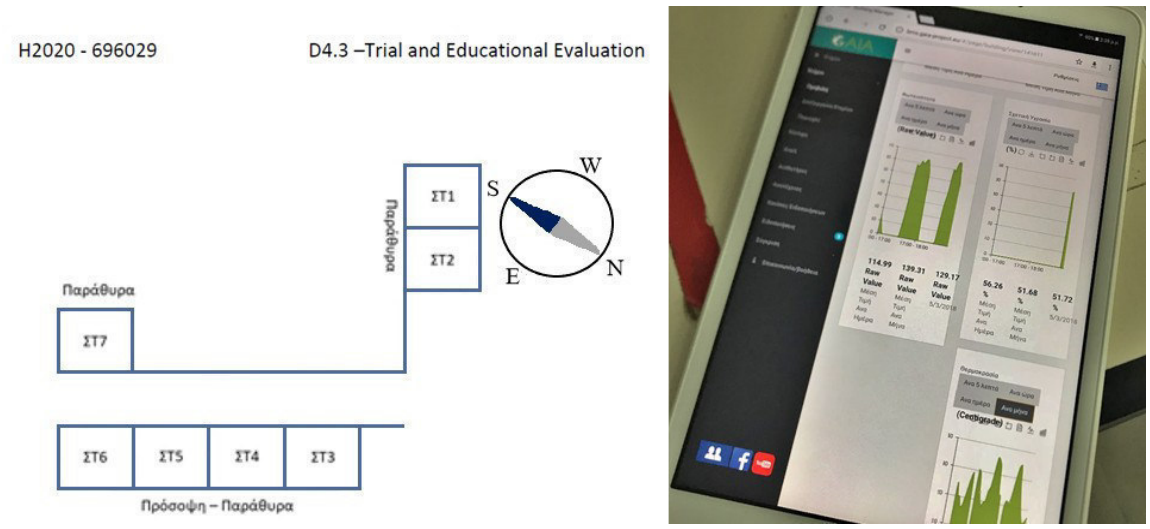


Abbildung 2 Gebäudeumriss der Klassenräume und GAIA Gebäude-App (P. Koulouris)

Gruppenweise wurden die Schüler eingeteilt, Intervalle per *GAIA Gebäude-App* zu beobachten (Beispiel: wenn das Licht eingeschaltet war, die Schüler es selbständig ausschalten, wenn es nicht mehr gebraucht wurde). Bei der Berechnung des Stromverbrauches wurden verschiedene Variablen miteinbezogen, wie beispielsweise die Lichtintensität der Sonne oder die Feuchtigkeit im Klassenzimmer. Alle gesammelten Variablen wurden miteinander verglichen, um herauszufinden, warum Klassenräume im Nordosten beispielsweise mehr Licht benötigten als Klassenräume im Westen. Die Behauptung, dass Klassen aus dem Süden beispielsweise betrogen haben, Strom zu sparen, wurden damit widerlegt. Die projektinternen Onlineplattform *('GAIA challenge', 2020)* gaben den Schülern eine Möglichkeit, sich durch problemorientiertes Lernen das nötige Wissen selbständig anzueignen und herzuleiten. Gleichermaßen wurde der Stromverbrauch des kompletten Schulgebäudes wöchentlich überwacht und Anomalien bei steigendem Stromverbrauch an Elternabenden oder Wochenenden durch außerschulische Konferenzen diskutiert. Die Ergebnisse und Aktionen der Schüler im Rahmen der Intervention wurden während des Schuljahres noch im Schulgebäude ausgestellt. Alle Klassenräume waren mit gleich vielen Lampen ausgestattet, wodurch man gegen Ende der Intervention etwa die Hälfte der Energiekosten einsparen konnte ("GAIA Green awareness in action," 2020). Die Einsparungen für jedes Klassenzimmer wurden wiederum individuell ermittelt.

Die Interventionsstudie wurde von Lehrkräften vor Ort durchgeführt. Für die

Vergleichbarkeit konzentrierte sich die Aktivitäten auf eine griechische Schule im Großraum Athen. Ein Jahr zuvor haben drei weitere Schulklassen aus zwei anderen Schulen auch teilgenommen, welche ursprünglich als Kontrollklassen angedacht waren. Da keine Unterschiede zwischen den verschiedenen Klassen in Bezug auf Umweltwissen, Umwelteinstellung und Umweltverhalten gefunden werden konnte, galt die komplette Stichprobe als theoretische Grundlage für die Interventionsstudie und die Validierung der neu entwickelten Umwelt-Wissensfragen.

C.5 Ergebnisse und Diskussion

Die vorliegende Arbeit untersucht im ersten Teil exemplarisch die aktuelle Wahrnehmung aus einer westeuropäischen Bevölkerungsschicht bei 464 Studierenden. Thematisch bildet diese einen Konsens beider Teilstudien, wodurch sich Querbindungen erschließen lassen. Der zweite Teil der Arbeit ist fokussiert auf eine grüne Bildungsinitiative – Energie sparen im Klassenzimmer, welche sich in Theorie und Praxis aufteilt und ebenfalls eine Einheit bildet.

Teilstudie A Vorstellungen von Studierenden im Kontext Umweltbildung

Der Cohen´s Kappa Koeffizient ergab als Qualitätsmerkmal einen Intra- und Interrater Reliabilitätswert von jeweils 0,95 (Selbst-Kategorisierung) und 0,86 (Fremd-Kategorisierung). Beide Werte lassen auf eine gute Übereinstimmung der Beobachtungen rückschließen (Cohen, 1968). Insgesamt wurden 18 % aller Beobachtungen Re-kategorisiert. Die Wahrnehmungen der beiden Begriffe Umweltbildung (UB) ($N_{Beobachtungen}$ = 595) und Bildung für eine Nachhaltige Entwicklung (BNE) ($N_{Beobachtungen}$ = 648) sind nach einer Kontingenzanalyse zufolge über alle sieben Kategorien hinweg unabhängig (C_{corr} = 0,37; $N_{Beobachtungen}$ = 1.243; $p < 0{,}001$). Gleiches gilt zwischen den Beobachtungen der Wünsche nach mehr Informationen ($N_{Beobachtungen}$ = 254) in der Umweltbildung ($N_{Beobachtungen}$ = 595) und der Wahrnehmung des Umweltbildungsbegriffes (C_{corr} = 0,536; N = 849; $p < 0{,}001$). Die Anzahl der Ergebnisse variieren je nach Fragestellung in den einzelnen Hauptkategorien. So wurden beispielsweise 165 Beobachtungen bezüglich der Ressourcen bei BNE gemacht, hingegen nur 65 Beobachtungen bei der Wahrnehmung von Umweltbildung. Bei der Frage, welche Informationsquelle am meisten zur Aufklärung von Umweltbildung beigetragen hat, wurde das Elternhaus an erster Stelle genannt. Medien, Schule und außerschulische Lernorte wurden zu gleichen Anteilen an zweiter Stelle erwähnt, gefolgt von Werbung und Politik an letzter Position. Die Fremdwahrnehmung der Naturverbundenheit zwischen Mensch und Natur

wurde deutlich höher eingestuft (M = 5,024; SD = 1,174) als die der Selbstwahrnehmung (M = 3,954, SD = 1,145).

Die Wahrnehmungen bezüglich der drei Dimensionen Ökologie, Ökonomie und Soziales folgten keinem einheitlichen Muster. Nicht nur die Anzahl der Beobachtungen unterscheiden sich in den jeweiligen Hauptkategorien, sondern auch bezüglich einer neuen Unterkategorie: „nächster Generationen Aspekt“, welcher nur in der Hauptkategorie Soziales in BNE beobachtet wurde. Dies ist insofern erfreulich, weil mit dem Ziel der Agenda 2030, die Soziale Dimension gestärkt werden soll. Bisher galt diese als die schwächste der drei Dimensionen (Lehtonen, 2004). Begriffsnennungen wie beispielsweise Menschenrechte, Frieden oder Geschlechtergerechtigkeit wurden weder bei der Umweltbildung noch bei BNE beobachtet. Das Wort Ressource wurde besonders häufig bei der Wahrnehmung von BNE genannt, welche Manni und Kollegen (2013) bei ihrer Studie auch gefunden haben. Bei der Aussage „sparsamer Umgang mit Ressourcen“ beispielsweise kann man nicht daraus schließen, ob eine Einstellungs- oder eine Verhaltenspräferenz dahintersteckt. Diesbezüglich wurde diese Teilstudie um weitere Hauptkategorien, nämlich die derzeitigen ökologischen Problemstellungen, Bildung, Umwelteinstellungen und Umweltverhalten erweitert. Bei der Frage, zu welchen Themengebieten in der Umweltbildung sich Studierende noch mehr Informationen wünschen, haben weniger als die Hälfte eine Äußerung gemacht: Die häufigsten Aussagen gingen von der Frage aus „wie man die Umwelt schützen kann“, „wie man Abfälle vermeidet“ oder „wie man das Lernen fördert“. Dergleichen wünschten sich Studierende mehr Informationen zum Klimawandel. Diese Äußerungen knüpften an die Frage an, welche unterschiedlichen Informationsquellen zur Aufklärung in der Umweltbildung der Studierenden beigetragen haben. Schule und außerschulische Lernorte sind neben Medien gleichermaßen an zweiter Stelle benannt. Die Erkenntnisse aus der Umweltbildungsforschung haben bereits vor zwanzig Jahren ergeben, dass das Elternhaus für die Erziehung in der Umweltbildung wichtig ist (z. B. Eagles & Demare, 1999). Naturverbundenheit wird aus der Sichtweise von Studierenden eher als anthropozentrisch betrachtet, wohingegen sie gleichzeitig von einer ökozentrischen Weltsicht als Ideal überzeugt sind.

Teilstudie B Vorstellungen von Studierenden im Kontext Umwelt und Natur

Der Cohen´s Kappa Koeffizient ergab als Qualitätsmerkmal einen Intra- und Interrater Reliabilitätswert von jeweils 0,76 (Selbst-Kategorisierung) und 0,60 (Fremd-

Kategorisierung). Beide Werte lassen auf eine gute Übereinstimmung der Beobachtungen rückschließen (Cohen, 1960). Insgesamt wurden 15 % aller Beobachtungen Re-kategorisiert. Die erste Frage bezog sich auf die Wahrnehmung des Umweltbegriffs. Induktiv konnten alle Beobachtungen drei ethischen Sichtweisen (biozentrisch, ökozentrisch und anthropozentrisch) zugeordnet werden. Insgesamt wurden 14 Kategorien mittels einer hierarchischen Clusteranalyse untersucht, um Muster im Datensatz zu erkennen. Ein Fünftel aller Studierenden haben Aussagen ausschließlich zu einer ethischen Sichtweise getroffen, wohingegen alle anderen Studierenden verschiedene Vorstellungen angegeben haben ($N_{Beobachtungen}$ = 498 ohne Natur, $N_{Beobachtungen}$ = 549 mit Natur). 40 Prozent aller Aussagen gehen auf die Wahrnehmung Natur zurück, welche mit der Umwelt gleichgesetzt wurde. Emotionen und Gefühle werden im Zusammenhang mit der Natur ausschließlich als positiv empfunden. Binäre Regressionsanalysen ergaben in dieser Stichprobe keine Unterschiede bei den drei am häufigsten genannten Kategorien (Ruhe, Freude und Ästhetische Wertschätzung) in Bezug auf den Wert der Naturverbundenheit. Bei der Frage nach der größten Umweltgefährdung und der Wahrnehmung, den eigenen Fußabdruck zu verringern, wurden 1430 studentische Beobachtungen ($N_{Umweltgefährdung}$ = 633, $N_{ökol.Fußabdruck}$ = 797) gemacht. Einer Kontingenzanalyse zur Folge sind die Beobachtungen über alle fünf Hauptkategorien unabhängig entstanden (C_{corr} = 0,54; N = 1.430; p < 0,001). Die Anzahl der Beobachtungen variiert in den jeweiligen Hauptkategorien jedoch unterschiedlich stark. Der Wert der Naturverbundenheit wirkte sich hier über alle Kategorien hinweg unterschiedlich aus.

Nach der Definition von Umwelt umfasst dieser Begriff aus heutiger Sicht alle lebenden Organismen sowie deren Beziehungen untereinander als auch mit ihrer Umgebung (Ingold, 2014). Die meisten Studierenden assoziierten eine Vielzahl von wissenschaftlichen Konzepten, welche in Folge einer hierarchischen Clusteranalyse kein erkennbares Muster ergaben. Ein Viertel aller Studierenden haben den Mensch ($N_{Beobachtungen}$ = 84) mit dem Begriff Umwelt verbunden, worin die meisten sich als einen Teil der Umwelt sehen (Kategorie: uns umgibt/wir leben, $N_{Beobachtungen}$ = 128), während andere sich als Mittelpunkt sehen (Kategorie: ich lebe/mich umgibt, $N_{Beobachtungen}$ = 84). Unter dem gleichen Gesichtspunkt haben Schülern einer anderen Studie mehrheitlich den Begriff mit einzelnen Arten verbunden, ohne menschliche Wahrnehmungen einzubeziehen (Pointon, 2014). Einer weiteren Studie zufolge setzen viele Erwachsene den Umweltbegriff mit der Natur gleich (Flogaitis & Agelidou, 2003; Munoz und Kollegen, 2009). Diese konnte unsere Teilstudie ebenfalls bestätigen. Aus der Naturbewusstseinsforschung hat die Natur zwei wichtige Bedeutungen: Einerseits gilt die Natur als Symbol für gutes Leben und andererseits verbindet man die Natur als ein Ort der

Entspannung und Erholung (Gebhard, 2013). Bei der Frage, welche Gefühle und Emotionen ($N_{Beobachtungen}$ = 651) mit dem Naturbegriff verbunden werden, haben sich zehn Kategorien induktiv aus der Summe aller Antworten ergeben. Überwiegend wurden Beobachtungen aus den Hauptkategorien Ruhe ($N_{Beobachtungen}$ = 277), Freude ($N_{Beobachtungen}$ = 149) und ästhetische Wertschätzung ($N_{Beobachtungen}$ = 120) gemacht, welche sich mit der vorgenannten Aussage decken. Mehr als 100 Beobachtungen stehen für zwei Unterkategorien innerhalb der Hauptkategorie Ruhe, nämlich Freiheit ($N_{Beobachtungen}$ = 117) und Stille ($N_{Beobachtungen}$ = 104). Diese Ergebnisse lassen sich auch mit der Studie von Schuster (2008) vergleichen. Dort haben über Tausend Jugendlichen mehrheitlich den Naturbegriff mit Ruhe, Erholung, Wald, Schönheit, Tiere und Pflanzen verbunden. Die Vorstellungen der größten Umweltgefährdung ($N_{Beobachtungen}$ = 650) und gleichzeitig die Vorstellungen Studierender, ihren eigenen ökologischen Fußabdruck zu verringern ($N_{Beobachtungen}$ = 981), klaffen weit auseinander. Einer binären Regressionsanalyse zu Folge gibt es keine Unterschiede zwischen dem Level der Naturverbundenheit und der Ansicht, dass der Mensch ($N_{Beobachtungen}$ = 191) die größte Umweltbedrohung darstellt. Zu Mobilität & Transport ($N_{Beobachtungen}$ = 233), sowie Ressourcen & Konsum ($N_{Beobachtungen}$ = 318) wurden mehr Beobachtungen gemacht, je höher der Wert der Naturverbundenheit vonseiten der Studierenden angegeben wurde. Gleiches gilt auch bei der Müllvermeidung ($N_{Beobachtungen}$ = 126). Den Beobachtungen zufolge sehen Studierende eine Möglichkeit ihre eigene Mobilität einzuschränken, indem sie mehr öffentliche Verkehrsmittel nutzen oder mit dem Fahrrad fahren. Nicht verwunderlich andererseits, wenn die Universität im Zentrum der Stadt liegt und es keine Parkplatzmöglichkeiten gibt. In Sache Konsum könnte ihren Aussagen zufolge ein Umdenken bei einigen Studierenden hinsichtlich dem Fleischverzicht und ein Umsteigen auf regionale und saisonale Produkte stattfinden ($N_{Beobachtungen}$ = 150).

Teilstudie C Unterrichtsmodul in der Theorie – Pfadmodell

Diese Teilstudie beschäftigt sich mit den Zusammenhängen von Umweltwissen (Systemwissen, Handlungswissen und Effektivitätswissen), Umwelteinstellungen (Naturschutzpräferenz, Wertschätzung und Natur(aus)nutzungspräferenz) und den sechs Verhaltenspräferenzen (Konsum, Energiesparen, Mobilität und Transport, Recycling, Vikariierende Verhalten in Bezug auf Umweltschutz und Abfallvermeidung) in einem Pfadmodell. Um die Qualität der neu entwickelten Wissensitems zu überprüfen wurde das Rasch-Modell eingesetzt. Die 30 getesteten Items (je zehn pro Wissensdimension) lagen in

diesem Fall in einem angemessenen Bereich (0,84 ≤ wMNSQ ≤ 1,10). Des Weiteren weisen die Items eine akzeptable Personenreliabilität auf (Werte zwischen -3 und +2). Die orthogonale Struktur der 2-MEV-Skala von Bogner (2018) konnte mittels einer explorativen Faktorenanalyse bestätigt werden. Der Kaiser-Meyer-Olkin (KMO) Test ergab einen Wert von 0,8 und war damit akzeptabel. Die Reliabilität lag für den Faktor Naturschutzpräferenz (n_{Items} = 7) bei einem Cronbach´s Alpha Werte von 0,78; Wertschätzung (n_{Items} = 6) bei 0,57 und für den Faktor Natur(aus)nutzungspräferenz (n_{Items} = 7) bei 0,59. Diese Werte waren statistisch ausreichend. Für die sechs Verhaltenspräferenzen der GEB-Skala (Kaiser und Kollegen, 2007) lagen die Cronbach´s Alpha Werte teilweise in einem ausreichenden Bereich (Konsum 0,53 (N_{Items} = 8); Energiesparen 0,33 (N_{Items} = 6); Mobilität und Transport 0,36 (N_{Items} = 3); Recycling 0,57 (N_{Items} = 6); Vikariierende Verhalten in Bezug auf Umweltschutz 0,70 (N_{Items} = 9) und Abfallvermeidung 0,47 (N_{Items} = 8). Die konfirmatorische Faktorenanalyse zeigte unterschiedliche Zusammenhänge zwischen Umweltwissen, Umwelteinstellung und Umweltverhalten, sowie die Zusammenhänge zu den jeweiligen Unterkategorien.

Umweltwissen weist eine höhere Linearität zu Umwelteinstellung (ξ = 0,69, p > .001), als zu Umweltverhalten auf (ξ = 0,37, p = .001). Bei Umwelteinstellungen und Umweltverhalten besteht der größten linearen Zusammenhang (ξ = 0,80, p > .001) in dieser Teilstudie. Ursächlich betrachtet ist der Einfluss der drei Wissensdimensionen zu Umweltwissen ähnlich, ebenso die Unterskalen zu Umwelteinstellungen. Die Natur(aus)nutzungspräferenz steht wie auch in der explorativen Faktorenanalyse negativ in Beziehung zur Umwelteinstellung. Die Verhaltenspräferenzen von Umweltverhalten stehen dabei in einem unterschiedlichen Zusammenhang. Höhere Werte von Recycling suggerieren eine höhere Zustimmung, während Mobilität & Transport eine niedrigere Zustimmung erhielten. Dies könnte daran liegen, dass die Schüler die Abfalltrennung von Kindesbeinen an kennen, während sie bei der Mobilität & Transport noch abhängig von den Eltern sind. Die Schüler stammen aus dem Großraum Athen und werden in der Regel von deren Eltern zur Schule gebracht, welche außerhalb der Stadt liegt. Während das Pfadmodell im Kontext Energiesparen im Klassenzimmer für die theoretischen Zusammenhänge stand, widmet sich Teilstudie D den Zusammenhängen zwischen Umweltwissen, Umwelteinstellung und Umweltverhalten in der Praxis. Bis heute gibt es wenige Publikationen, welche alle drei Bereiche gleichzeitig abdecken. In einer Studie von Geiger, Dombois & Funke (2018) lag der Fokus beispielsweise bei einem Kulturvergleich zwischen Argentinien und Deutschland. Anstelle der 2-MEV-Skala wurde die alte NEP-Saka von Dunlap & Van Liere (1978) verwendet, wodurch keine Vergleichbarkeit möglich ist.

Teilstudie D Unterrichtsmodul in der Praxis – Evaluation

Die Items von Umweltwissen (N_{Items} = 15) sind wie bei Teilstudie C mittels einem probabilistischen Rasch-Modell auf deren Qualität überprüft worden (T0: 0,83 ≤ wMNSQ ≤ 1,09, T1: 0,79 ≤ wMNSQ ≤ 1.17). In einem weiteren Schritt wurde für alle Wissensitems zusammen eine logit-Transformation durchgeführt und für jeden Schüler ein individueller Rasch-Personenschätzer-Wert (logits) ermittelt. Das Gleiche gilt auch für alle Items vom Umweltverhalten (N_{Items} = 21). Einer Regressionsanalyse von Umweltwissen zufolge, zeigte sich ein Wissenszuwachs über alle drei Dimensionen hinweg zwischen dem Vor-Test (T0) und dem Nach-Test (T1) (F = 12,66, df = 130, r^2 = 0,09, p = 0,001). Leistungsstarke Schüler (hohe logit-Werte) haben im Durchschnitt mehr Items beantworten können, als leistungsschwache Schüler (niedrige Logit-Werte). Sowohl Jungen als auch Mädchen haben durch die Interventionsstudie dazu gelernt, wobei die Mädchen im Vor-Test besser abgeschnitten haben. Der Levene-Test bestätigte, dass es keine Homogenität zwischen den drei Wissensdimensionen und den drei Einstellungspräferenzen gab. Infolgedessen kam es bei Systemwissen zu einem Verlust und gleichzeitig zu einem Zuwachs von Handlungswissen und Effektivitätswissen. Umwelteinstellungspräferenzen hatte keinen Einfluss gegenüber dem Wissenserwerb. Es lernten sowohl Schüler mit hoher als auch mit niedriger Natur(aus)nutzungspräferenz dazu. Schüler mit einem niedrigen Personen-Schätzer-Wert in Bezug auf Umweltverhalten zeigten eine niedrigere Naturschutzpräferenz im Vor-Test und zogen im Nach-Test mit den Schülern mit einer hohen Umweltschutzpräferenz gleich. Bei Schülern mit hoher Natur(aus)nutzungspräferenz zeigten vor der Intervention höhere anthropozentrische Verhaltenspräferenzen und zogen mit Schüler niedriger Natur(aus)nutzungspräferenz gleich. Vergleicht man den Wissenszuwachs unter Einbezug auf Umweltverhalten, so haben Schüler mit einem niedrigen Personen-Schätzer-Wert mehr dazu gelernt, als Schüler mit hohen Werten.

Bezogen auf die drei Dimensionen von Umweltwissen kann das angestrebte Energiesparen im Klassenzimmer ebenfalls zu einem gesteigerten Umweltwissen beisteuern. Jedoch unterscheidet sich diese Teilstudie von anderen Studien (z. B. Fremerey & Bogner, 2014; Liefländer und Kollegen, 2015; Thorn & Bogner, 2018) in einem Punkt: während Handlungswissen und Effektivitätswissen im Einzelnen gesteigert werden konnten, kam es beim Systemwissen zu einer Abnahme. Handlungswissen erfordert konkrete Handlungsentscheidungen, welche durch die Intervention gezielt in den Schulalltag eingebettet waren. Darüber hinaus bedarf es einer konsequenten Umsetzung im Alltag. In diesem Fall konnte man mithilfe von technischen Geräten zeigen, dass die

Energiekosten um mehr als die Hälfte gesenkt werden konnten. Diese Teilstudie widerspricht daher der Aussage, dass alle drei Wissensarten notwendig sind, um Schüler zu ökologisch-nachhaltigem Handeln zu befähigen (Liefländer und Kollegen, 2015). Umwelteinstellungen haben im Gegensatz zu zahlreichen anderen Studien keinen Einfluss auf das Umweltwissen gehabt. Es profitierten sowohl diejenigen, welche hohe oder niedrige Natuschutzpräferenzen angegeben haben, als auch Schüler mit niedrigen und hohen Natur(aus)nutzungspräferenzen. In Bezug auf den Personen-Schätzer-Wert von Umweltverhalten profitieren die Schüler in puncto Wissenszuwachs, welche eher niedrige Umweltpräferenzen angegeben haben. Der Zuwachs war allerdings nicht sehr hoch und grundsätzlich ist es eher schwierig, Gewohnheiten zu ändern, wie Studien mit Erwachsenen gezeigt haben (Henn, Taube, & Kaiser, 2019; Rieger und Kollegen, 2016). Grüne Initiativen zielen nicht darauf ab, Umweltbewusstsein und Verhaltenspräferenzen zu erzwingen (Grønhøj & Thøgersen, 2017). Ihr Schwerpunkt liegt auf der Gestaltung der Fähigkeiten der Schüler durch Faktoren wie beispielsweise Wissen, Motivation, Einstellungen, Werte und Handeln. Diese wiederum vermitteln die Basis, welche sie zu umweltbewusste Bürger befähigen (Marcinkowski & Reid, 2019). Dabei soll ihnen ein eigener Raum für freie Handlungsentscheidungen gewährleistet werden (Bandura, 1982).

C.6 Schlussfolgerung und Ausblick

Vorstellungen von Studierenden haben gezeigt, dass Erfahrungen in Sachen Nachhaltigkeit im Laufe ihres Lebens bereits stattgefunden haben. Die beiden Begriffe Umweltbildung und Bildung für eine Nachhaltige Entwicklung (BNE) werden nicht gleichsam wahrgenommen, wie beispielsweise „der nächsten Generationen Aspekt“ oder bei der Häufigkeit von der Begriffsnennung „Ressource“ bei BNE. Das Problembewusstsein und die Aufnahmebereitschaft für die Wahrnehmung von Umweltzerstörungen bildet sich bei Kindern schon sehr früh aus und kann sich im Jugendalter noch stärker ausprägen (Gebhard, 2013). Die Sensibilisierung, dass der Mensch die größte Bedrohung für die Umwelt darstellt und ein Umdenken stattfinden muss, zeigte sich durch ein breites Spektrum verschiedenster Möglichkeiten an Begriffsnennungen, seinen eigenen Fußabdruck zu verringern. Die Bereitschaft, sich noch mehr Informationen in puncto Umweltbildung anzueignen, war jedoch nicht sehr groß. Die Werte spiegeln ein breites Spektrum von Motivationen wider und unterscheiden sich als solche von ökologischen Weltanschauungen und Umweltbelangen (Steg & De Groot, 2012). Studierende haben verschiedenste Konzepte mit der Umwelt

verbunden und sehen sich selbst als ein Teil davon. Sie gehen aber eher von einer ökozentrischen Weltansicht als Ideal aus und sehen sich dabei selbst als anthropozentrisch. Im Sinne der Alltagsphantasien hängen Gefühle und Vorstellungen zusammenhängen (Gebhard, 2009), welche aus Erfahrungen und schönen Kindheitserinnerungen resultieren können. Ruhe, Frieden und ästhetische Wertschätzung waren dabei die am häufigsten genannten Aussagen bezüglich der Gefühle/Emotionen gegenüber der Natur. Studierende gaben an, dass die meiste Aufklärung bezüglich des Umweltbildungskontextes durch das Elternhaus stattgefunden hat, gefolgt von der Bildungsinstitution Schule. Kritiker sehen den Wandlungsprozess in eine Nachhaltige Entwicklung eher als einen Schritt in Richtung Anthropozentrismus (Kopnina, 2012, 2020). Eine soziale Erwünschtheit kann auch bei dieser Arbeit nicht ausgeschlossen werden, was sich aus den Antworten der Studierenden ableiten lässt.

Das Unterrichtsmodul – Energiesparen im Klassenzimmer – konnte zeigen, wie eng nachhaltiger Unterricht in Theorie und Praxis miteinander verzahnt sein können. Das Pfadmodell illustrierte dabei den Zusammenhang der drei latenten Dimensionen (Umweltwissen, Umwelteinstellungen und Umweltverhalten), unter Einbezug der jeweiligen Unterkategorien. Durch die konsequente Umsetzung im Klassenzimmer wurde das Drei-Säulen-Modell der nachhaltigen Entwicklung erfolgreich umgesetzt. Dabei galt der *ökonomische Aspekt* dem Hauptthema, durch den internen Wettbewerb zwischen den einzelnen Klassen den gesamten Energieverbrauch zu minimieren. Nicht nur unter Einbindung aller Schüler und Lehrer der sechsten Jahrgangsstufe zielte der *soziale Aspekt* auf eine größere Erreichbarkeit weiterer sozialer Kontakte ab (z. B. Familien, Freunde und Kontakte in sozialen Netzwerke). Schlussendlich diente das Ganze auch dem *ökologischen Aspekt*, durch die eingesparten CO_2 Emissionen gemeinsam einen Teil zum Umweltschutz beizutragen. Durch den Einsatz von technischen Messgeräten konnte bestätigt werden, dass es durch die Handlungsbereitschaft der Schüler möglich wurde, den Energieverbrauch bereits während der Intervention zu reduzieren. Dies spiegelte sich in den Daten des Wissenszuwachses, insbesondere beim Handlungswissen, wider. Eine ökologische Einstellung ist dabei unerlässlich, langfristig Handlungsentscheidungen ohne sozialen Druck (Wettbewerb) auszuführen.

Grundsätzlich können beim „Wissenserwerb“ sowohl soziale als auch kulturelle Faktoren einem Einfluss auf die Ergebnisse mit ausüben (Geiger Dombois & Funke, 2018; Kollmuss & Agyeman, 2002), ebenso das Alter, das Geschlecht und der Bildungsstand (Liefländer & Bogner, 2014). Diese Unterschiede gelten auch in Bezug auf

Umwelteinstellungen und Umweltverhalten, welche schlussendlich das Umweltbewusstsein formen. Persönliche Erfahrungen und wissenschaftliche Erkenntnisse (Andresen und Kollegen, 1999) vonseiten der Schule tragen zur Formung von Vorstellungen bei (Driver, 1989; Piaget, 1964). Die Auswertungen des Unterrichtsmoduls der sechsten Jahrgangsstufe stehen exemplarisch für ein osteuropäisches Land. Es besteht auch hier noch weiterer Forschungsbedarf, das Pfadmodell von nachhaltigem Unterricht in Theorie und Praxis einzusetzen, um eine allgemeine Gültigkeit aussprechen zu können. EU-Projekte beispielsweise würden sich hier gut anbieten, weil durch sie eine höhere Erreichbarkeit von Schulen gewährleistet werden kann. Bei einer größeren Stichprobe wären auch Vergleiche zwischen Kulturen und sozialen Schichten eher möglich. Es bedarf jedoch einer größeren Bereitschaft vonseiten der Schulen, Evaluationen zuzulassen. Prinzipiell ist eine Veröffentlichung solcher Projekte anzustreben, damit die Öffnung von Schulen nicht nur ein theoretisches Konstrukt bleibt. Dadurch kann gewährleistet werden, dass auch andere Bildungsintuitionen erreicht werden können und davon profitieren. Die Ergebnisse der Vorstellungen von Studierende stehen ebenfalls exemplarisch für eine Bevölkerungsschicht mit hohem Bildungsniveau eines westeuropäischen Landes. Auch hier besteht noch weiterhin Forschungsbedarf, kulturelle und soziale Faktoren zu untersuchen, inwiefern der Nachhaltigkeitsbegriff eine Allgemeingültigkeit hat oder sich hinsichtlich anderer Variablen, unterscheidet.

D Literaturverzeichnis Synopsis

Andresen, L., Boud, D., & Cohen, R. (1999). Experience-based learning. In *G. Foley (Ed.), Understanding adult education and training (2nd ed., pp. 225–239)*. Sydney: Allen & Unwin. https://doi.org/10.1016/j.nepr.2008.05.002.

Arbuckle, J. L. (1997). *Amos user's guide* (3.6). IL: SmallWaters Corp.

Bandura, A. (1982). Self-efficacy mechanism in human agency. *American Psychologist*, *37*(2), 122–147. https://doi.org/10.1037/0003-066X.37.2.122.

Boeve-de Pauw, J., & Van Petegem, P. (2011). The effect of Flemish eco-schools on student environmental knowledge, attitudes, and affect. *International Journal of Science Education*, *33*(11), 1513–1538. https://doi.org/10.1080/09500693.2010.540725.

Boeve-de Pauw, J., & Van Petegem, P. (2013). The effect of eco-schools on children's environmental values and behaviour. *Journal of Biological Education*, *47*(2), 96–103. https://doi.org/10.1080/00219266.2013.764342.

Bogner., F. X. (1999). Empirical evaluation of an educational conservation programme introduced in Swiss secondary schools. *International Journal of Science Education*, *21*(11), 1169–1185.

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.

Bogner, F. X. (2002). The influence of a residential outdoor education programme to pupil's environmental perception. *Journal of Psychology of Education*, *7*, 225–237.

Bogner, F. X. (2018). Environmental values (2-MEV) and appreciation of nature. *Sustainability*, *10*(2). https://doi.org/10.3390/su10020350.

Bogner, F. X., Brengelmann, J. C., & Wiseman, M. (2000). Risk-taking and environmental perception. *Environmentalist*, *20*(1), 49–62.

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. (1999). Toward Measuring Adolescent Environmental Perception. *European Psychologist*, *4*(3), 139–151. https://doi.org/10.1027//1016-9040.4.3.139.

Bond, T. G., & Fox, C. M. (2001). Applying the Rasch model. *Psychology Press*.

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.

Botar, O. (2017). Defining Biocentrism. *Biocentrism and Modernism*, 15–46.

Boylan, M. (2013). *Environmental Ethics*. (M. Boylan, Ed.), *Encyclopedia of Biodiversity* (Second Edi). Wiley-Blackwell. https://doi.org/10.1016/b0-12-226865-2/00106-1.

Braun, T., Cottrell, R., & Diekers, 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.

Browne, M. W., & Cudeck, R. (1993). Alternative ways of assessing model fit. In K. A. Bollen & J. S. Long (Eds.), *Testing Structural Equation Models* (pp. 136–162). Newbury Park, CA: Sage.

Carson, R. (1962). *Silent Spring*. Boston, MA: Houghton Mifflin Co.

Cedillo, C. V. (2016). On Empathy, Anthropocentrism, and Rhetorical Tropes: An Analysis of Online "Save the Bees!" Campaign Images. In *Screening the Nonhuman: Representations of Animal Others in the Media* (p. 185).

Cohen, J. (1960). A coefficient for agreement for nominal scales. *Education and Psychological Measurement, 20*, 37–46.

Cohen, J. (1968). Weighted Kappa: Nominal scale agreement with provision for scaled disagreement or partial credit. *Psychological Bulletin*, *70*(213–220).

Diekmann, A., & Preisendörfer, P. (1998). Environmental behavior-discrepancies between aspirations and reality. *Rationality and Society*, *10*(1), 79–102.

Driver, R. (1989). Students' conceptions and the learning of science. *International Journal of Science Education*, *11*(5), 481–490.

Dunlap, R. E., & Van Liere, K. D. (1978). The "new environmental paradigm". *The Journal of Environmental Education*, *9*(4), 10–19.

Eagles, P. F. J., & Demare, R. (1999). Factors Influencing Children ' s Environmental Attitudes. *The Journal of Environmental Education*, *30*(4), 33–37.

Earth Day Overshoot. (2020). Day, Earth Overshoot. "About earth overshoot day.

Epskamp, S., Eskamp, M. S., & MplusAutomation, S. (2019). Package 'semPlot'.

Fah, L. Y., & Sirisena, A. (2014). Relationships between the knowledge, attitudes, and behaviour dimensions of environmental literacy: A structural equation modelling approach using smartpls. *Jurnal Pemikir Pendidikan*, *5*, 119–144.

Flogaitis, E., & Agelidou, E. (2003). Kindergarten teachers' conceptions about nature and the environment. *Environmental Education Research*, *9*(4), 461–478.

Fox, J., Weisberg, S., Adler, D., Bates, D., Baud-Bovy, G., & Ellison, S. (2012). packages car.

Fox, J., Weisberg, S., Friendly, M., Hong, J., Andersen, R., Firth, D., & Taylor, S. (2016). Effect displays for linear, generalized linear, and other models.

Fremerey, C., & Bogner, F. X. (2014). Learning about Drinking Water: How Important are the Three Dimensions of Knowledge that Can Change Individual Behavior? *Education Sciences*, *4*(4), 213–228. https://doi.org/10.3390/educsci4040213.

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.

GAIA challenge. (2020). Retrieved from http://gaia-challenge.com.

GAIA Green awareness in action. (2020). Retrieved from http://gaia-project.eu.

Gardner, G. T., & Stern, P. C. (1996). *Environmental problems and human behavior*. Boston, USA: Allyn and Bacon.

Gebhard, U. (2009). Zur Wahrnehmung und psychischen Verarbeitung der Umweltzerstörung. In *Kind und Natur: die Bedeutung der Natur für die psychische Entwicklung* (pp. 238–267). Springer-Verlag.

Gebhard, U. (2013). Intuitive Vorstellungen bei Denk- und Lernprozessen: Der Ansatz „Alltagsphantasien“. In D. Krüger & H. Vogt (Eds.), *Theorien in der biologiedidaktischen Forschung Ein Handbuch für Lehramtsstudenten und Doktoranden* (4th ed., pp. 117–128). Springer-Lehrbuch.

Geiger, S. M., Dombois, C., & Funke, J. (2018). The role of environmental knowledge and attitude: Predictors for ecological behavior across cultures? An analysis of argentinean and german students. *Environmental Psychology*, *22*(1), 69–87.

George, J. L., & Frear, D. E. H. (1966). Pesticides in the Antarctic. *Journal of Applied Ecology*, *3*, 155–167.

Grob, A. (1995). A structural model of environmental attitudes and behavior. *Journal of Environmental Psychology*, *15*, 209–220.

Grønhøj, A., & Thøgersen, J. (2017). Why young people do things for the environment: The role of parenting for adolescents' motivation to engage in pro-environmental behaviour. *Journal of Environmental Psychology*, *54*, 11–19.

Hargrove, C. (1992). Weak anthropocentric intrinsic value. In Oelschlager (Ed.), *After Earth Day: continuing the conservation effort*. University of North Texas Press, Denton, TX.

Henn, L., Taube, O., & Kaiser, F. G. (2019). The role of environmental attitude in the efficacy of smart-meter-based feedback interventions. *Journal of Environmental Psychology*, *63*, 74–81. https://doi.org/10.1016/j.jenvp.2019.04.007.

Holodynski, M., & Oerter, R. (2012). Emotionen. In W. Schneider (Ed.), *Entwicklungspsychologie* (7th ed., pp. 497–519).

Hooper, D., Coughlan, J., & Mullen, M. R. (2008). Structural equation modeling: Guidelines for determining model fit. *Electronic Journal of Business Research Methods*, *6*(1), 53–60.

Hungerford, H. R., & Volk, T. L. (1990). Changing learner behavior - through environmental education. *The Journal of Environmental Education Research*, *21*(3), 8–21.

Ingold, T. (2014). Culture and the perception of the environment. In E. Croll & D. Parkin (Eds.), *Bush Base, Forest Farm*. https://doi.org/10.4324/9780203036129.

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*. https://doi.org/10.1080/00958964.2010.503716.

Kaiser, F. G. (1998). A general measure of ecological behavior. *Journal of Applied Social Psychology*, *28*(5), 395–422. https://doi.org/10.1111/j.1559-1816.1998.tb01712.x.

Kaiser, F. G., Hartig, T., Brügger, A., & Duvier, C. (2011). Environmental Protection and Nature as Distinct Attitudinal Objects: An Application of the Campbell Paradigm.

Environment and Behavior, *45*(3), 369–398. https://doi.org/10.1177/0013916511422444.

Kaiser, F. G., Oerke, B., & Bogner, F. X. (2007). Behavior-based environmental attitude: Development of an instrument for adolescents. *Journal of Environmental Psychology*, *27*(3), 242–251. https://doi.org/10.1016/j.jenvp.2007.06.004.

Kaiser, F. G., Roczen, N., & Bogner, F. X. (2008). Competence Formation in Environmental Education : Advancing Ecology-Specific Rather Than General Abilities. *Umweltpsychologie [Environmental Psychology]*, *12*(2), 56–70.

Kaiser, M. O. (1974). Kaiser-Meyer-Olkin measure for identity correlation matrix. *Journal of the Royal Statistical Society*, *52*, 296–298.

Kollmuss, A., & Agyeman, J. (2002). Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behaviour? *Environmental Education Research*, *8*(3), 239–260. https://doi.org/10.1080/13504620220145401.

Kopnina, H. (2012). Education for sustainable development (ESD): The turn away from 'environment' in environmental education? *Environmental Education Research*, *18*(5), 699–717. https://doi.org/10.1080/13504622.2012.658028.

Kopnina, H. (2020). Education for the future? Critical evaluation of education for sustainable development goals. *Journal of Environmental Education*, 1–12. https://doi.org/10.1080/00958964.2019.1710444.

Lehtonen, M. (2004). The environmental-social interface of sustainable development: Capabilities, social capital, institutions. *Ecological Economics*, *49*(2), 199–214.

Liefländer, A. K., & Bogner, F. X. (2014). The effects of children's age and sex on acquiring pro-environmental attitudes through environmental education.,. *The Journal of Environmental Education*, *45*(2), 105–117.

Liefländer, A. K., Bogner, F. X., Kibbe, A., & Kaiser, F. G. (2015). Evaluating Environmental Knowledge Dimension Convergence to Assess Educational Programme Effectiveness. *International Journal of Science Education*, *37*(4), 684–702. https://doi.org/10.1080/09500693.2015.1010628.

Liefländer, A. K., Fröhlich, G., Bogner, F. X., & Schultz, P. W. (2013). Promoting connectedness with nature through environmental education. *The Journal of Environmental Education*, *19*(3), 370–384. https://doi.org/10.1080/13504622.2012.697545

Mair, P., Hatzinger, R., & Maier, M. J. (2009). Extended Rasch Modeling: The R Package eRM.

Maloney, M. P., & Ward, M. P. (1973). Ecology: Let's hear from the people: An objective scale for the measurement of ecological attitudes and knowledge. *American Psychologist*, *28*(7), 583–586.

Manni, A., Sporre, K., & Ottander, C. (2013). Mapping What Young Students Understand and Value Regarding Sustainable development. *International Electronic Journal of Environmental Education*, *3*(1), 17–35.

Marcinkowski, T., & Reid, A. (2019). Reviews of research on the attitude–behavior relationship and their implications for future environmental education research. *Environmental Education Research*, *25*(4), 459–471. https://doi.org/10.1080/13504622.2019.1634237.

Mayring, P. (2000). Qualitative Content Analysis. *Qualitative Social Research*, *1*(2).

Meadows, D. H., Meadows, D. L., Randers, J., & Behrens, W. W. (1972). The limits to growth. New York.

Meinhold, J. L., & Malkus, A. J. (2005). Adolescent environmental behaviors: Can knowledge, attitudes and self-efficacy make a difference? *Environment and Behavior*, *37*(4), 511–532. https://doi.org/10.1177/0013916504269665.

Messick, S. (1995). Validity of psychological assessment: Validation of inferences from persons' responses and performances as scientific inquiry into score meaning. *American Psychologist*, *50*(9).

Milfont, T. L., & Duckitt, J. (2004). The structure of environmental attitudes: A first- and second-order confirmatory factor analysis. *Journal of Environmental Psychology*, *24*(3), 289–303.

Munoz, F., Bogner, F., Clement, P., & Carvalho, G. S. (2009). Teachers' conceptions of nature and environment in 16 countries. *Journal of Environmental Psychology*, *29*(4), 407–413. https://doi.org/10.1016/j.jenvp.2009.05.007.

Palmer, J. A. (1998). *Environmental education in the 21st century: Theory, practice, progress and promise*. London (Routledge).

Piaget, J. (1964). Cognitive development in children: Piaget development and learning. *Journal of Re*, *2*, 176–186.

Pointon, P. (2014). 'The city snuffs out nature': young people's conceptions of and relationship with nature. *Environmental Education Research*, *20*(6), 776–794. https://doi.org/10.1080/13504622.2013.833595.

Prince, M., & Felder, R. (2006). Inductive teaching and learning methods: definitions, comparisons, and research bases. *Journal of Engineering Education*, *95*(2), 123–138. https://doi.org/10.1002/j.2168-9830.2006.tb00884.x.

Revelle, W. (2012). Procedures for psychological, psychometric, and personality research. Retrieved 25 February 2020, from https://doi.org/10.1007/s11336-008-9102-z

Rieckmann, M. (2017). *Education for Sustainable Development Goals: Learning Objectives*. Paris, France: UNESCO.

Rieger, A., Thummert, R., Fridgen, G., Kahlen, M., & Ketter, W. (2016). Estimating the benefits of cooperation in a residential microgrid: A data-driven approach. *Applied Energy*, *180*, 130–141. https://doi.org/10.1016/j.apenergy.2016.07.105.

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.

Rosseel, Y. (2012). lavaan : an R package for structural equation modeling and more Version 0 . 3-1 (BETA). *Journal of Statistical Software*, *48*(2), 1–36. https://doi.org/10.1002/jae.767.

Schmitz, G. L., & Rocha, J. B. T. (2018). Environmental Education Program as a Tool to Improve Children's Environmental Attitudes and Knowledge. *Education*, *8*(2), 15–20. https://doi.org/10.5923/j.edu.20180802.01.

Schultz. (2002). Inclusion with nature: Understanding the psychology of human–nature interactions. In . In P. Schmuck & P. W. Schultz, (Eds.), T. psychology of

sustainable Development, (pp. 61–78). New, & Y. Kluwer. (Eds.), *Psychology of sustainable development* (pp. 61–78). Boston.

Schumm, M. F., & Bogner., F. X. (2016). The impact of science motivation on cognitive achievement within a 3-lesson unit about renewable energies. *Studies in Educational Evaluation*, *50*, 14–21.

Schuster, K., Hartkemeyer, T., & Krömker, D. (2008). Naturschutzorientierte Lebensstilorientierungen bei Jugendlichen [Nature conservation-oriented lifestyle orientations among students]. In D. Schuster, K., Hartkemeyer, T., Krömker (Ed.), *Gesellschaft und Naturschutz* (pp. 89–92). Bonn, Bad Godesberg, Germany: Bad Godesberg.

Steg, L., & De Groot, J. I. (2012). Environmental values. In *The Oxford handbook of environmental and conservation psychology*.

Stern, P. C., & Dietz, T. (1994). The Value Basis of Environmental Concern. *Journal of Social Issues*, *50*(3), 65–84. https://doi.org/10.1111/j.1540-4560.1994.tb02420.x.

Suzuki, R., & Shimodaira, H. (2006). Pvclust: an R package for assessing the uncertainty in hierarchical clustering. *Bioinformatics*, *22*(12), 1540–1542.

Taylor, P. W. (2013). Respect for nature: A theory of environmental ethics. In *Environmental Ethics* (pp. 152–162).

Thompson, S. C. G., & Barton, M. A. (1994). Ecocentric and Anthropocentric Attitudes Toward the Environment. *Journal of Environmental Psychology*, *14*, 149–157.

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

UNESCO-IEEP. (1985). Environmental Education: Module for Pre-Service Training of Science Teachers and Supervisors for Secondary Schools. In *Environmental Educational Series* (Vol. 9, p. 123).

UNESCO-UNEP. (1975). The Belgrade Charter: A framework for environmental education.

UNESCO UNEP. (1978). Recommendations of the Intergovernmental Conference on Environmental Education Tbilisi. USSR. France: UNESCO.

UNGA. (2015). *Transforming our world: The 2030 agenda for sustainable development*. *A New Era in Global Health*. New York, NY: UN General Assembly.

United Nation. (1992). Rio Declaration on Environment and Development - Preamble. In S. M. Wheeler & T. Beatley (Eds.), *The Sustainable Urban Development Reader* (3rd ed., pp. 79–86). Taylor & Francis.

UNWCED (United Nations World Commission on Environment and Development). (1987). Our Common Future (Brundtland Report). Oxford: Oxford University Press, UK.

Urban, D. (1986). Was ist Umweltbewußtsein? *Zeitschrift Für Soziologie*, *15*(5), 365.

Vicente-Molina, M. A., Fernandez-Sainz, A., & Izagirre-Olaizola, J. (2013). Environmental knowledge and other variables affecting pro-environmental behaviour: comparison of university students from emerging and advanced countries. *Journal of Cleaner Production*, *61*, 130–138. https://doi.org/10.1016/j.jclepro.2013.05.015.

Wiseman, M., & Bogner, F. X. (2003). A higher-order model of ecological values and its relationship to personality. *Personality and Individual Differences*, *34*(5), 783–794.

Worldbank. (2020). Retrieved 26 February 2020, from https://data.worldbank.org/indicator/EN.POP.DNST?end=2018&locations=CH&start=1997&year_high_desc=false.

Zelenika, I., Moreau, T., Lane, O., & Zhao, J. (2018). Sustainability education in a botanical garden promotes environmental knowledge, attitudes and willingness to act. *Environmental Education Research*, *24*(11), 1581–1596. https://doi.org/10.1080/13504622.2018.1492705.

Zelezny, L. C. (1999). Educational interventions that improve environmental behaviors: A meta-analysis. *The Journal of Environmental Education*, *31*(1), 5–14.

E Darstellung des Eigenanteils

Alle Teilarbeiten wurden von mir selbstständig als Erstautorin konzipiert, verfasst und mithilfe von Herrn Prof. F.X. Bogner überarbeitet. Bei Teilstudie D hat zusätzlich Herr P. Koulouris den Teil des Unterrichtsmoduls verfasst (*1.2. Green Awareness in Action (GAIA) Intervention*), sowie die Bilder aus Griechenland für die Teilstudie zur Verfügung gestellt.

Der Fragebogen der Teilstudie A + B für Studierende wurde von mir konzipiert, eigenständig ausgewertet und verfasst. Alle Fragebögen wurden durch mich vor Ort an alle Studierende am Ende der Vorlesung mit Zustimmung der jeweiligen Dozenten verteilt und wieder eingesammelt.

Der Fragebogen der Teilstudie C + D für die Schülerinnen und Schüler wurde von mir konzipiert, eigenständig ausgewertet und verfasst. Alle Evaluationsinstrumente mit Ausnahme der Wissensitems wurden der Literatur entnommen:

- Umweltbewusstseins-Skala; 2-MEV-Skala (Bogner. 1999; Bogner 2002; Wiseman und Bogner. 2003),
- Umweltverhaltens-Skala; GEB-Skala (Kaiser und Kollegen, 2007) und
- Naturverbundenheits-Skala; (INS)-Skala (Schultz, 2002)

Die Wissensfragen basieren auf den Materialien des GAIA-Projekts (http://gaia-project.eu). Außerdem wurden die von mir neu entwickelten Wissensitems mithilfe eines Experten-Ratings (Mitarbeiter Biologie Didaktik Lehrstuhl) auf die drei Wissensdimensionen überprüft. Nach Absprache mit P. Koulouris wurden die Wissensitems zusammen mit den anderen Fragen als Fragebogen an den jeweiligen Schulen und Klassen durch die jeweiligen Lehrpersonen verteilt. Die Interventionsstudie wurde von Lehrkräften vor Ort durchgeführt.

F Teilstudien

Im Rahmen der Dissertation wurden wie folgt vier Teilstudien verfasst:

Teilstudie A

Maurer, M., & Bogner, F. X. (2019). How freshmen perceive Environmental Education (EE) and Education for Sustainable Development (ESD). *PLoS ONE*, *14*(1). https://doi.org/10.1371/journal.pone.0208910

Teilstudie B

Maurer, M. & Bogner, F.X. (2020). First steps towards sustainability? University freshmen perceptions on nature versus environment. *PLoS ONE*, *15*(6). https://doi.org/10.1371/journal.pone.0234560

Teilstudie C

Maurer, M. & Bogner, F.X. (2020) Modelling Environmental Literacy with environmental knowledge, values and (reported) behaviour. *Studies in Educational Evaluation,* 65(100863). https://doi.org/10.1016/j.stueduc.2020.100863

Teilstudie D

Maurer, M., Koulouris, P., & Bogner, F. X. (2020). Green Awareness in Action — How Energy Conservation Action Forces on Environmental Knowledge, Values and Behaviour in Adolescents' School Life. *Sustainability*, *12*(3), 955. https://doi.org/10.3390/su12030955

F.1 Teilstudie A

PLOS ONE

RESEARCH ARTICLE

How freshmen perceive Environmental Education (EE) and Education for Sustainable Development (ESD)

Michaela Maurer*, Franz Xaver Bogner

Centre of Math & Science Education, Department for Biology Education, University of Bayreuth, Bayreuth, Germany

* Michaela.Maurer@uni-bayreuth.de

OPEN ACCESS

Citation: Maurer M, Bogner FX (2019) How freshmen perceive Environmental Education (EE) and Education for Sustainable Development (ESD). PLoS ONE 14(1): e0208910. https://doi.org/10.1371/journal.pone.0208910

Editor: Helen Kopnina, The Hague University of Applied Science, NETHERLANDS

Received: May 24, 2018

Accepted: November 22, 2018

Published: January 14, 2019

Data Availability Statement: The minimum underlying data set necessary to support the results of this study is available within the paper and its Supporting Information files.

Funding: This project is a part of the "Qualitätsoffensive Lehrerbildung", a joint initiative of the Federal Government and the Länder which aims to improve the quality of teacher training. The programme is funded by the Federal Ministry of Education and Research (Grant: 01JA160, https://www.qualitaetsoffensive-lehrerbildung.de/ to MM). This project is furthermore a part of the 'OSOS -

Abstract

Concepts of 464 university freshmen towards Environmental Education (EE) and Education for Sustainable Development (ESD) were analyzed. Responses were classified into seven main categories: 'ecological aspects', 'ecological problems', 'economical aspects', 'social aspects', 'environmental attitudes', 'environmental behavior' and 'education'. Analyses of sustainability concepts show a large discrepancy between EE and ESD, whereby the latter includes an additional sub-group: 'the next generation aspect'. Labeling individual sources of EE in a retrospective assessment identified the family as the most important source of knowledge, followed by media, school and outreach. Further differences were detected between students' self-perception and their ideal conception of environmental behavior, by using the scale Inclusion of Nature in Self (INS). Only some EE statements produced higher (unfulfilled) expectations 'economic aspects', 'environmental behavior' and 'ecological problems'. In contrast fewer (unfulfilled) expectations were observed in the categories of 'education' and 'ecological aspects'.

Introduction

Overview of Environmental Education history

In addition to Environmental Education (EE), the term Education for Sustainable Development (ESD) has been in use for several decades. Do the concepts behind EE and ESD overlap? Initial approaches to natural phenomena in EE go back to early European Educational Reformers (*e.g.* Comenius, Rousseau, Pestalozzi, Goethe and Humboldt), long before 'EE' was defined, and before the attempt was made to integrate EE approaches into a general concept of education [1]. At the UCN/UNESCO 'International Working Meeting on Environmental Education' (USA, 1970), the 'original definition' of EE was ". . . the process of recognizing values and clarifying concepts to develop skills and attitudes necessary to understand and appreciate the inter-relatedness among man, his culture, and his biophysical surroundings. EE also entails practice in decision-making and self-formulation of a code of behavior about issues concerning environmental quality" [2]. A few years later, the term EE was recognized at the UN

Open School For Open Society' project, funded by the European Union's Horizon 2020 (grant agreement No. 741572, https://www.openschools.eu/ to MM). This publication was funded by the German Research Foundation (DFG) and the University of Bayreuth in the funding programme Open Access Publishing. The authors are responsible for the content of this publication.

Competing interests: The authors have declared that no competing interests exist.

Conference on Human Environment in Stockholm [3]. The earliest environmental movements triggered the publication of Carson's book: 'Silent Spring', in which she claimed that DDT and other pesticides harm the environment [4] (DDT was found in *e.g.* Adèlie penguins and Weddell seals) [5]. Years later environmental movements used this claim to enforce a global ban of DDT. Due to the environmental problems of the 20th century, such as 'acid rain' (*e.g.* [6]), 'air pollution'(*e.g.* [7]) or 'ozone layer decline'(*e.g.* [8]), the global population developed an increasing environmental awareness, compatible with the EE goals concerning 'attitudes', 'motivations' and 'commitment to work individually towards solutions of current problems' [3, 9, 10, 11]. These goals were reinforced after the Belgrade Charter [9] and expanded in the Tbilisi Declaration in the late 70s [10]. In the 90s, the Rio-Conference defined EE in a broader sense, by developing a global action plan ('Agenda 21') with regard to sustainable development (SD) [11]. Although the term 'SD' originated in the book *Silvicultura oeconomica* (1713) by Carlowitz, that focused only on 'forestry' [12], today the term ESD includes 'local', 'national' and even 'global actions', which deal with present and future aspects of SD as a new guide for 'lifelong development competencies' [11]. ESD is a combination of three aspects: environmental (ecological), economic (including poverty reduction, corporate responsibility and accountability of society) and social (including employment, human rights, gender equity, peace and human security) aspects [13, 14, 15]. In graphic representations, they are often illustrated a same-sized circles with a circle labelled "human well-being" in the center representing the quality of life [16]. To the present day, the relationship between EE and ESD has been controversial: some authors consider ESD as the most effective approach to deal with current problems, as ESD may best meet the Rio-Conference recommendations [15]. Since Rio [11], ESD approaches concentrating on sustainable, modified attitudes and behaviors have gradually been included from primary to higher education worldwide [15, 17]. To support learning, students need diverse access to educational contents, and therefore topics, skills and different teaching methods must vary [18]. Researchers have been interested in measuring 'environmental awareness', 'attitudes based on connectedness to nature' or 'behavior towards the environment' for several decades. An example of a standardized and world-wide accepted measuring instrument is the 'Inclusion of Nature in Self (INS)' scale [19], which was used in this study. By consulting another measuring technique, namely the 'General Ecological Behavior (GEB)' [20], five sub-scales where classified into sub-categories to describe the main category of 'ecological behavior'. Another approach to 'sustainable development' claims that unprecedented material consumption, human greed and the human economic subsystem are huge problems of the modern world [21], which is why some authors see ESD critically. The concepts of 'SD' and 'ESD' are contradictory in their view of how 'sustainability' deals with the conflict between 'economic growth' and 'environmental protection' [22]. How far can natural resources [23] in developing countries be distributed fairly [24] and how is this problem related to 'human welfare', 'equality' and 'equal rights' [23]? Another point of discussion could be that people can choose between exploitation and protection of the environment [25] (*e.g.* by lifestyle or consumer behavior), subscribing to an anthrophocentrical or an ecocentrical view. Critics are concerned that sustainability tends towards anthropocentrism [23] if the rights and interests of human beings are the main focus. In contrast to that, the ecocentric approach puts special emphasis on the moral responsibility of humanity towards fellow humans [15], plants, animals and ecosystems [26]. Other authors argue that neither EE nor ESD solve crucial controversial disputes like 'polyvalent decisions'. Replacing 'nuclear power' with 'wind power systems' brings new problems like 'noise pollution' and 'bird protection' [27]. It is particularly hard to raise students' awareness of the value of nature [23] (*e.g.* 'you will protect what you love but on the other hand, you will not protect what you don't know'), because students have great difficulty understanding the underlying complex processes (*e.g.* why a forest dies) [27].

In addition, even ecologically oriented students struggle to deal with SD issues if they were taught by poorly trained teachers [23].

Overview of Environmental Education history in school

The history of education suggests that EE can support children in achieving an eco-friendly way of life, not merely in acquiring knowledge about the bio-physical natural environment [28]. In the 60s, pupils gained only knowledge by studying species and physical systems. Later in the 70s practical knowledge was acquired through outdoor adventures and urban studies. The global education efforts of the 80s, which included for example [29] a variety of teaching methods (*e.g.* inquiry learning, problem-based learning, project based learning, case-based teaching, discovery learning or just in-time teaching) [18] already incorporated EE modules while ESD still was in its infancy. Since the 90s, EE has become a recognized approach around the globe and formal and informal efforts have been made to integrate cognitive, affective and psychomotoric aspects of learning [30]. However, diversity of teaching methods does not automatically lead to success, particularly if students' have poor environmental knowledge, attitudes and behavior [31]. Not only 'factual-knowledge' but also 'action-related knowledge' and 'effectiveness knowledge' need to be increased [32] to promote positive environmental behavior. A few studies have examined short-term inputs (*e.g.* [33]) and residential program interventions [34], both of which have led to an increase of environmentally friendly attitudes and behavior. In our present study we monitor how freshmen perceive the terms EE and ESD after completing primary and secondary school during the UN decade. We assume that participants have some conceptions of EE and ESD, because their parents grew up during the evolutionary period of EE.

Conceptions

Learning is an adaptive process where learners' conceptual schemes are progressively reconstructed by a wide range of experiences and ideas [35]. It is assumed that learners consider both naive personal and scientifically correct explanations [36]. Nowadays, students receive information from the media, which are not always scientifically based. Over a period of 25 years, Hansen [37] tested the knowledge of Norwegian students about environmental topics three times. He concluded that the students' knowledge increased from the first to the last data collection. Furthermore, students were increasingly confused, perhaps because of the unlimited flood of information provided by *e.g.* media. Students often retain common sense beliefs and combine newly acquired school knowledge with their naive conceptions [38]. In addition to media, teachers also exert a significant influence on students' conceptions. Çimer *et al.* [39] concluded that experienced teachers had more knowledge and fewer misconceptions than beginners. Teachers' misconceptions should be eliminated before they are passed on to their students. Since the early 70s, conceptual ideas have been classified as pre-conceptions (*e.g.* [40]), misconceptions (*e.g.* [41, 42]), alternative conceptions (*e.g.* [43, 44]), common-sense concepts (*e.g.* [45]), initial conceptions (*e.g.* [46]) or individual perceptions (*e.g.* [47]). Conceptions of certain EE and ESD topics such as climate change (*e.g.* [48]), pollution (*e.g.* [49]), biodiversity (*e.g.* [50]) sustainability (*e.g.* [51]) or gene technology (*e.g.* [52]) have been studied in detail. To date there are no published studies about students' conceptions of EE or ESD. Fröhlich and colleagues [53] concluded that the concepts of younger students concerning a specific topic differ from those of older students, because conceptions are age-dependent [54]. Pedagogical and curricular emphases vary in the different countries, and states and schools and have a fundamental influence on student's conceptions [55].

Research goals

It is our main goal to monitor those freshmen's understanding of 'EE' and 'ESD' who grew up during the 'UN Decade for Sustainable Development'. We had four objectives: first, to analyze conceptions of EE and ESD with the respect to three dimensions: 'ecological', 'social' and 'economical'. Second, to detect the origins of individual environmental knowledge. Third, to analyze the relationship between humans and nature. Fourth, to determine the freshmen's (unfulfilled) expectations of EE.

Methods

Ethics statement

The Ethics Committee of Northwest and Central Switzerland (EKNZ) has confirmed that the research project 'How Freshmen perceive Environmental Education (EE) and Education for Sustainable Development (ESD)' is in line with the general ethical and scientific standards for research with humans. It posed no health hazards in accordance with the Human Research Act (HRA, Article 51, paragraph 2). The project didn't fall under the remit of the cantonal or federal law (Human research Act) and therefore an approval was not necessary by an ethic committee, because this project was not defined as a research project as per HRA Art. 2. All data privacy laws were respected. Gender, age and study status of participants were recorded pseudo-anonymously.

Sample

Our sample consisted of 464 Swiss German freshmen from a variety of study programs (*e.g.*, biology, pharmacy, economics; $N = 464$, $M = 21.3$, $SD = \pm 3.1$, male = 33.5%, female = 66.5%). All participants were confronted with three open and two closed questions testing individual concepts, knowledge and outlook concerning terms associated with the environment. The open questions included conceptions of Environmental Education (EE), Education for Sustainable Development (ESD) and individual (unfulfilled) expectations of EE. The first closed question listed six categories of EE sources ('politics', 'advertisement', 'media', 'outreach', 'school', 'family'). All participants were asked to assess the individual importance of the sources of environmental knowledge using a four-point Likert-scale ('1 = weak', '2 = middling', '3 = strong' and '4 = very strong'). The second closed question was based on a 7-INS (Inclusion of Nature in Self; adapted from [19]) scale (scale: 'A = very low' to 'G = very strong') with two overlapping circles labelled 'self' and 'nature' to show the relationship to each other.

Data analyses

Statistical tests were conducted using R (Version 2.14.2). We analyzed both closed questions using Student's T-Test, since the variables were normally distributed (Q-Q plot). Based on the current German syllabus [56], we extracted five main categories from the open questions inductively (ecological aspects, ecological problems, economical aspects, social aspects, education) and two main categories based on students' statements deductively (environmental attitudes, environmental behavior) [57] (Fig 1).

Categorization

To define the terms of ESD and EE more precisely, we used 28 identical sub-categories assigned to seven main categories ('ecological aspects', 'economical aspects', 'social aspects', 'environmental behavior', 'environmental attitudes', 'ecological problems' and 'education') (Table 1). In the cases of the question about EE (unfulfilled) expectations, we allocated 70 sub-

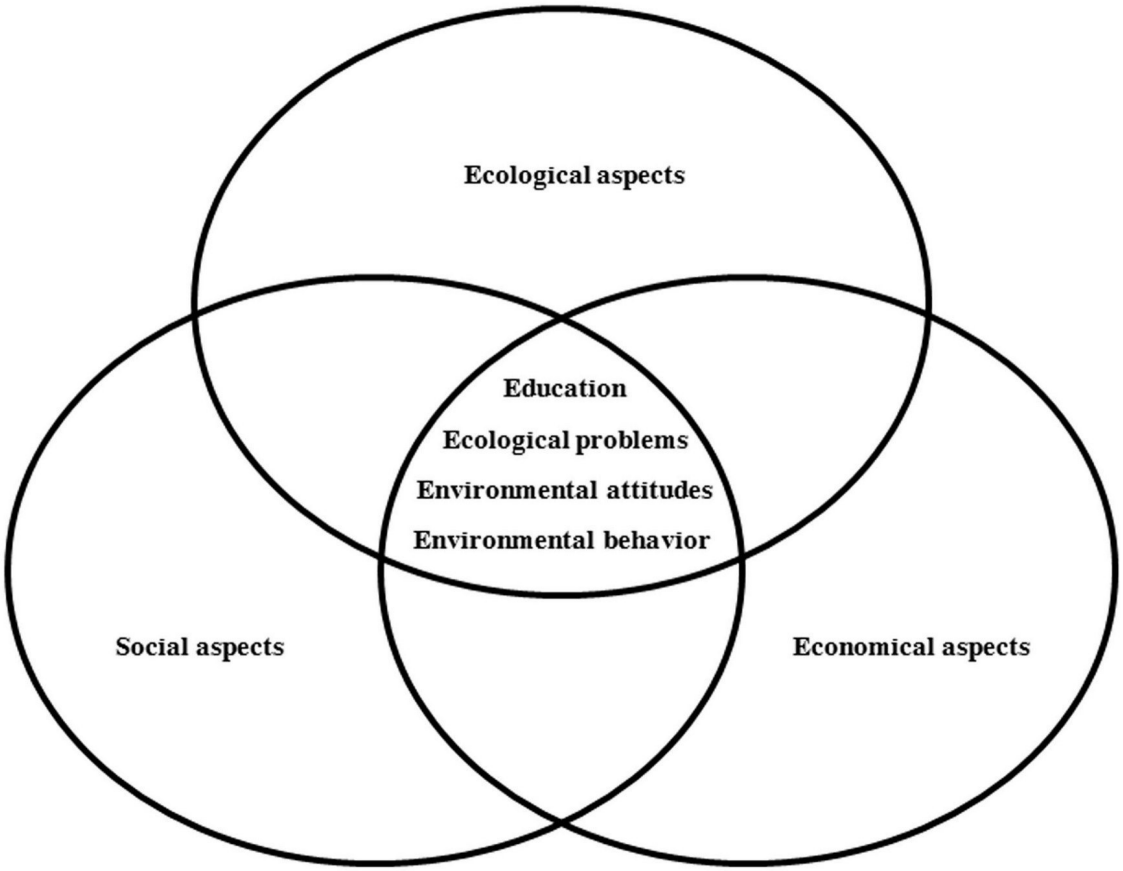


Fig 1. Categories of Environment Education and Education for Sustainable Development.

https://doi.org/10.1371/journal.pone.0208910.g001

categories. We summarized each main category as one vote, irrespective of the frequency with which each participant mentioned the sub-categories within each main category.

To assign all participant statements to main or sub-categories, we accepted synonyms like nature or habitat instead of 'Environment' and information or lesson instead of 'Education' for 'Environmental Education'. From 1443 observed statements we randomly selected 18% to assess the inter- and intra-reliability. We computed a score of 0.95 for inter-reliability and 0.86 for intra-reliability using Cohen's Kappa Coefficient [58]. For the contingency analysis C_{corr} we set a limit of 0.2 and a significance level of $\alpha = 0.001$. In our quantitative analysis we included the Bonferroni correction for both analyses separately.

Results

All categories based on open questions (definitions, see Table 2), which are displayed exemplary on few examples in Table 1. A four-step analysis revealed the following: first, concept ideas about ESD and EE. Second, retrospectively labelled individual sources of EE. Third, the individual connectedness to nature in the Inclusion of Nature in Self (INS) and finally,

Table 1. Categorization examples from freshmen between EE and ESD.

		Main categories						
ID	Statements	1	2	3	4	5	6	7
55	**Recapturing(2) humans(4)** to the **environment(4)**, **becoming more conscious(2) and economical(6)** (EE).	0	1	0	1	0	1	0
	Economically using resources(2) and **preserving the environment(2)** (ESD).	0	1	0	0	0	0	0
63	**Information(1)**, built **awareness(2)** towards **nature(4)** and environment (EE).	1	1	0	1	0	0	0
	Information(1) about topics: **conservation of resources and handling(2): nutrition (6)**, **economy(3)**, **social(5)**, **environment(4)** (ESD).	1	1	1	1	1	1	0
214	**Promote ecological awareness(2)** (EE).	0	1	0	0	0	0	0
	Learn(1), what we can do **to protect(2)** our **earth(4)** for **future generations(5)** (ESD).	1	1	0	1	1	0	0
370	**Learn(1)** how to **handle towards the environment(2)** (EE).	1	1	0	0	0	0	0
	To **teach(1) humans(4)**, that **resources(3) are limited** and **we should consume(6) only as much as we can produce(2)** (ESD).	1	1	1	1	0	1	0

Main categories: (1) Education, (2) Ecological attitudes, (3) Economical aspects, (4) Ecological aspects, (5) Social aspects, (6) Ecological behavior and (7) Environmental problems

https://doi.org/10.1371/journal.pone.0208910.t001

(unfulfilled) expectations of EE issues in comparison to the freshmen's individual concept ideas of EE.

A qualitative content analysis categorized students' ideas about Environmental Education (EE) and Education for Sustainable Development (ESD) (Fig 2). We identified 1243 statements (n_{ESD} = 648, n_{EE} = 595) belonging to seven defined main categories (Table 1). A contingency analysis showed a relationship over all categories between ESD and EE (C_{corr} = 0.37, n = 1243, $p < 0.001$).

The main categories 'social aspects' (C_{corr} = 0.205, n = 1243, $p < 0.001$) and 'economical aspects' (C_{corr} = 0.296, n = 1243, $p < 0.001$) resulting this small effect (C_{corr} limit 0.2 and a significance level of 0.001, see method).

A quantitative analysis yielded six categories of sources of Environmental Education: 'advertisement' (M = 1.592, SD = 0.727), 'politics' (M = 1.733, SD = 0.786), 'media' (M = 2.377, SD = 0.879), 'school' (M = 2.406, SD = 0.768), 'outreach' (M = 2.411, SD = 0.830) and 'family' (M = 2.880, SD = 0.846) (Fig 3). A Paired Student's T-Test after testing normal distribution (Fig 4) indicated differences between the categories 'advertisement' and 'politics' (t = -3.251, df = 436, p = 0.001), 'advertisement' and 'media' (t = -17.197, df = 435, $p < 0.001$), 'advertisement' and 'school' (t = -16.062, df = 433, $p < 0.001$), 'advertisement' and 'outreach' (t = -15.817, df = 430, $p < 0.001$), 'advertisement' and 'family' (t = -24.686, df = 439, $p < 0.001$), 'politics' and 'media' (t = -12.192, df = 435, $p < 0.001$), 'politics' and 'school' (t = -13.076, df = 433, $p < 0.001$), 'politics' and 'outreach' (t = -12.524, df = 430, $p < 0.001$), 'politics' and 'family' (t = -22.908, df = 438, $p < 0.001$), 'media' and 'family' (t = -9.188, df = 436, $p < 0.001$), 'school' and 'family' (t = -8.740, df = 434, $p < 0.001$) and the categories 'outreach' and 'family' (t = -8.807, df = 431, $p < 0.001$). The effect size of all analysis explain less than 8% variance between two category pairs.

The Inclusion of Nature in Self scale (INS) [19] describes the relationship between nature and the self (Fig 5).

A Paired Student's T-Test indicated a difference between 'self-perception' (M = 3.954, SD = 1.145) and 'human-perception' (M = 5.024, SD = 1.174) (Fig 6A and 6B) with respect to connectedness to nature (t = 20.5, df = 451, $p < 0.001$). A moderate effect (r = 0.48) explains 23.04% of the dependency between them.

Table 2. Defined categories of freshmen´s conceptions of Education for Sustainable Development (ESD) and Environmental Education (EE).

Category of conceptions	Definition	Examples
Ecological aspects	Interaction between organisms with other biotic and abiotic components of their environment.	organisms, nature, animals & plants, habitats
Ecological problems	Problems connected to environmental problems.	Environmental influence, pollution, climate change
Social aspects	The individual, in relation to its own social environment and thinking towards nature and fellow humans.	Sustainable lifestyle, next generation aspect
Environmental attitudes	Beliefs of people and society concerning nature, ecology and issues of the environment.	Awareness, connected with limited resources
Economical aspects	Economy resources and innovation.	Research, product/ resources, innovation
Environmental behavior	Behavioral patterns based on general ecological behavior (adjusted deductively from sub-scales of GEB) [20].	Consumption, waste avoidance, recycling
Education	Accumulation of individual knowledge.	Knowledge, information, understanding

https://doi.org/10.1371/journal.pone.0208910.t002

The second qualitative content analysis categorized students' ideas about 'Environmental Education' (Fig 2) and '(unfulfilled) Environmental Expectation' (Fig 7). We identified 849 statements ($n_{EnvironmentalEducation} = 595$, $n_{(unfulfilled)EnvironmentalExpectation} = 254$) belonging to seven defined main categories (Table 2). A contingency analysis showed a relationship over all categories between 'Environmental Education' and '(unfulfilled) Environmental Expectation' ($C_{corr} = 0.536$, $n = 849$, $p < 0.001$).

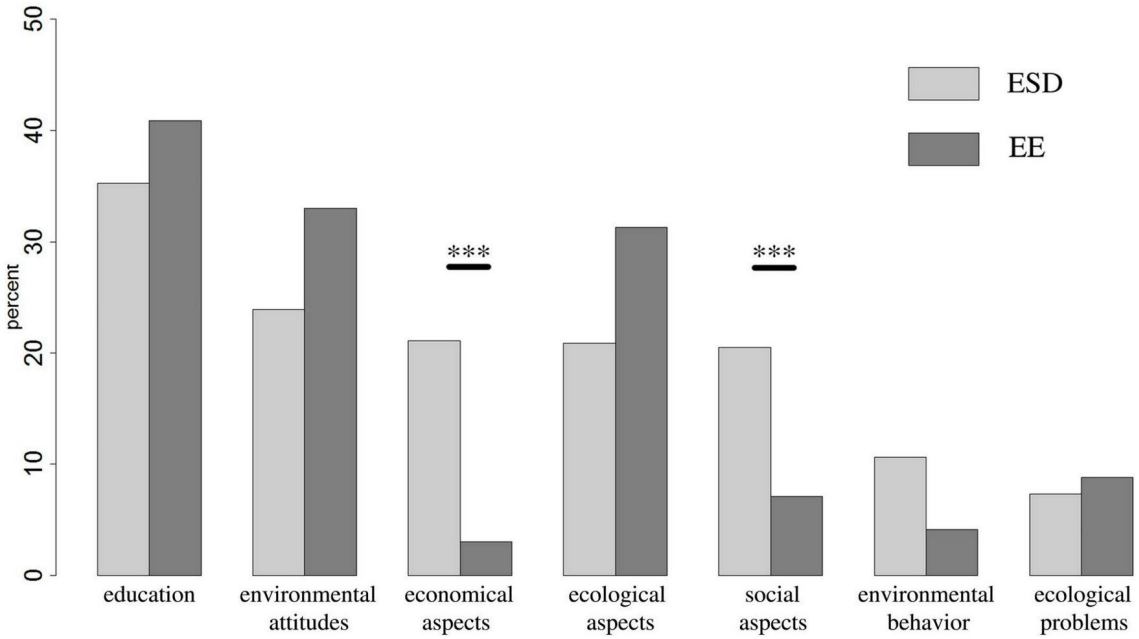


Fig 2. Percentage distribution of freshmen concept ideas of Education for Sustainable Development (ESD) and Environmental Education (EE). $N_{participants} = 464$.

https://doi.org/10.1371/journal.pone.0208910.g002

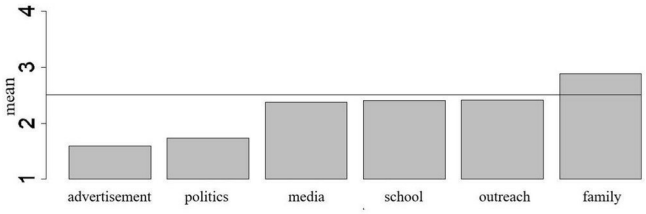


Fig 3. Comparison of overall mean scores when retrospectively labelling individual sources of Environmental Education ($N = 464$).

https://doi.org/10.1371/journal.pone.0208910.g003

The main categories 'education' ($C_{corr} = 0.385$, $n_{observed} = 203$, $n_{not\ observed} = 646$, $p < 0.001$) and 'ecological aspects' ($C_{corr} = 0.201$, $n_{observed} = 174$, $n_{not\ observed} = 675$, $p < 0.001$) produce a significantly higher number of 'Environmental Education' statements in comparison to fewer (unfulfilled) 'Environmental Expectation' statements. On the other hand, we obtained fewer statements in the main categories 'ecological problems' ($C_{corr} = 0.334$, $n_{observed} = 104$, $n_{not\ observed} = 745$, $p < 0.001$), 'environmental behavior' ($C_{corr} = 0.357$, $n_{observed} = 67$, $n_{not\ observed} = 782$, $p < 0.001$) and 'economical aspect' ($C_{corr} = 0.237$, $n_{observed} = 41$, $n_{not\ observed} = 808$, $p < 0.001$) if compared with a higher '(unfulfilled) Environmental Expectation' based on our definition (C_{corr} limit 0.2 and a significant level of 0.001, see method).

Discussion

The 'ecological' dimension in ESD and EE

In 2015, 17 Sustainable Development Goals (SDGs) were formulated, including the basic ecology of local and global ecosystems (*e.g.* 13 'climate change', 14 'life below water' or 15 'life on land') [59]. The roots of the definition of 'ecology'–linking the biotic and abiotic world–go back to Aristotle, Buffon, Wallace, Darwin or Haeckel [60]. For one in three participants, we observed a minimum of one statement in the main category of 'ecological aspects' in EE, but only for one in five in ESD. EE clearly contained more statements in the sub-categories of 'habitat' and 'ecosystem/environmental impacts' than did ESD. In both EE and ESD, we observed few statements concerning 'animals', 'plants' or 'humans'. Within the 'ecological' category, we combined statements about 'climate change', 'environment pollution' and 'environment influences' as sub-categories of the main category 'ecological problems'. Less than 10% of

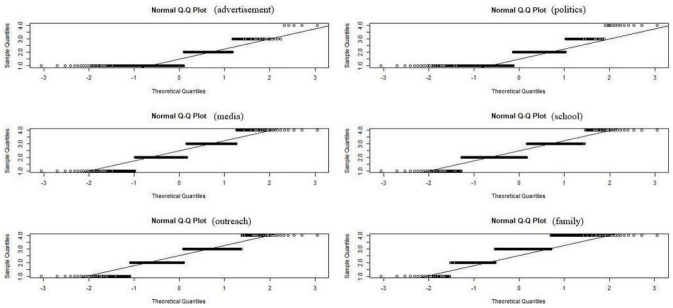


Fig 4. All Q-Q plot graphics of EE sources show a normally distributed data based on the Likert-scale.

https://doi.org/10.1371/journal.pone.0208910.g004

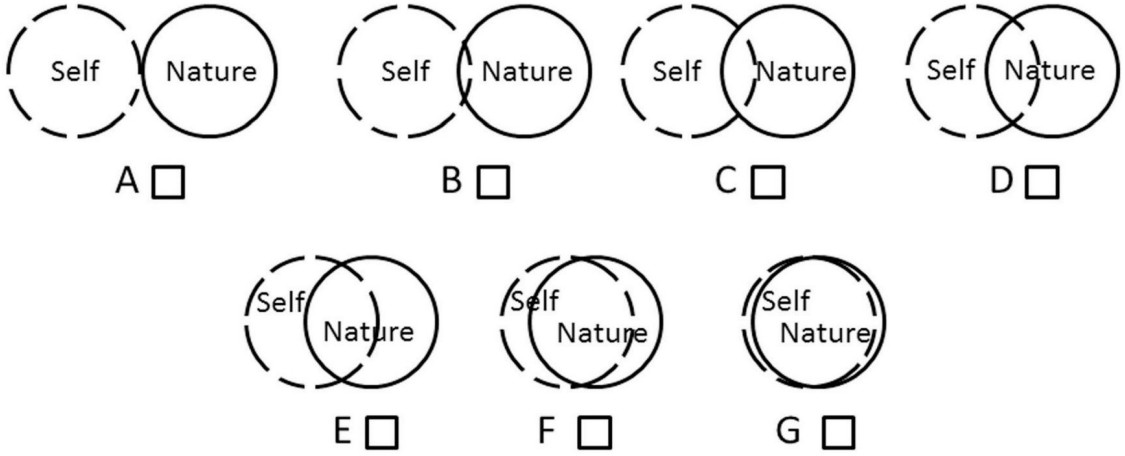


Fig 5. INS adapted with two overlapping circles labelled 'nature' and 'self' [19].

https://doi.org/10.1371/journal.pone.0208910.g005

participants mentioned one statement in EE, or in both EE and ESD, although *e.g.* 'climate change' is one of the essential focuses in ESD [61] and–next to 'micro plastic' [62], 'hormones in rivers and lakes' [63] or 'sunscreen particle' in oceans [64]–the greatest threat to our environment [65, 66].

The aspect of the 'social' dimension in ESD and EE

The 'social' category–as an essential environmental issue–has commonly been recognized as the weakest 'pillar' of sustainable development [13, 67]. We assigned for one in five

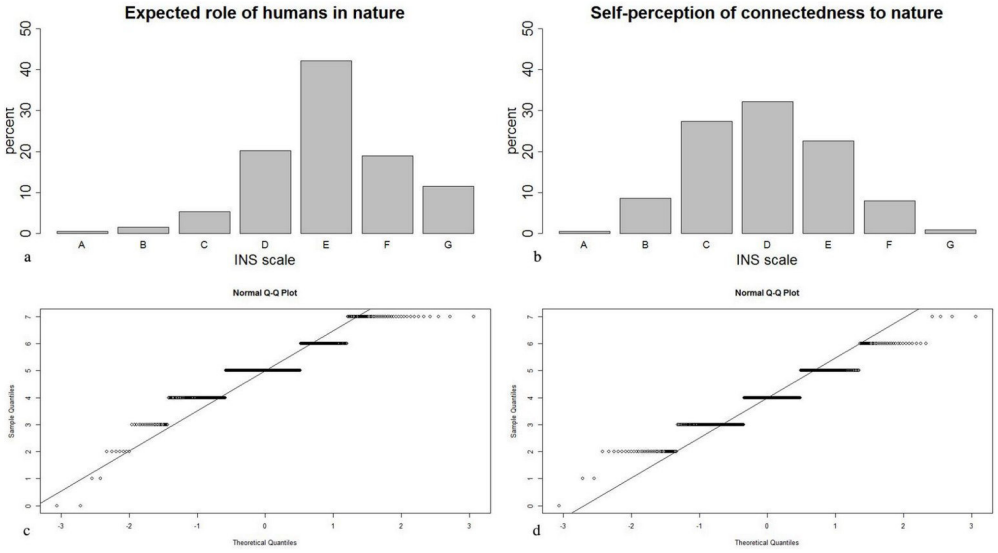


Fig 6. Connectedness to nature: 'human-perception' (a, c) and 'self-perception' (b, d) including Q-Q plot graphics showing normally distributed data based on the Likert scale.

https://doi.org/10.1371/journal.pone.0208910.g006

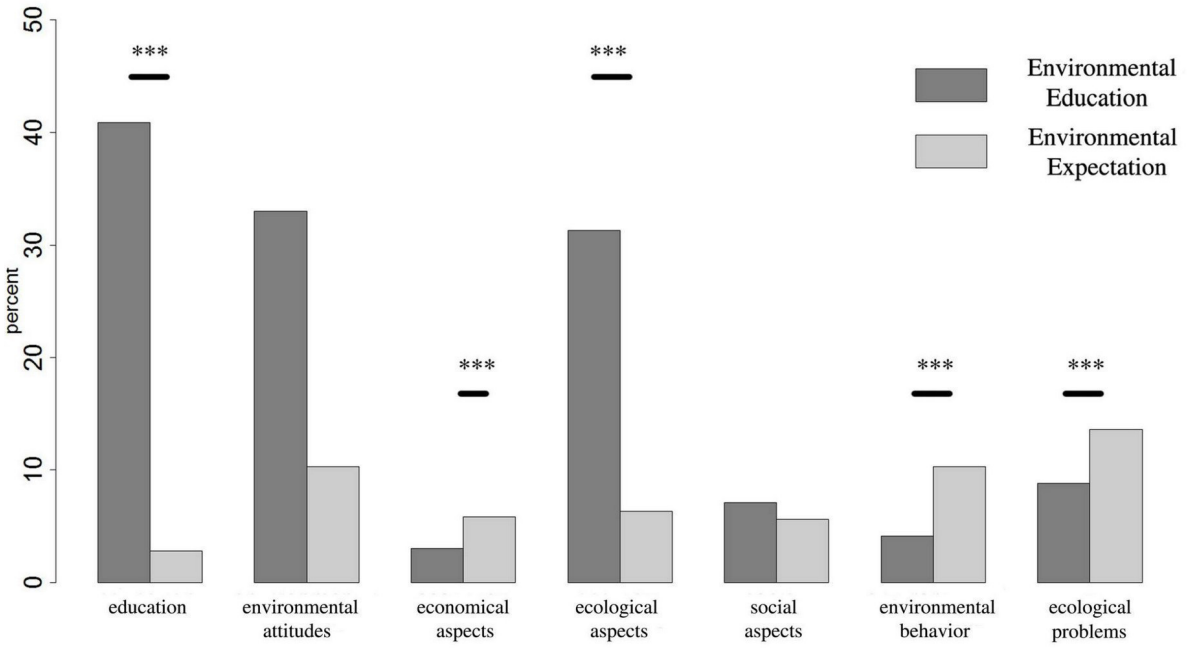


Fig 7. Conceptions about 'Environmental Education (EE)' (row of order see Fig 2) and individual 'environmental expectations'.

https://doi.org/10.1371/journal.pone.0208910.g007

participants a minimum of one statement to the main category of 'social aspects' in ESD, and for one in fourteen participants in EE. The effect size in the category 'social' is small, but was perceived from freshmen stronger in ESD than in EE. This is quite in line with a recent study with over 2400 Swedish students, where ESD was assigned an essential role in a more sustainable future [68]. Further, the 'next generation aspect', where we observed 23 statements, might provide a first indication of more thoughtful behavior towards value-oriented decisions [27]. In a Brazilian study 68% of all participants were confused when they were asked questions about their opinion of ESD, because in their past they were familiar only contact with EE. EE already contains 'social' and 'economical' elements [69]. Other social issues like 'employment', 'human rights', 'gender equity', 'peace' or 'human security', although regarded as essential [63], appeared neither in EE nor ESD in our sample.

The aspect of the 'economical' dimension in ESD and EE

Economic growth with all its effects on society and environment is expected to be a key concept of ESD [69]. However, in our case one in five participants yielded a minimum of one statement in the main category of 'economical aspects' in ESD. In contrast, only one in 34 participants did so for EE. Similar to Manni and colleagues [70], we counted the word resources in the various main categories 165 times in ESD and 65 times in EE. In our opinion, it makes a difference whether the concept of ESD contains resources (as a single word, impersonal) or 'conservation of resources and handling' (personal). For example, the statement of one freshman: 'sparingly using resources and preserving the environment' fits best to the main category 'environmental attitudes' (Table 1) following our definition (Table 2). Unfortunately, we

cannot tell if this statement was made in reference to a social (*e.g.* next generation aspect), economical (sparingly consume to save money) or ecological background (avoid products with palm oil to protect rain forests). Within the main category of 'environmental attitudes', we observed 70 statements in the EE subcategory of 'appreciate/perceive/preserve the environment' and only 18 statements in the same sub-category of ESD. The same applies to all the other sub-categories within the main category of 'environmental attitudes' ('awareness of/ responsibility for nature', 'to save resources' and 'environmental protection'). This shows a countertrend to the definition of environment [2] as found in ESD. In conclusion, the conceptual patterns clearly do not follow the protocol of 'economical', 'ecological' and 'social' aspects as single dimensions of EE and ESD. On average, each participant mentioned statements of only two out of seven main categories. Additionally, the results of the contingency analysis revealed the frequency between the categories and their classification to EE and ESD based on students' perception. In conclusion we had a small effect size over all categories, which was derivate from the categories of 'social' and 'economical aspects'.

Environmental Education in relation to lifetime learning aspect and connectedness to nature

Although the frequencies of conceptions differed, the most important source for EE is 'family'. Other studies have reported this for earlier age-groups: Eagles & Demare [71] reported for 6th-graders that talking about the environment at home while watching nature films, and reading about the environment were the most frequent sources of EE. 'Family' is apparently also important for the age group in our study and seems to be an imprinting factor on individuals' attitudes towards and knowledge about EE. Pe'er and colleagues [72] described a significant positive relationship between the mother's education (as an indicator of socioeconomic status) and a student's environmental knowledge and attitudes. They assume that growing up in a well-educated family supports more pro-environmental attitudes. Further, they found out that well educated individuals had greater exposure to ecological ideas than less educated individuals. EE and/or ESD may need a long period–from early childhood throughout adolescence to adulthood–to become established. In our sample, it is not clear which type of media contributes to most EE conceptions. Even eLearning tools such as HOBOS, is an outstanding means of replacing direct experience of nature by observing beehives remotely [73]. Commercial advertising (*e.g.* flyers and posters) and politics seem to play a very minor role in EE in our sample. In conclusion, long-term sources such as family or school, including different kinds of media (*e.g.*, TV, journals and books), are perceived as the most important sources in EE (Fig 3). Connectedness to nature, as a common goal for 'Environmental Education Programs' in schools [74], is expected to positively influence individual environmental behavior (*e.g.* [32]). Our results (that younger students are more engaged than older ones) are in accordance with the literature (*e.g.* [75]). In addition, differences appeared between an anthropocentric self-perception view based on the Inclusion of Nature in Self (INS) scale (Fig 6A) and the overall view of the relationship between humans and nature (Fig 6B).

Environmental Education (unfilled) expectations

Less than half of our participants replied to the open question concerning individual expectations of EE, although low scores were observed over all categories in general. Frequent categories like 'ecological aspects', 'environment attitudes' and 'education' were infrequent, while other main categories such as 'environmental behavior', 'economical aspects' and 'ecological problems' were observed more frequently. The frequent questions of freshmen about topics like: 'how to protect the environment', 'how to avoid waste' or 'how to encouraged learning

ecologically sensitive behavior' demonstrate, that the required environmental knowledge has been conveyed insufficiently or not even at all at school for example. Nevertheless, individual statements in relation to anthropocentric impacts such as 'climate change', 'global warming', 'carbon dioxide emissions' and other 'harmful environmental influences' in the main category of 'ecological problems' occurred less frequently than expected, although topics like 'climate change' (*e.g.* [61]), 'micro plastic' (*e.g.* [62]) or 'hormones in rivers and lakes' (*e.g.* [63]) have a strong media presence. The most frequent observation in the main category of 'ecological behavior' occurred in the sub-categories of nutrition consumptions (*e.g.* regional/seasonal, alternative or genetically engineered foods). In the main category 'economical aspects' terms like innovation and alternative energies' were mentioned often. Additionally, the results of the contingency analysis revealed the frequency between the categories and their classification to EE and EE Expectation, based on students' perception. In conclusion we had a small effect size over all categories, which was derivate from the categories of 'education', 'economical aspects', 'ecological aspects', environmental behavior' and 'ecological problems'.

Conclusion

The sustainable aspect according to the Rio-conference [11] is in line with a newly observed sub-category named 'next generation' and only included in ESD, which is considered as an expansion of EE. Higher numbers of statements in the sub-categories of 'avoiding waste' and 'alternative consumptions' (*e.g.* regional/seasonal, alternative or genetically engineered foods) arise from the category 'environmental behavior' in a clear development towards sustainability in ESD. The term resources was observed more frequently in ESD, 165 times in contrast to 65 times in EE. It is pleasing that freshmen obviously wanted more information on topics like 'renewable energies' or 'innovations' in the category of 'economical aspects', presented as an open question in (unfulfilled) EE expectations. This may show a general tendency towards economic growth, although this topic was not included in questions about (unfulfilled) expectations in ESD. Derived from this example and others, we assume that the perceptions of freshmen are composed of two coexisting approaches with overlapping conceptions in EE and ESD. Based on the freshmen's strong limited ecological conceptions about habitats and humans, we counted fewer observations of these terms in ESD than in EE. In summary: fewer concepts in the category 'environmental attitudes', may not be in line with the original definition of environment in EE [2] and suggest a trend away from the ecocentric view. This observation was confirmed by the results of the Inclusion of Nature in Self (INS) scale of connectedness to nature, which showed that freshmen think of themselves as quite anthropocentric and yet are simultaneously convinced that an ecocentric world view is the ideal (Fig 6A and 6B). Although general interest in '(unfulfilled) environmental expectation' was low, the highest rate was observed in the main category of 'environmental problems' including current ecological problems like climate change. Retrospectively, family, school (especially teachers), outreach and media seem to be the most important sources of EE in our sample: they are crucial points of contact from early childhood to adulthood and help young people to become responsible citizens.

Supporting information

S1 Dataset. Dataset of EE and ESD conceptions.
(XLSX)

Acknowledgments

We are grateful to all students involved in this study for their time and engagement. We also thank Michael Wiseman for discussing the earlier stages of our paper. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the position of the founding institutions.

Author Contributions

Conceptualization: Michaela Maurer.

Data curation: Michaela Maurer.

Formal analysis: Michaela Maurer.

Funding acquisition: Franz Xaver Bogner.

Investigation: Michaela Maurer.

Methodology: Michaela Maurer.

Project administration: Michaela Maurer, Franz Xaver Bogner.

Resources: Michaela Maurer, Franz Xaver Bogner.

Software: Franz Xaver Bogner.

Supervision: Franz Xaver Bogner.

Validation: Michaela Maurer.

Visualization: Michaela Maurer.

Writing – original draft: Michaela Maurer.

Writing – review & editing: Michaela Maurer, Franz Xaver Bogner.

References

1. Rosaleen J. Outdoor learning: past and present: Past and Present. Berkshire, England: Open University Press; 2012. 144 p.
2. IUCN. International Working Meeting on Environmental Education in the School Curriculum, Final Report. Gland, Switzerland: IUCN; 1970.
3. UNESCO. The Stockholm Declaration. Stockholm: UNESCO. 1972.
4. Carson R. Silent Spring. Boston, MA: Houghton Mifflin Co.; 1962. 363 p.
5. George JL, Frear DEH. Pesticides in the Antarctic. J Appl Ecol. 1966; 3:155–67.
6. McCormick J. The global threat of acid pollution. London; 2009. 257 p.
7. Seinfeld JH, Pandis SN. Atmospheric Chemistry and Physics: From Air Pollution to Climate Change. New York: John Wiley & Sons; 1998. 1191 p.
8. Parson E. Protecting the Ozone Layer: Science and Strategy. New York: Oxford University Press; 2003.
9. UNESCO-UNEP. The Belgrade Charter: A global framework for environmental education. Connect: UNESCO-UNEP Environmental Education Newsletter; 1976, 1(1): 1–2.
10. UNESCO UNEP. The Tbilisi Declaration: Final report intergovernmental Conference on Environmental Education. Paris, France: UNESCO ED/MD/49; 1978. p. 1–96.
11. UN. Rio Declaration on Environment and Development—Preamble. 1992.
12. vonCarlowitz HC. Sylvicultura oeconomica oder hauswirtschliche Nachricht und naturmassige Anweisung zur wilden Baumzucht nebst grundlicher Darstellung/Wie zu fordest durch Gottliche Benehmen dem allenthalben und insgemein eintreffenden Grossen Holz/Mangel. Erben, Leipzig; 1732.
13. Lehtonen M. The environmental-social interface of sustainable development: Capabilities, social capital, institutions. Ecol Econ. 2004; 49(2):199–214.

14. Reilly S, Petrillo DH, Demchik M. Environmental Education's Role in Sustainable Development: Three Case Studies from India, South Africa & the United States. Int Resour Manag. 2008; (NR 523).
15. UNESCO. The UN Decade for Education for Sustainable Development (DESD 2005–2014): the first two years. Paris; 2007.
16. McKeown R. Education for sustainable development toolkit. Version 2. Knoxville, Tennessee; 2002.
17. Gibson HL, Chase C. Longitudinal Impact of an Inquiry-Based Science Program on Middle School Students' Attitudes Toward Science. Sci Educ. 2002; 86(5):693–705. https://doi.org/10.1002/sce.10039.
18. Prince M, Felder R. Inductive teaching and learning methods: definitions, comparisons, and research bases. J Eng Educ [Internet]. 2006; 95(2):123–38. Available from: http://onlinelibrary.wiley.com/doi/10.1002/j.2168-9830.2006.tb00884.x/abstract.
19. Schultz. Inclusion with nature: Understanding the psychology of human–nature interactions. In Schmuck P & W P., (Eds.), Development T psychology of sustainable, (pp. 61–78). New York: Kluwer.
20. Kaiser FG, Oerke B, Bogner FX. Behavior-based environmental attitude: Development of an instrument for adolescents. J Environ Psychol. 2007; 27(3):242–51.
21. Rees WE. More jobs, less damage: a framework for sustainability. Altern J. 1995; 21(4):24–30.
22. Czech B. Prospects for reconciling the conflict between economic growth and biodiversity conservation with technological progress. Conserv Biol. 2008; 22(6):1389–98. https://doi.org/10.1111/j.1523-1739.2008.01089.x PMID: 19076872
23. Kopnina H. Education for sustainable development (ESD): The turn away from 'environment' in environmental education? Environ Educ Res. 2012; 18(5):699–717.
24. Banerjee SB. Who Sustain Whose Development? Sustainable Development and the Reinvention of Nature. Organ Stud [Internet]. 2003; 24(1):143–80. 77.
25. McCormick J. Reclaiming Paradise: The Global Environmental Movement. Vol 660. Indiana University Press, Bloomington; 1991. 263 p.
26. Kopnina H. Revisiting education for sustainable development (ESD): Examining anthropocentric bias through the transition of environmental education to ESD. Sustain Dev. 2014; 22:73–83.
27. Rost J. Umweltbildung—Bildung für nachhaltige Entwicklung. Was macht den Unterschied? [Environmental Education–Education for Sustainable Development. What is the difference between them?]. Zeitschrift für Internationale Bildungsforschung und Entwicklungspädagogik)[Journal International Eduction research development pedagogy]. 2002; 25:7–12.
28. UNESCO-IEEP. Environmental Education: Module for Pre-Service Training of Science Teachers and Supervisors for Secondary Schools. In: Environmental Educational Series. 1985. p. 123.
29. Palmer JA. Environmental Environmental Education In The 21ST Century Theory, practice, progress and promise. London (Routledge); 1998.
30. De Kock A, Sleegers P, Voeten MJM. New Learning and the Classification of Learning. Rev Educ Res. 2004; 74(2):141–70. https://doi.org/10.3102/00346543074002141.
31. Rickinson M. Learners and Learning in Environmental Education: A Critical Review of the Evidence. Environ Educ. 2001; 7(3):207–317. https://doi.org/10.1080/13504620120065230.
32. Kaiser FG, Roczen N, Bogner FX. Competence Formation in Environmental Education: Advancing Ecology-Specific Rather Than General Abilities. Umweltpsychologie [Environmental Psychology]. 2008; 12(2):56–70.
33. Fremerey C, Bogner F. Learning about Drinking Water: How Important are the Three Dimensions of Knowledge that Can Change Individual Behavior? Educ Sci [Internet]. 2014; 4:213–228. https://doi.org/10.3390/educsci4040213.
34. Liefländer AK, Bogner FX. The effects of children's age and sex on acquiring pro-environmental attitudes through environmental education. J Environ Educ. 2014; 45(2):105–117. https://doi.org/10.1080/00958964.2013.875511.
35. Driver R. Students' conceptions and the learning of science. Int J Sci Educ. 1989; 11(5):481–490.
36. Andresen L, Boud D, Cohen R. Experience-based learning. In: Foley G (Ed), Understanding adult education and training (2nd ed, pp 225–239) [Internet]. Sydney: Allen & Unwin.; 1999. Available from: http://complexworld.pbworks.com/f/Experience-basedlearning.pdf.
37. Hansen PJK. Knowledge about the Greenhouse Effect and the Effects of the Ozone Layer among Norwegian Pupils Finishing Compulsory Education in 1989, 1993, and 2005-What now? Int J Sci Educ. 2010; 32(3):397–419. https://doi.org/10.1080/09500690802600787.
38. Floden RE, Buchmann M. 'Breaking with Everyday Experience for Guided Adventures in Learning', in Buchmann M and Floden M (eds). Detachment and Concern: Conversations the Philosophy of Teaching and Teacher Education, Cassell, London.

39. Çimer OS, Çimer A, Ursavas N. Student teachers' conceptions about global warming and changes in their conceptions during pre-service education: a cross sectional study. Educ Res Rev. 2011; 6 (8):592–7.
40. Novak JD. A Theory of Education. NY, USA: Cornell University Press; 1977.
41. Doran RL. Misconception of selected science concepts held by elementary school students. J Res Sci Teach. 1972; 9:127–37. https://doi.org/doi:10.1002/tea.3660090204.
42. Schmid S, Bogner FX. Is there more than the sewage plant? University freshmen's conceptions of the urban water cycle. PLoS One. 2018. 13(7): 1–14. https://doi.org/10.1371/journal.pone.0200928.
43. Driver R, Easley J. Pupils and Paradigms: a Review of Literature Related to Concept Development in Adolescent Science Students. Stud Sci Educ. 1978; 5(1):61–84. https://doi.org/10.1080/03057267808559857.
44. Thorn CJ, Bissinger K, Thorn S, Bogner FX. Trees live on soil and sunshine!—Coexistence of scientific and alternative conception of tree assimilation. PLoS One [Internet]. 2016; 11(1). Available from: http://dx.doi.org/10.1371/journal.pone.0147802.
45. Halloun IA, Hestenes D. The initial knowledge state of college physics students. Am J Phys. 1985; 53:1043–1055.
46. Chi MTH, Slotta JD, Leeuw N De. From things to processes: a theory of conceptual change for learning science concepts. Learn Instr. 1994; 4:27–43.
47. Schönfelder ML, Bogner FX. Individual perception of bees: Between perceived danger and willingness to protect. PLoS One. 2017; 12(6):1–16. https://doi.org/10.1371/journal.pone.0180168.
48. Sellmann D, Bogner FX. Climate Change and the Sustainable Use of Water Resources—Chapter 47: Educational in Global Climate Change at a Botanical Garden: Student's Perceptions and Inquiry-Based Learning. Walter Leal Filho, editor. Berlin: Springer-Verlag; 2012. 779–786 p.
49. Brody MJ. Understanding of Pollution among 4th, 8th, and 11th Grade Students. J Environ Educ. 1991; 22(2). https://doi.org/10.1080/00958964.1991.9943051.
50. Kilinc A, Yeşiltaş NK, Kartal T, Demiral Ü, Eroğlu B. School Students' Conceptions about Biodiversity Loss: Definitions, Reasons, Results and Solutions. Res Sci Educ. 2013; 43(6):2277–307. https://doi.org/10.1007/s11165-013-9355-0.
51. Walshe N. Understanding students' conceptions of sustainability. Environ Educ Res. 2008; 14(5):537–58. https://doi.org/10.1080/13504620802345958.
52. Franke G, Scharfenberg F, Bogner FX. Investigation of Students' Alternative Conceptions of Terms and Processes of Gene Technology. ISRN Educ. 2013;2013. http://dx.doi.org/10.1155/2013/741807.
53. Fröhlich G, Goldschmidt M, Bogner FX. The effect of age on students' conceptions of agriculture. Stud Agric Econ [Internet]. 2013; 115(1):61–67. Available from: http://dx.doi.org/10.7896/j.1301.
54. Trowbridge JE, Mintzes JJ. Alternative conceptions in animal classification: A cross-age study. J Res Sci Teach. 1988; 25(7):547–71. https://doi.org/10.1002/tea.3660250704.
55. Lederman N. Students' and teachers' conceptions of the nature of science: A review of the research. J Res Sci Teach [Internet]. 1992; 29(4):331–359. Available from: http://onlinelibrary.wiley.com/doi/10.1002/tea.3660290404/abstract.
56. KMK. (2003). Richtlinien für die Umweltbildung an den bayerischen Schulen. [Guidelines for Bavarian schools in environmental education]. ISB, München [Munich]; 2003.
57. Mayring P. Qualitative Content Analysis. Qual Soc Res. 2000; 1(2).
58. Cohen J. A coefficient for agreement for nominal scales. Educ Psychol Meas. 1960; 20:37–46.
59. UN. The Sustainable Development Goals Report. 2017.
60. Mc.Comas WF. The ideal environmental science curriculum: I. History, rationale, misconceptions & standards. Am Biol Teach. 2002; 64(9):665–72. https://doi.org/10.1662/0002-7685(2002)064[0665:TIESCI]2.0.CO;2.
61. Crate SM, Nuttall M (Eds.). Anthropology and Climate Change: From Encounters to Action. Left Coast Press, Walnut Creek, CA; 2007.
62. Ivar do Sul JA, Costa MF. The present and future of microplastic pollution in the marine environment. Environ Pollut. 2014; 185:352–64. https://doi.org/10.1016/j.envpol.2013.10.036 PMID: 24275078
63. Kolpin DW, Furlong ET, Meyer MT, Thurman EM, Zaugg SD, Barber LB, et al. Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999–2000: A national reconnaissance. Environ Sci Technol. 2002; 36(6):1202–11. PMID: 11944670
64. Downs CA, Kramarsky-Winter E, Segal R, Fauth J, Knutson S, Bronstein O, et al. Toxicopathological Effects of the Sunscreen UV Filter, Oxybenzone (Benzophenone-3), on Coral Planulae and Cultured

Primary Cells and Its Environmental Contamination in Hawaii and the U.S. Virgin Islands. Arch Environ Contam Toxicol. 2016; 70(2):265–88. https://doi.org/10.1007/s00244-015-0227-7. PMID: 26487337

65. Fischlin A, Midgley GF, Price JT, Leemans R, Gopal B, Turley C, et al. Ecosystems, their properties, goods and services. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Chapter 4), UK: Cambridge University Press; 2007. 211–272 p.
66. UNESCO. United Nations Decade of Education for Sustainable Development (2005–2014): International Implementation Scheme. Paris; 2005.
67. Woolcock M. The Place of Social Capital in Understanding Social and Economic Outcomes. In John F. Helliwelled. The Contribution of Human and Social Capital to Sustained Economic Growth and Well-Being (Ottawa: HDRC)(Proceedings of an OECD/HRDC conference, Quebec, March 19–21, 2000).
68. DeBoeve JP, Gericke N, Olsson D, Berglund T. The Effectiveness of Education for Sustainable Development. Educ Sustain Dev Sustain. 2015; 7(11). https://doi.org/10.3390/su71115693.
69. Gadotti M. Education for Sustainability: A Critical Contribution to the Decade of Education for Sustainable Development. Green Theory Prax J Ecopedagogy. 2008; 4(1):15–64.
70. Manni A, Sporre K, Ottander C. Mapping What Young Students Understand and Value Regarding Sustainable development. Int Electron J Environ Educ. 2013; 3(1):17–35.
71. Eagles PFJ, Demare R. Factors Influencing Children's Environmental Attitudes. J Environ Educ. 1999; 30(4):33–7.
72. Pe'er S, Goldman D, Yavetz B. Environmental Literacy in Teacher Training: Attitudes, Knowledge, and Environmental Behavior of Beginning Students. J Environ Educ [Internet]. 2007; 39(1):45–59. Available from: http://www.tandfonline.com/doi/abs/10.3200/JOEE.39.1.45-59.
73. Schönfelder ML, Bogner FX. Two ways of acquiring environmental knowledge: by encountering living animals at a beehive and by observing bees via digital tools. Int J Sci Educ. 2017; 39(6):723–41. https://doi.org/10.1080/09500693.2017.1304670.
74. Frantz CMP, Mayer FS. The importance of connection to nature in assessing environmental education programs. Stud Educ Eval [Internet]. 2014; 41:85–9. Available from: http://dx.doi.org/10.1016/j.stueduc.2013.10.001.
75. Liefländer AK, Fröhlich G, Bogner FX, Schultz PW. Promoting connectedness with nature through environmental education. Environ Educ Res. 2013; 19(3):370–384. https://doi.org/10.1080/13504622.2012.697545.

F.2 Teilstudie B

PLOS ONE

RESEARCH ARTICLE

First steps towards sustainability? University freshmen perceptions on nature versus environment

Michaela Maurer*, Franz Xaver Bogner

Department of Biology Education, University of Bayreuth, Z-MNU (Centre of Math & Science Education), Bayreuth, Germany

* Michaela.Maurer@uni-bayreuth.de

OPEN ACCESS

Citation: Maurer M, Bogner FX (2020) First steps towards sustainability? University freshmen perceptions on nature versus environment. PLoS ONE 15(6): e0234560. https://doi.org/10.1371/journal.pone.0234560

Editor: Andrew R. Dalby, University of Westminster, UNITED KINGDOM

Received: March 12, 2020

Accepted: May 28, 2020

Published: June 15, 2020

Data Availability Statement: All relevant data are within the manuscript and its Supporting Information files.

Funding: This project is a part of the "Qualitätsoffensive Lehrerbildung", a joint initiative of the Federal Government and the Länder which aims to improve the quality of teacher training. The programme is funded by the Federal Ministry of Education and Research (Grant: 01JA1901, https://www.qualitaetsoffensive-lehrerbildung.de). This publication was also funded by the German Research Foundation (DFG) and the University of

Abstract

The Global Earth Overshoot Day, the date when all annually available natural resources are consumed, is set for July this year. For densely populated European countries like Germany or Switzerland, that specific day is due even earlier (May). To overcome such an unsustainable lifestyle, immediate actions are required, which includes substantial educational efforts. As the model of "Sustainable Development" is complex, appropriate pedagogical actions need to support cognitive learning, critical thinking and behavioural actions. Knowledge about individual conceptions in relation to the *Environment*, *Nature* and *Ecological Footprints* contributes to pre-conditions to succeed. To what extent present teaching methods influenced individual conceptions during the first UN-decade regarding those terms is illustrated by 464 Swiss-German university freshmen who participated in our paper-pencil test, which is based on four open questions. The term of *Environment* was perceived as the sum of biocentric, ecocentric and anthropocentric views. The participants often equated the term to *Nature* and associated it with positive feelings or emotions. Therefore, calm, joy and aesthetic appreciation were predominantly named. Regardless of the concept, humans were perceived as the *Greatest Environmental Threat*. In contrast, recommendations to reduce *Environmental Footprints* regarding mobility & transport, waste avoidance and consumption differ. Following a binary logistic regression analysis, the involvement of the Inclusion of Self Scale (INS) was used as an explanatory variable to detect patterns of those conceptions. Relating sustainable concepts, natural resources were frequently named exceeding saving water and energy or other association dealt with second-hand issues or regional/ seasonal usages. Such ideas are shaped by experiences and scientific expertise.

Introduction

Transformation into a sustainable future

First environmental movements date back to the early 1970s, when pesticides were spreading uncontrollably around the globe. Habitats far away from any settlement, for instance, those of penguins and seals, were found contaminated although no one would have suspected it. In

Bayreuth in the funding programme Open Access Publishing.

Competing interests: The authors have declared that no competing interests exist.

consequence, Carson's *Silent Spring* became one of the first publications to raise awareness of environmental problems within the general public [1]. Fifty years later, young people still have to demonstrate for saving the planet. Monitoring anthropocentric influences and overusing natural resources is not unknown. The famous book *Club of Rome–The Limits to Growth* [2] has already identified resources such as soil, air, water and genetic diversity as most vulnerable [3]. The *Brundtland-report* [4] in the 1980s was an initial step to roadmap sustainability, urging "to keep options open for future generations, the present generation must begin now, and begin together, nationally and internationally". All initiatives stressed the need for education beyond cognitive levels, affecting attitude and behaviour levels which may lead to appropriate action [5–9]. The Rio conference formulated Education for Sustainable Developments (ESD) requesting re-orientation first within Agenda 21 [10] and second with Agenda 2030 [11]. The three pillars: ecology, economy and social aspects are considered to impact individual awareness to tackle the environmental crisis. Observing young people's perceptions of environment, nature, concern and willingness to act could help to understand our current development. Education for Sustainable Development (ESD) requires general education, innovative focus of learning (assessment, anticipatory and networked thinking), subjective experience (experience of nature), understanding for coherences (economy, ecology and social aspect) and ethics (understanding of values) that fosters environmental awareness and impacts environmental behaviour [12,13].

Conceptions

Educational efforts are supposed to support thinking experiences, as learning processes are characterised by personal experiences and scientific explanations [14]. According to Piaget, for instance, individuals adapt their sum of knowledge during life, influenced by participation in social activities [15]. Approaching (subjectification) develops individual perceptions whereas withdrawing (professional objectivation) creates realities and perceptions [16]. Constructivism is the theory of knowledge in which learners are identifying constructs from a subject [17]. Radical constructivism forms memories and imagination in minds. Imaginations are important to interpreting individual surroundings of representation into individual world conceptions [18]. Relating to environmental issues, emotions and feelings (e.g. fears, joy) are compulsory [19] e.g. for sensitive topics like climate change or biodiversity loss [20]. However, besides scientific conceptions, alternative conceptions coexist (*e.g.* [21]). Educational background in this study was the most important determinant for increasing scientific knowledge when 6^{th} graders, 10^{th} graders and freshmen were asked about the perception of tree assimilation and wood synthesis ($N = 885$). Misconceptions in environmental education cause problems [22], especially if teachers are inexperienced or follow on their misconceptions [23]. Bonnett & Elliot [24] already pointed to a close relationship between natural environments and human beings. Psychological factors may explain why some people are more motivated to protect the environment [25] than others (*e.g.* intrinsic motivation to reduce consumption). Overall, several studies about teachers' [26] and students' conceptions point to complex processes [27]. Studies about environment versus nature, emotional perceptions and sustainable self-perceptions about environmental threats may help to reduce the footprint by detecting respective interrelations [28].

Environmental ethic

The term *environmental ethic*, dating back to the 1970s, addresses aspects of environmental crises (*e.g.* forest dieback, acid rain, air pollution). It is part of the ethic discipline of normative appropriate and morally responsible interaction [29] with the natural world [3].

Environmental perception constructs an individual image of the world based on individual imagination [30]. This concept, as defined by Uexkúll [31], represents the exploration of living organisms of the outer world (called physiological environment). Thus, bacteria, fungi and other living organisms were neglected. Today, however, the term includes all living organisms that are part of the biospheric ecosystem [32,33]. Therefore, it includes all biotic and abiotic factors as well as the relationships between organisms. The fundamental question is, thereby, whether nature's value is dependent on humans or has its in-made value [3,34] since nature is all that is not man-made. Two antagonistic views coexist:

i. anthropocentric refers to human-beings utilising resources such as water, soil and air [35]. Within this context, protecting the environment depends on humans' benefits (e.g. protecting honeybees for pollination and honey extraction), non-human organism or natural phenomena are of instrumental or aesthetic value [36],

ii. physiocentric is a generic term for a pathocentric, biocentric and ecocentric focus that humans have to respect. Pathocentric includes the ability to suffer (human and higher life forms) whereas biocentric represents nature and all living organisms with intrinsic values [37]. Two options are distinguished: egalitarian bio-centric ones, where all living organism have the same value or hierarchically modularised values, where all living organism have different values (scala naturae–from the bacterium to the human being). Ecocentric values including all elements of nature (biotic and abiotic) are equally represented *e.g.* animal and plant species, rivers or mountains, and even ecosystems according to Aldo Leopold and Arne Næss [38]. Efforts to protect eco-systems are subsumed under holism.

The value of biodiversity displays how closely ethics and the environment are interrelated [39]. Ecology simply provides the respective knowledge to understand the dynamics of biodiversity without necessarily including information about ethical values. In return, ethics is by far too vast a topic to explain this value without ecological knowledge. It is, however, indispensable to clarify responsibilities if the protection of pollinators is concerned. Observing different groups' perceptions regarding the benefits and conservation of bees via semantic differentials, beekeepers' displayed the highest interest, followed by university students and primary students [36]. Education is, thereby, the basis for attitudes/values and pro-environmental behaviour [40]. This has recently been demonstrated while assessing tenth graders ($N = 275$) regarding their perceptions of biodiversity [41]. Only one of three concepts was regularly identified (species diversity) whereas the others were only occasionally detected (genetic diversity and ecosystem diversity). A biodiversity module (Future Forest) obtained long-term knowledge gains by linking a citizen science project which aimed at engaging this cohort of students ($N = 205$) in biodiversity-related subjects [42].

However, it is known from literature that the connectedness of nature level operates positively with environmental behaviour and values [43,44]. Surprisingly, there is a lack of studies with young adults, which link concepts of the *Environment* or *Nature* linking to sustainable aspects. Leisure activities lead to the destruction of and alienation from nature [45]. It prompts lead open research questions regarding perceptions in comparison to the following.

Research goals

Our main research goal was (i) to monitor freshmen´s conceptions about the environment; (ii) what kind of emotions/feeling they have towards nature; (iii) which notions of the most eminent environmental hazards exist and (iv) how freshmen present ideas to reduce their ecological footprint.

Methods

Ethics statement

According to the general ethical and scientific standards for research with humans, our paper-pencil test was in line with all required standards (HRA, Article 51, paragraph 2). Data like gender, age and study-status were recorded pseudo-anonymously.

Sample

Our study included 464 Swiss German university freshmen from a wide range of study programs ($N = 464$, $M = 21.3$, $SD \pm 3.1$, female = 66.5%). The Swiss population density is 216 people per square meter in 2018 [46]. As our paper-pencil test was used for another recent study [47], we compared both. We adapted the findings of the seven-point Likert scale (Inclusion of Nature in Self (INS)–Scale ("A = very low" to "G = very strong") [48], with two overlapping circles labelled 'self' and 'nature' to show the relationship between the two of them.

Categorisation

After extracting the main categories by applying the qualitative content analysis of Mayring [49], our study was based on four fields:

i. perceptions about *environment*, where we used 14 categories inductively that we separated into three main categories: anthropocentric ("I live/surround me", "anthropocentric influence"), biocentric ("animals", "plants", "organism", "environmental protection", "human") and ecocentric ("abiotic", "planet earth", "ecosystem", "habitat", "interaction between organism", "we live/surrounds us", "nature"),

ii. *emotions and feelings* connected with *nature*, where we used 43 sub-categories inductively concerning to ten main categories ("admiration", "anger", "anxiety", "aesthetic appreciation", "calmness", "disgust", "fear", "joy", "sadness" and "shame") (Table 1),

iii. *greatest environmental hazard*, where we allocated 19 sub-categories and

iv. *reducing the ecological footprint*, where we allocated 21 sub-categories for five identical main categories ("awareness", "mobility & transport", organism", resource & consumption" and "waste") (Table 1).

To assess 2620 statements, 15% of all data were randomly selected after six months from the first author (inter-rater reliability) and a second nonpartisan person (intra-rater reliability) to test the quality (Table 2).

According to literature, Cohen's kappa scored almost perfectly above 0.75 and substantial above 0.60. The values of zero, a randomly correlation is assumed [50]. The resulting Cohen's kappa scores indicate an overall open questions a good level of agreement between the raters (Table 2).

Data analyses

All statistical tests were analysed using R (The R Foundation for Statistical Computing for Windows Version 3.6.0; www.r-project.org). To explore the general concepts, we applied Ward.D2 hierarchical cluster analysis (package pvclust; for method, see [51]) based on multi-scale bootstrap resampling. It provides p-values that in line with the data. Furthermore, we used binary logistic regression analysis to examine the effects between the main categories (observed = one, not observed = zero) following the categorical variables through the Inclusion

Table 1. Coding guidelines for the main categories of freshmen´s perception.

Categories of conceptions	Definition	Examples
Anthropocentrism (a)	Humans being in the centre of their perspective on nature	Pollutant uptake, the environment that surrounds me
Biocentrism (a)	All living things, including plants and animals	Human, animal plant, organism
Ecocentrism (a, c)	Nature being in the centre and mean views are solely needs	Ecosystem, river, environment that surround us
Admiration (b)	The feeling or description of admiring something	Fascination (*e.g.* nature), respect (*e.g.* natural forces)
Anger (b)	A strong feeling that makes you unpleasant because something unfair happens	frustration, brutality against nature
Anxiety (b)	An uncomfortable feeling of worry about something that is happening or might happen in the future	not take care of nature, dependence
Aesthetic Appreciation (b)	Include an aesthetic appreciation of the objects or powerfully description based on nature for instance (= aesthetic emotion meaning)	aesthetics, unspoiled landscape
Calmness (b)	A peaceful, quiet or relaxed state without hurried movement or noise	free, freedom, silence, relaxation
Disgust (b)	A strong feeling of disapproval and dislike against something, *e.g.* an organism	disgust for animals, birds
Fear (b)	An unpleasant emotion or thought that occurs when you are frightened or worried.	fear of the destruction, cryophobia, less food
Joy (b)	A memory or thing that causes happiness or connectedness to nature	hobby, time off, luck, satisfaction
Sadness (b)	A feeling of being sad or unhappy	the destruction caused by human activities
Shame (b)	An uncomfortable feeling of guilt	feelings of guilt, charm
Awareness (c)	Knowledge or perception of a situation or fact	human interference (environmental hazard) versus conscious behaviour (ecological footprint-reverse)
Resources & Consumption (c)	Consumption behaviour of non-renewable, or less often, renewable resources and consumption of goods	energy and water consumption, overproduction (environmental hazard) versus preferring regional and seasonal products (ecological footprint-reverse)
Mobility & Transport (c)	Mobile transportation, used for transporting people or goods on land, especially on roads	increasing mobility (environmental hazard) versus limiting mobility and using alternatives *e.g.* public transport (ecological footprint-reverse)
Waste (c)	End products, resulting from private households or industry	plastic, waste (environmental hazard) versus avoidance of disposable packaging (ecological footprint-reverse)

Freshmen perceptions based on open questions belonging to the categories for *environmental ethics* (a), *emotions and feelings* (b) and the *greatest environmental hazard* relating to their ecological footprint (c) (retrieved and adapted from the Cambridge dictionary).

https://doi.org/10.1371/journal.pone.0234560.t001

of Nature in Self (INS)–Scale [48]. For the contingency analysis C_{corr}, we set a limit of 0.2 and a significance level of $\alpha = 0.001$.

Results

We formed all categories inductively from open questions (definitions, see Table 1). Some examples are displayed in Table 3.

Table 2. Cohen's kappa scores for inter- and intra-reliability.

	Cohens-Cappa	
Questions:	**Interrater reliability**	**Intrarater reliability**
(i) How do freshmen's perceive their environment?	0.70	0,55
(ii) What kind of emotions/feelings do they connect with nature?	0.91	0.70
(iii) Which notions of the greatest environmental hazards do they have?	0.75	0.52
(iv) How can freshmen reduce their ecological footprint?	0.67	0.61

https://doi.org/10.1371/journal.pone.0234560.t002

Table 3. Categorisation examples from freshmen perceptions of the *environment*.

		Main categories		
ID	Statements	Anthropho-centric[1]	Biocentric[2]	Ecocentric[3]
78	Everything that **surrounds me**[1]: **nature**[3] as well as **animals**[2] and **humans**[2]	1	1	1
80	Everything that **surrounds me**[1] as a **human**[2] outside of my personality. **friends**[3], **family**[3], **nature**[3]	1	1	1
88	**Abiotic**[3] and **biotic**[2] world, where **I live**[1]	1	1	1
253	**Nature**[3], the **world**[3] in which **we live**[3]	0	0	1

https://doi.org/10.1371/journal.pone.0234560.t003

Environment

321 freshmen responded to the question of how they perceive the term *environment*: five of one participant yielded perceptions of either anthropocentric, biocentric or ecocentric (see methods). The conceptual patterns of 14 sub-categories do not follow a certain environmental ethical view (anthropocentrism, biocentrism and ecocentrism, see method) as one branch [51] (Fig 1). Students see themselves rather as a part of the environment ($N = 128$, sub-category "we live/surround us") in the centre of the environment ($N = 45$, "I live/surround me). Some concepts were observed on one branch (*e.g.* animals and plants).

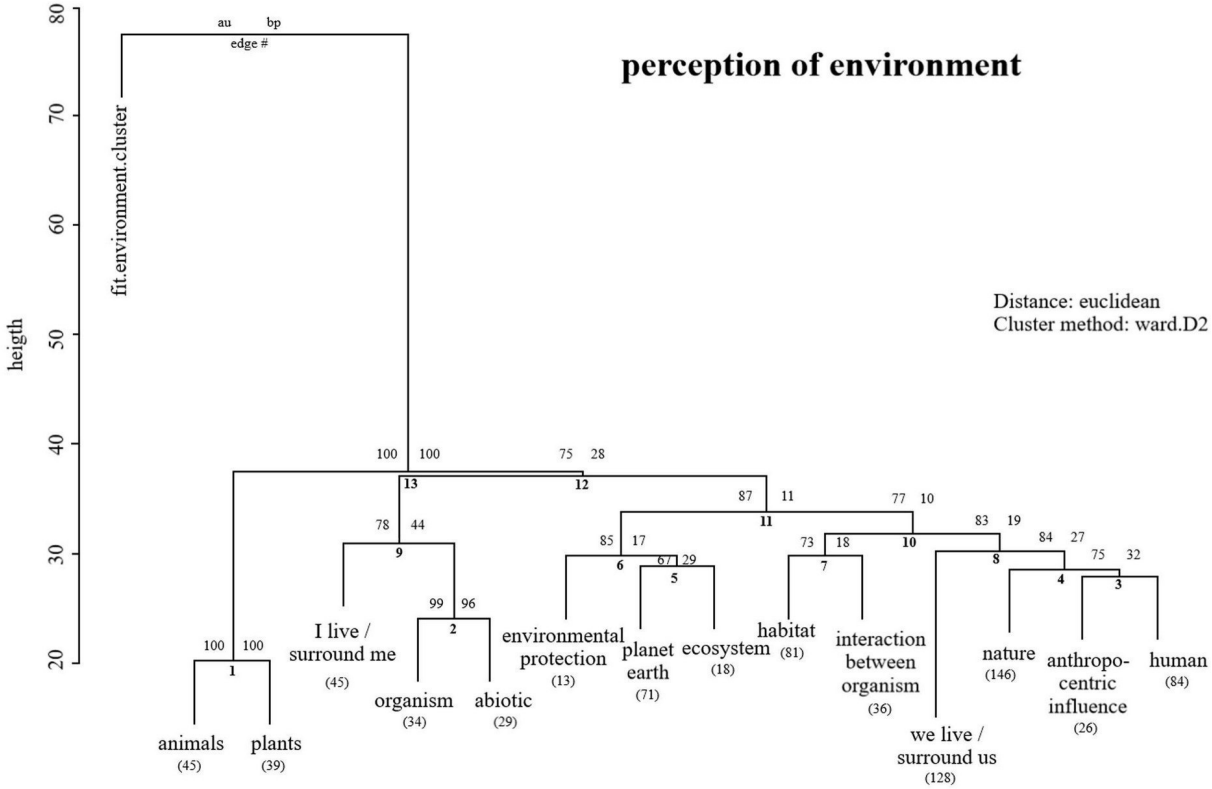


Fig 1. Cluster dendrogram with p-values based on the freshmen's perception of the *environment*. Numbers above the branches on the right: standard bootstrap p-value and on the left illustrate approximately unbiased (AU) p-values (Clusters with AU > = 95% are indicated by the rectangles and are considered to be strongly supported our data). Numbers in brackets below the categories are the observation of all participants.

https://doi.org/10.1371/journal.pone.0234560.g001

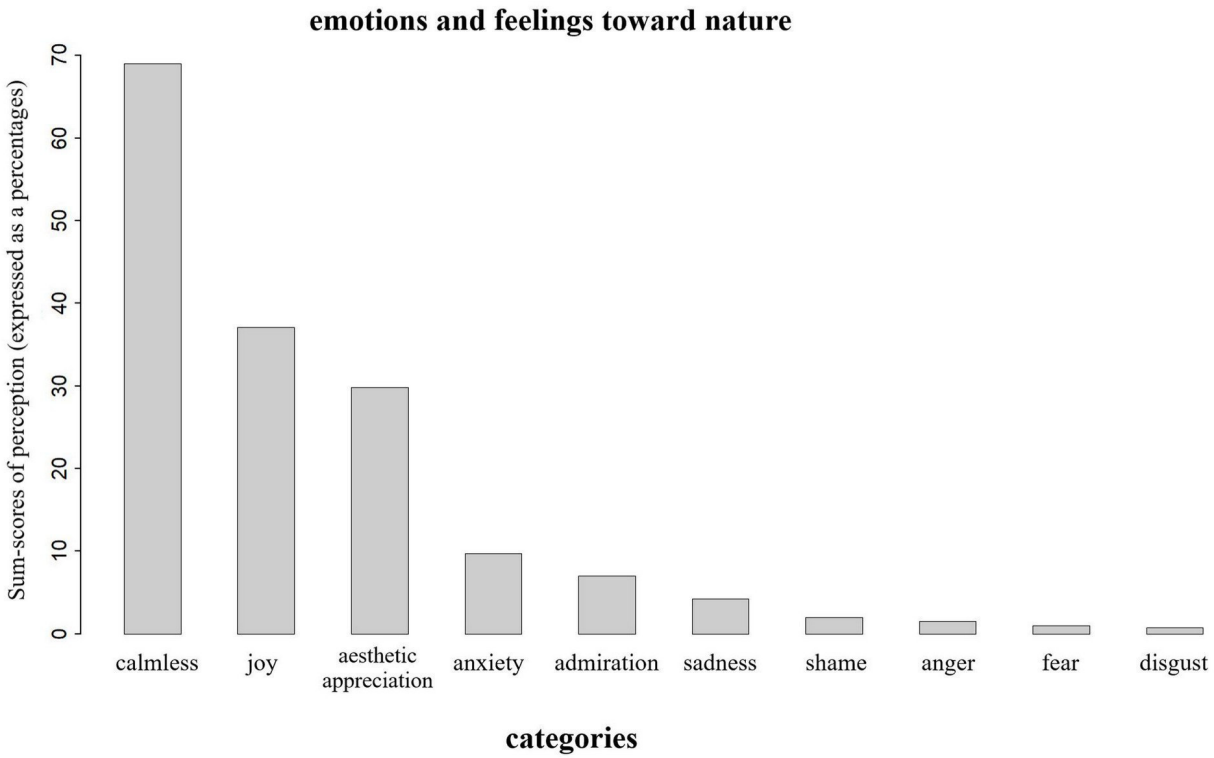


Fig 2. Reflection of freshmen ($N = 402$) perception following emotions and feelings.

https://doi.org/10.1371/journal.pone.0234560.g002

Emotions and feelings to nature

Freshmen ($N = 402$) associate *emotions and feelings* with nature as a variety of different perceptions belonging to ten categories (Fig 2). Nature was mainly connected to positive feelings and emotions. The connectedness to nature as an explanatory variable explained no difference between the categories of the three main observations (*e.g.* joy: $\beta_{intercep} = -0.97$, $SD \pm 0.39$, *z-value* = -2. 52, $p = 0.001$, odds ratio = 0.93). Nature stands predominantly for human welfare like freedom, silence and private activities outside. The negative trend was less evident (*e.g.* sadness of the destruction of nature or disgust for particular species).

The relationship between nature and the self was analysed via the Inclusion of Nature in Self scale (INS) in an earlier study of the same participants ($M = 3.954$, $SD \pm 1.15$) [47]. We used those results in the following as the independent variable and the binary category as depend variable. A binary logistic regression analysis [family = binomial ("logit")] delivered different outcomes between the categories regarding perceptions of the biggest environment hazard and reducing the ecological footprint (Table 4).

Environmental hazard versus ecological footprint

A qualitative content analysis categorised the students' ideas about the environmental hazard and reduction of their ecological footprint. We identified 1430 statements ($n_{environmental\ hazard}$

Table 4. Binary logistic regression of coefficients regarding emotions.

Category	$\beta_{intercept}$	SD	z-value	*Pr(>|z|)*	eβ
Admiration	1.30	±0.40	-3.31	>0.001	1.14
Joy	1.05	±0.37	-2.87	>0.001	1.09
Aesthetic appreciation	-0.97	±0.39	-2.52	0.01	0.99

eβ = Odds ratio

https://doi.org/10.1371/journal.pone.0234560.t004

= 633, $n_{ecological\ footprint}$ = 797), which form five main categories (definitions, see Table 1). A contingency analysis showed a relationship of all categories between environmental hazards and reducing their ecological footprint (C_{corr} = 0.54, n = 1430, $p < 0.001$). Perceptions of reducing their ecological footprint are much higher of all categories in comparison to the perception of the greatest environmental hazard. A second analysis, a hierarchical cluster analysis, confirmed similarities that conceptions were not following the same clusters based on both questions (Fig 3).

A binary logistic regression analysis [family = binomial ("logit")] delivered different outcomes between the categories regarding perceptions of the biggest environment hazard and reducing ecological footprint (Table 5).

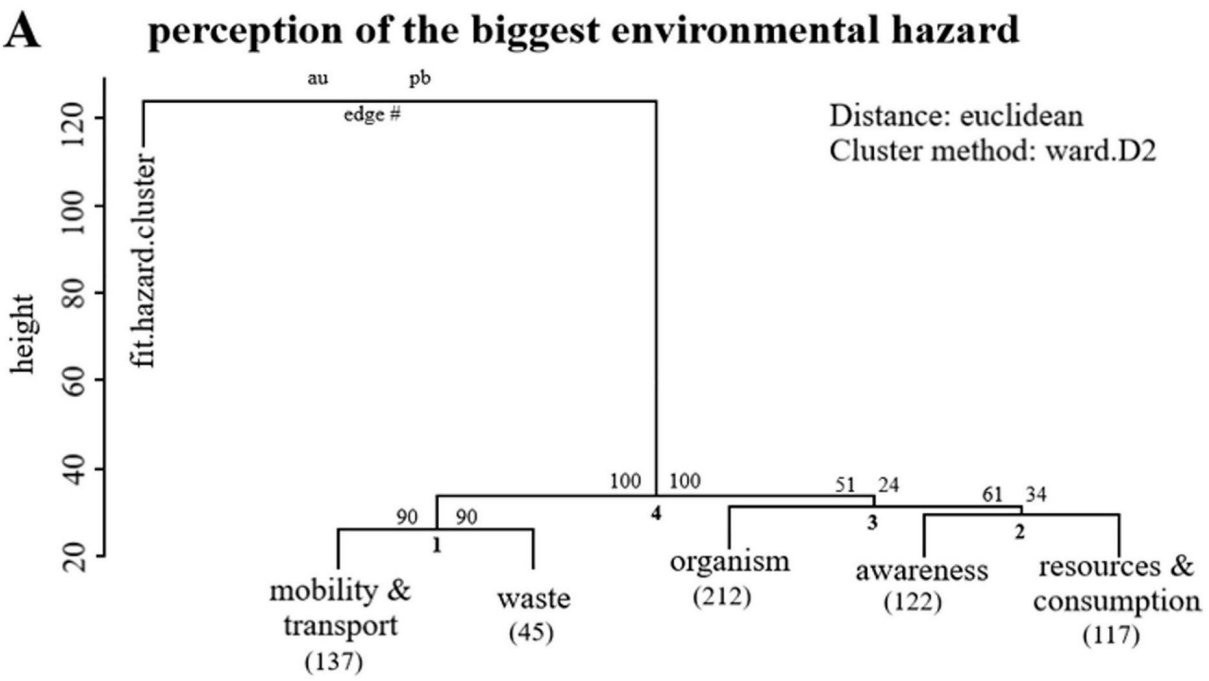
For some categories, the variable INS displayed an approval if a concept was mentioned or not. For the category *resources & consumption*, for example, more concepts were observed if the INS level was higher on both open questions regarding environmental hazard and reducing ecological footprint (Fig 4A). In contrast, for the category of *waste*, less approval follows a higher connectedness to nature level by the question of environmental hazard, whereas a more approval follows a higher connectedness to nature level by the question of reducing ecological footprint (Fig 4B).

Discussion

Environmental ethics aims at how humans think about their interaction with nature. It links theory (*e.g.* knowledge) and practice (*e.g.* experience), which form life-long conceptions [17]. According to the literature, two antagonistic preferences prevail either to protect or to utilise the environment [36,52,53]. In essence, two psychometric measurements were well established in the 1990s to measure both. Whereas the *New Environmental Paradigm* (NEP) was developed as a one-dimension scale for adults [54], the, *Two Major Environmental Value Model* (2-MEV) assesses two higher-order factors (preservation, utilization and appreciation of nature) to identify both values for adults and adolescents [52,55]. We decided to integrate the measuring instrument of the *Inclusion of Nature in Self* (INS) scale [56] as a reference-value for connectedness to nature. Concerning the freshmen's perceptions of our previous study, which was based on closed questions present a clear result: The connectedness to nature level [48] to out a tendency towards an anthropocentric self-perception for all participants (M = 3.954, SD ± 1.15) in comparison to a human-perception of an ecocentric worldview as ideal (M = 5.024, SD ± 1.17) [47]. We used this variable as a independent variable for binary logistic regression analysis. Differences of observation were found between some categories of the greatest environmental hazards and concept ideas of reducing the freshmen's ecological footprint categories.

Environment and nature

For the environment, the overall conceptions display a range of scientific concepts including human perception. This is not in line with a study of adolescents (13–14 years old), where no


A
perception of the biggest environmental hazard
au
pb
edge #
fit.hazard.cluster
height
20
40
60
80
100
120
Distance: euclidean
Cluster method: ward.D2
100
100
51
24
61
34
90
90
4
3
2
1
mobility &
transport
(137)
waste
(45)
organism
(212)
awareness
(122)
resources &
consumption
(117)

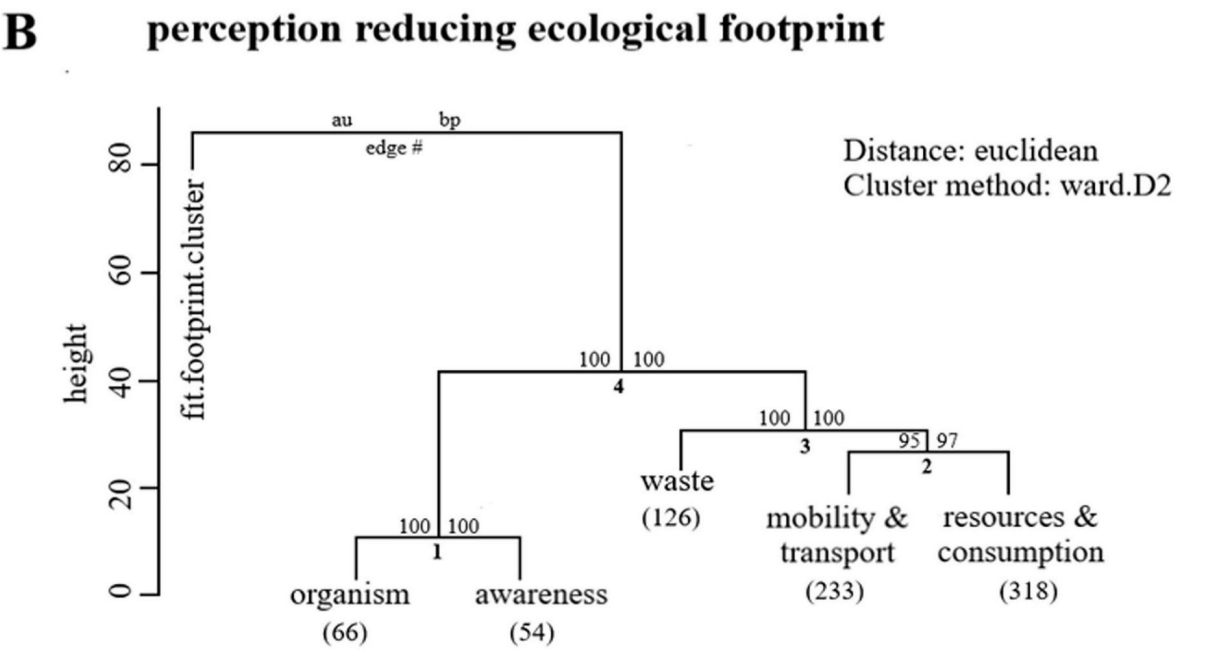

B
perception reducing ecological footprint
au
bp
edge #
fit.footprint.cluster
height
0
20
40
60
80
Distance: euclidean
Cluster method: ward.D2
100
100
100
100
95
97
100
100
4
3
2
1
waste
(126)
mobility &
transport
(233)
resources &
consumption
(318)
organism
(66)
awareness
(54)

Fig 3. Cluster dendrogram with p-values based on the freshmen's perception: (A) greatest environmental hazard ($N_{participant's}$ = 400) and (B) reducing ecological footprint ($N_{participant's}$ = 413). Numbers above the branches on the right: standard bootstrap p-value and on the left illustrate approximately unbiased (AU) p-values (Clusters with AU > = 95% are indicated by the rectangles and are considered to be strongly supported our data). Numbers in brackets below the categories are the observation of all participants.

https://doi.org/10.1371/journal.pone.0234560.g003

human dominance was observed [57]. Half of them followed the idea of nature, a finding that other studies with adults confirmed [58,59]. According to literature, the *environment* was associated in the 1990s with degradation [60] whereas in our study only a few conceptions concerning anthropocentric influences (*e.g.* town) were observed. In contrast, *nature* is perceived as almost entirely positive in itself, in the present and the past. Regarding the most observed main categories concerning *emotion/feelings* toward nature, we identified three sub-categories: calmness (N = 277), joy (N = 149) and aesthetic appreciation (N = 129). This stands for a good, self-determined life, a symbol of nature as a good life and a place for relaxation [61]. Most observations referred to freedom/free and silence. This is in line with more than thousands of young people, who associated the concept of nature with peace, recreation, forest, beauty, animals and plants [62]. Nature, in general, is often accompanied by beautiful childhood memories [63]. How can we protect the environment when some concepts are missing or misunderstood? Our study findings revealed little information about perceptions of animals, plants, organism or humans. No conceptions relating to fungi, microorganisms or bacteria were observed. Fewer findings referred to ecological threats and less interest (adapted from the previous study [47]), detected by the same participants. Furthermore, it omitted that conceptions regarding the term *environment* by a view and self-interest regarding the subjective theory. As already outlined, conceptions are perceived to depend on the topic. Values reflect intrinsic motivation [64] to protect the environment. However, social desirability rises with increasing age, which is confirmed by numerous studies (*e.g.* [65–67]). Several authors criticize the shift toward sustainable development. Bonnet, for example, rejected the sustainable concept of a human-related relationship with nature [57]. The Brundtland Report (known as Our Common Future) fosters sustainability first [4], following the Rio Declaration of Agenda 2021 and 2030 [6,68]. An appropriate ecocentric education possibility is necessary because it includes all lifeforms and ecosystems with its intrinsic value [69]. This is significant because human welfare concerning ESD is positioned in the centre [70,71]. We concluded that is not important whether perceptions of the environment are following just one ethical concept. It is more important how many conceptions are available in accordance with a persons' prevalent

Table 5. Binary logistic regression of coefficients regarding environmental hazard[1] and footprint[2].

Category	$\beta_{intercept}$	SD	z-value	*Pr(>|z|)*	eβ (INS)
Awareness[1]	-1.34	±0.40	-3.41	>0.001	1.08
Awareness[2]	-1.72	±0.53	-3.28	>0.001	0.92
Mobility & transport[1]	-0.50	±0.37	-1.35	0.177	0.93
Mobility & transport[2]	-0.22	±0.34	-0.66	0.512	1.06
Resources & consumption[1]	-1.31	±0.40	-3.31	>0.001	1.10
Resources & consumption[2]	0.03	±0.37	0.082	0.934	1.21
Organism[1]	-0.11	± 0.34	0.31	0.754	0.99
Organism[2]	-1.47	± 0.49	-3.03	0.002	0.92
Waste[1]	-1.37	± 0.55	-2.50	0.012	0.81
Waste[2]	-1.49	± 0.39	-3.82	0.001	1.14

eβ = Odds ratio

https://doi.org/10.1371/journal.pone.0234560.t005

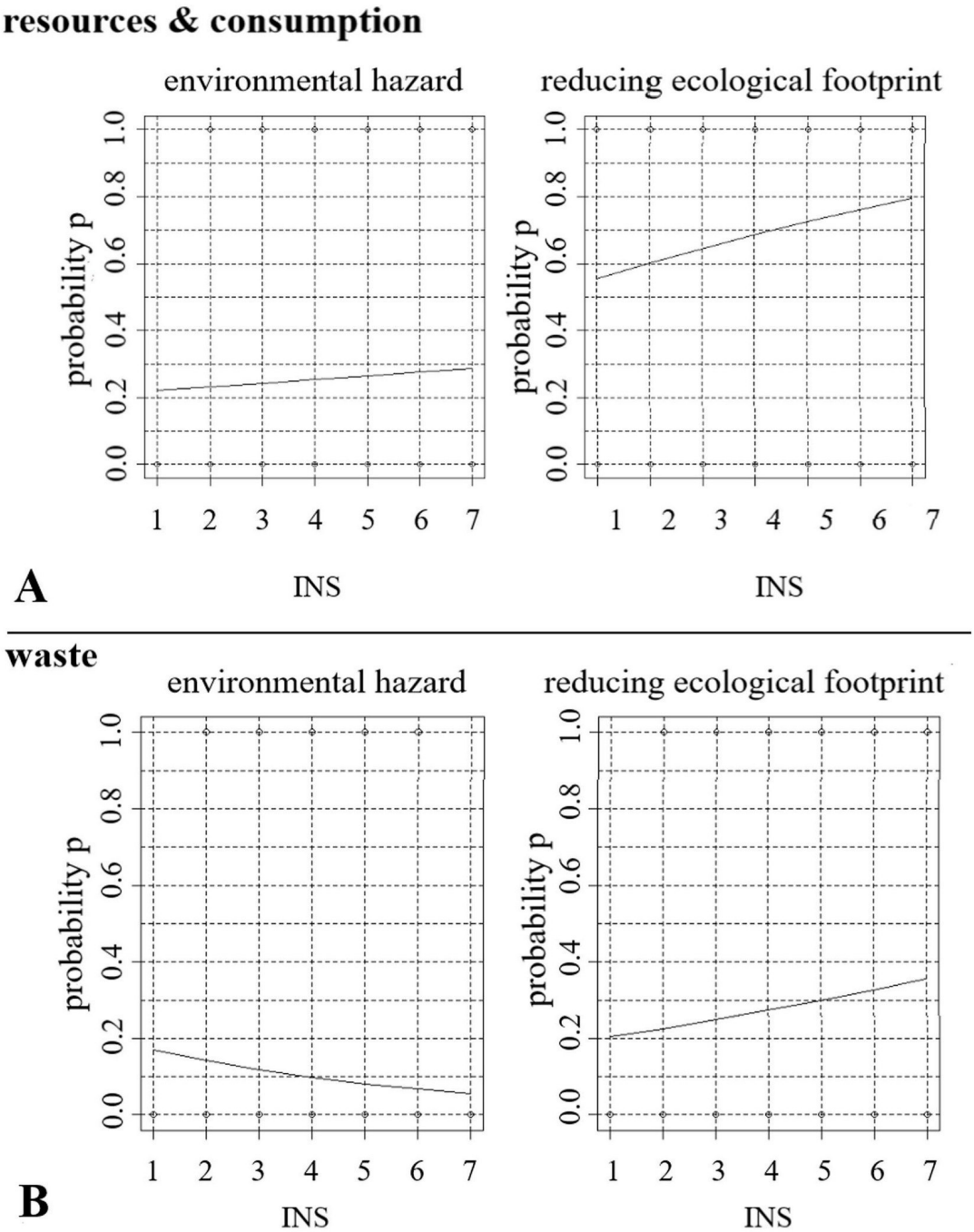


Fig 4. Binary logistic regression analysis, exemplary (A) *resources & consumption* and (B) *waste* perception of the greatest environmental hazard and present ideas to reduce their ecological footprint.

https://doi.org/10.1371/journal.pone.0234560.g004

values-system. Here, we confirm self-interest regarding feelings and emotions. However, the environment was under a wide range of humans as a part of it.

Environmental hazard versus ecological footprint perceptions

The *Club of Rome* became one of the first publications pointing at the limitations of sustainability [2]. Further documents highlighted the planetary carrying capacity as affected by natural resources (soil, air, water and genetic diversity) [3]. Climate change, microplastic, light pollution, species extinction–the list of problems that are endangering the nature and environment, seems endless. How do people perceive threats to the environment and in what sense are humans willing to interact with nature? Concept ideas concerning the greatest environmental hazards and perceptions to reduce freshmen's' ecological footprints were not perceived equal. By using the connectedness to nature level as an explanatory variable, some categories showed no effect, but others do. Almost two hundred freshmen perceptions referred to the human as the greatest environmental hazard threat, independent of their declared value of connectedness to nature. One of the greatest threats concerns the sub-category *air and land pollution* ($N = 112$). The most important result regarding the ecological footprint was the mean category *resource and consumption*. Many conceptions were found regarding *saving energy and water* ($N = 163$), resources & *consumption* (*e.g.* fair trade, second hand and regional/ seasonal) ($N = 150$) and *food consumption* ($N = 107$). Regional and seasonal components seem to be the first step towards sustainability in the freshmen's' minds if they implement their concept idea in their daily life. According to various studies, humans work hard to change their habits in general [72,73]. The following study about consumer perception, awareness of meat production and consumer willingness of changing behaviour regarding sustainable protein consumption (alternatives, insects) was not received well [74]. Our present study findings pointed to a variety of conceptions regarding the main category *waste* and *mobility & transport*. One relevant sub-category refers to *restrict mobility* ($N = 110$) and *car/aircraft/ship* ($N = 111$). Similarities follow using more *public transport/riding a bicycle/carpool* ($N = 157$), which was not surprising if the university was in the city centre and parking lots possibilities are rare and expensive. Based on the participants declare value of connectedness to nature, the higher the INS was, the higher they scored in each of the three categories, which is *waste*, *mobility & transport* and *resources & consumption*. Intervention in environmental studies have shown that the effect of improving the connectedness to nature level contributes to an environmentally friendly consumption behaviour [75]. A suggestion would be add a reliable psychological measuring instrument [76] to explore patterns in conception and behaviour equally. A considerable proportion of variance is unpredictable (e.g. social desirability, self-interest) [77] that we cannot exclude in our data.

Conclusion

Sustainable perceptions are present in freshmen minds after having completed primary and secondary school within the past UN decade. As a result, half of all responses expressed ideas of fair trade, second hand and regional/ seasonal products. A similar pattern applies to saving energy and water resources. Alternatives to mobility and transport were often stated though perceptions and conscious implementation of concept ideas still requires disentanglement. General scientific concepts were present for the term environment (e.g. interaction between organism or habitat), which integrated humans as a part of it and as one of the greatest environmental hazards. The freshmen responses predominantly showed a self-perception as being a part of the environment (we live/surround us) against a small group in the centre, (I live/surround me). Many perceptions about the environment refer to nature associated with positive

emotions and feelings (e.g. hobby, calmness, relaxation). However, ESD creates conceptions aligned with danger and ideas for less exploitation of natural resources although concerning human prosperity. Green educational initiatives have shown that individual behaviour can be influenced positively in the course outreach modules, which has also been shown at the outreach facility Biosphere 2; there, students not only gained system knowledge based on an informal half-day educational program, the latter also induced changes in motivation or fascination, which affect behaviour accordingly [78]. Furthermore, a classroom project demonstrated that energy consumption can be reduced within a ten-week intervention based on a daily routine to prompt environmentally friendly behaviour [79]. In this case, students who demonstrate lower environmental behaviour scores increase their knowledge (action-related and effectiveness knowledge) to the same level as those with higher scores. Future studies concerning the ESD goals may need to focus on qualitative and quantitative conceptions and improve educational interaction in general.

Supporting information

S1 Dataset. Dataset of environment and nature.
(XLSX)

Acknowledgments

The authors are very grateful to all students for their time and engagement in this study. We also thank Tessa-Marie Baierl for proofreading. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the position of the founding institutions.

Author Contributions

Conceptualization: Michaela Maurer.

Data curation: Michaela Maurer.

Formal analysis: Michaela Maurer.

Funding acquisition: Franz Xaver Bogner.

Investigation: Michaela Maurer.

Methodology: Michaela Maurer.

Project administration: Michaela Maurer, Franz Xaver Bogner.

Resources: Michaela Maurer, Franz Xaver Bogner.

Software: Franz Xaver Bogner.

Supervision: Franz Xaver Bogner.

Validation: Michaela Maurer.

Visualization: Michaela Maurer.

Writing – Review & Editing: Franz Xaver Bogner.

Writing – original draft: Michaela Maurer.

References

1. Carson R. Silent Spring. Boston, MA: Houghton Mifflin Co.; 1962.

2. Meadows DH, Meadows DL, Randers J, Behrens WW. The limits to growth. New York; 1972.
3. Boylan M. Environmental Ethics. Second Edi. Boylan M, editor. Encyclopedia of Biodiversity. Wiley-Blackwell; 2013. https://doi.org/10.1016/b0-12-226865-2/00106-1
4. UNWCED (United Nations World Commission on Environment and Development). Our Common Future (Brundtland Report). Oxford: Oxford University Press, UK; 1987.
5. UNESCO-IEEP. Environmental Education: Module for Pre-Service Training of Science Teachers and Supervisors for Secondary Schools. Environmental Educational Series. 1985. p. 123.
6. Nation United. Rio Declaration on Environment and Development—Preamble. 3rd ed. In: Wheeler SM, Beatley T, editors. The Sustainable Urban Development Reader. 3rd ed. Taylor & Francis; 1992. pp. 79–86.
7. UNESCO-UNEP. Environmental Literacy. Connect. 1989: 1–2. Available: http://unesdoc.unesco.org/images/0015/001535/153577eo.pdf
8. UNESCO. The Stockholm Declaration. Stockholm, Sweden; 1972.
9. UNESCO UNEP. Recommendations of the Intergovernmental Conference on Environmental Education Tbilisi. USSR. France: UNESCO; 1978. pp. 1–96.
10. UN (United Nation). The Sustainable Development Goals Report 2017. New York; 2017.
11. Rieckmann M. Education for Sustainable Development Goals: Learning Objectives. Paris, France: UNESCO; 2017.
12. Bogner FX, Wiseman M. Outdoor ecology education and pupils' environmental perception in Preservation and Utilisation. Sci Educ Int. 2004; 15: 27–48.
13. Kollmuss A, Agyeman J. Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behaviour? Environ Educ Res. 2002; 8: 239–260. https://doi.org/10.1080/13504620220145401
14. Andresen L, Boud D, Cohen R. Experience-based learning. Foley G (Ed), Understandisng adult education and training (2nd ed, pp 225–239). Sydney: Allen & Unwin.; 1999. https://doi.org/10.1016/j.nepr.2008.05.002
15. Piaget J. Cognitive development in children: Piaget development and learning. J re. 1964; 2: 176–186.
16. Kaiser FG, Hartig T, Brügger A, Duvier C. Environmental Protection and Nature as Distinct Attitudinal Objects: An Application of the Campbell Paradigm. Environ Behav. 2011; 45: 369–398. https://doi.org/10.1177/0013916511422444
17. DeKock A, Sleegers P, Voeten MJM. New Learning and the Classification of Learning. Rev Educ Res. 2004; 74: 141–170. https://doi.org/10.3102/00346543074002141
18. Buell L. The future of environmental criticism: Environmental crisis and literary imagination. Blackwell Publishing; 2009.
19. Manni A, Sporre K, Ottander C. Mapping What Young Students Understand and Value Regarding Sustainable development. Int Electron J Environ Educ. 2013; 3: 17–35.
20. Gitay H, Suárez A, Watson R. Climate change and biodiversity. IPCC Rep. 2002; 77. https://doi.org/10.2307/1551672
21. Thorn CJ, Bissinger K, Thorn S, Bogner FX. 'Trees live on soil and sunshine!'—Coexistence of scientific and alternative conception of tree assimilation. PLoS One. 2016;11. https://doi.org/10.1371/journal.pone.0147802 PMID: 26807974
22. Gungordu N, Yalcin-Celik A, Kilic Z. Students' Misconceptions about the Ozone Layer and the Effect of Internet-Based Media on It. Int Electron J Environ Educ. 2017; 7: 1–16. Available: http://ezproxy.lib.uconn.edu/login?url=https://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=EJ1130607&site=ehost-live
23. Çimer OS, Çimer A, Ursavas N. Student teachers' conceptions about global warming and changes in their conceptions during pre-service education: a cross sectional study. Educ Res Rev. 2011; 6: 592–597.
24. Bonnett M, Elliot J. Editorial. Cambridge J Educ. 1999; 29: 309–311.
25. Pelletier LG, Tuson KM, Green-Demers I, Noels K, Beaton AM. Why Are You Doing Things for the Environment? The Motivation Toward the Environment Scale (MTES). J Appl Soc Psychol. 1998; 28: 437–468. https://doi.org/10.1111/j.1559-1816.1998.tb01714.x
26. Quinn F, Castéra J, Clément P. Teachers' conceptions of the environment: anthropocentrism, non-anthropocentrism, anthropomorphism and the place of nature. Environ Educ Res. 2016; 22: 893–917. https://doi.org/10.1080/13504622.2015.1076767
27. Payne P. Children's Conceptions of Nature. Aust J Environ Educ. 1998; 19–26.

28. Castéra J, Clément P, Munoz F, Bogner FX. How teachers' attitudes on GMO relate to their environmental values. J Environ Psychol. 2018; 57: 1–9.
29. Taylor PW. Respect for nature: A theory of environmental ethics. Environmental Ethics. 2013. pp. 152–162.
30. Ingold T. The Perception of the Environment: Essays on Livelihood, Dwelling and Skill. 1std Editi. Routledge; 2002.
31. VonUexkúll JJ. The theory of meaning. Simiotica. 1982; 42: 25–82.
32. Lévêque C. Ecology From Ecosystem to Biosphere. CRC Press; 2003.
33. Ingold T. Culture and the perception of the environment. In: Croll E, Parkin D, editors. Bush Base, Forest Farm. 2014. https://doi.org/10.4324/9780203036129
34. Attfield R. Environmental ethics: An overview for the twenty-first century. second edi. John Wiley & Sons; 2014.
35. Bogner FX, Brengelmann JC, Wiseman M. Risk-taking and environmental perception. Environmentalist. 2000; 20: 49–62.
36. Cedillo CV. On Empathy, Anthropocentrism, and Rhetorical Tropes: An Analysis of Online "Save the Bees!" Campaign Images. Screening the Nonhuman: Representations of Animal Others in the Media. 2016. p. 185.
37. Botar O. Defining Biocentrism. Biocentrism Mod. 2017; 15–46.
38. Thompson SCG, Barton MA. Ecocentric and Anthropocentric Attitudes Toward the Environment. J Environ Psychol. 1994; 14: 149–157.
39. O'neill J, Holland A, Light A. Environmental values. Abingdon, Routledge; 2008.
40. Bogner FX, Wiseman M. Toward Measuring Adolescent Environmental Perception. Eur Psychol. 1999; 4: 139–151. https://doi.org/10.1027//1016-9040.4.3.139
41. Schneiderhan-Opel J, Bogner FX. Between environmental utilization and protection: Adolescent conceptions of biodiversity. Sustainability. 2019;11. https://doi.org/10.3390/su11174517
42. Schneiderhan-Opel J, Bogner FX. The relation between knowledge acquisition and environmental values within the scope of a biodiversity educational module. Sustainability. 2020; 12. https://doi.org/10.3390/su12062323
43. Frantz CMP, Mayer FS. The importance of connection to nature in assessing environmental education programs. Stud Educ Eval. 2014; 41: 85–89. https://doi.org/10.1016/j.stueduc.2013.10.001
44. Otto S, Pensini P. Nature-based environmental education of children: Environmental knowledge and connectedness to nature, together, are related to ecological behaviour. Glob Environ Chang. 2017; 47: 88–94. https://doi.org/10.1016/j.gloenvcha.2017.09.009
45. Blumstein DT, Saylan C. The failure of environmental education (and how we can fix it). PLOSBiology. 2007;5. https://doi.org/10.1371/journal.pbio.0050120 PMID: 17439304
46. Worldbank. 2020 [cited 26 Feb 2020]. Available: https://data.worldbank.org/indicator/EN.POP.DNST?end=2018&locations=CH&start=1997&year_high_desc=false
47. Maurer M, Bogner FX. How freshmen perceive environmental education (EE) and education for sustainable development (ESD). PLoS One. 2019; 14: 1–16. https://doi.org/10.1371/journal.pone.0208910 PMID: 30640908
48. Liefländer AK, Fröhlich G, Bogner FX, Schultz PW. Promoting connectedness with nature through environmental education. J Environ Educ. 2013; 19: 370–384. https://doi.org/10.1080/13504622.2012.697545
49. Mayring P. Qualitative Content Analysis. Qual Soc Res. 2000;1.
50. Cohen J. A coefficient for agreement for nominal scales. Educ Psychol Meas. 1960; 20: 37–46.
51. Suzuki R, Shimodaira H. Pvclust: an R package for assessing the uncertainty in hierarchical clustering. Bioinformatics. 2006; 22: 1540–1542. https://doi.org/10.1093/bioinformatics/btl117 PMID: 16595560
52. Wiseman M, Bogner FX. A higher-order model of ecological values and its relationship to personality. Pers Individ Dif. 2003; 34: 783–794.
53. Bogner FX, Wiseman M. Adolescents' attitudes towards nature and environment: Quantifying the 2-MEV model. Environmentalist. 2006; 26: 247–254. https://doi.org/10.1007/s10669-006-8660-9
54. Dunlap RE, Van Liere KD. The "new environmental paradigm". J Environ Educ. 1978; 9: 10–19.
55. Bogner FX. Environmental values (2-MEV) and appreciation of nature. Sustainability. 2018;10. https://doi.org/10.3390/su10020350

56. Schultz. Inclusion with nature: Understanding the psychology of human–nature interactions. In: Schultz. In P. Schmuck & P. W., (Eds.), Development T psychology of sustainable, New (pp. 61–78)., Kluwer. Y, editors. Psychology of sustainable development. Boston; 2002. pp. 61–78.
57. Pointon P. 'The city snuffs out nature': young people's conceptions of and relationship with nature. Environ Educ Res. 2014; 20: 776–794. https://doi.org/10.1080/13504622.2013.833595
58. Munoz F, Bogner F, Clement P, Carvalho GS. Teachers' conceptions of nature and environment in 16 countries. J Environ Psychol. 2009; 29: 407–413. https://doi.org/10.1016/j.jenvp.2009.05.007
59. Flogaitis E, Agelidou E. Kindergarten teachers' conceptions about nature and the environment. Environ Educ Res. 2003; 9: 461–478.
60. Gerhard T. Die Geschichte ökologisch bedeutsamer Naturvorstellungen in deutschen Bildungskonzepten. Weinheim; 1990.
61. Kellert SR. The biological basis for human values of nature. In: Washington D., editor. The biophilia hypothesis. Island Press; 1993. pp. 42–69.
62. Schuster K, Hartkemeyer T, Krömker D. Naturschutzorientierte Lebensstilorientierungen bei Jugendlichen [Nature conservation-oriented lifestyle orientations among students]. In: Schuster K., Hartkemeyer T., Krömker D, editor. Gesellschaft und Naturschutz. Bonn, Bad Godesberg, Germany: Bad Godesberg; 2008. pp. 89–92.
63. Strife S, Downey L. Childhood development and access to nature: A new direction for environmental inequality research. Organ Environ. 2009; 22: 99–122. https://doi.org/10.1177/1086026609333340 PMID: 21874103
64. Steg L, De Groot JI. Environmental values. The Oxford handbook of environmental and conservation psychology. 2012.
65. Kaiser FG. A general measure of ecological behavior. J Appl Soc Psychol. 1998; 28: 395–422. https://doi.org/10.1111/j.1559-1816.1998.tb01712.x
66. Boeve-de Pauw J, Van Petegem P. Because my friends insist or because it makes sense? Motivation towards the Environment. Sustainability. 2017;9. https://doi.org/10.3390/su9050750
67. Oerke B, Bogner FX. Gender, age and subject matter: impact on teachers' ecological values. Environmentalist. 2010; 30: 111–122.
68. UNGA. Transforming our world: The 2030 agenda for sustainable development. A New Era Glob Heal. New York, NY: UN General Assembly; 2015.
69. Washington H, Taylor B, Kopnina H, Cryer P, Piccolo JJ. Why ecocentrism is the key pathway to sustainability Environmental education (EE) View project. 2017; 1: 35–41.
70. Kopnina H. Education for the future? Critical evaluation of education for sustainable development goals. J Environ Educ. 2020; 1–12. https://doi.org/10.1080/00958964.2019.1710444
71. Kopnina H. Education for sustainable development (ESD): The turn away from 'environment' in environmental education? Environ Educ Res. 2012; 18: 699–717. https://doi.org/10.1080/13504622.2012.658028
72. Henn L, Taube O, Kaiser FG. The role of environmental attitude in the efficacy of smart-meter-based feedback interventions. J Environ Psychol. 2019; 63: 74–81. https://doi.org/10.1016/j.jenvp.2019.04.007
73. Rieger A, Thummert R, Fridgen G, Kahlen M, Ketter W. Estimating the benefits of cooperation in a residential microgrid: A data-driven approach. Appl Energy. 2016; 180: 130–141. https://doi.org/10.1016/j.apenergy.2016.07.105
74. Hartmann C, Siegrist M. Consumer perception and behaviour regarding sustainable protein consumption: A systematic review. rends Food Sci Technol. 2017; 61: 11–25.
75. Fröhlich G, Sellmann D, Bogner FX. The influence of situational emotions on the intention for sustainable consumer behaviour in a student-centred intervention. Environ Educ Res. 2013; 19: 747–764. https://doi.org/10.1080/13504622.2012.749977
76. Kaiser FG, Oerke B, Bogner FX. Behavior-based environmental attitude: Development of an instrument for adolescents. J Environ Psychol. 2007; 27: 242–251. https://doi.org/10.1016/j.jenvp.2007.06.004
77. Kaiser FG, Hübner G, Bogner FX. Contrasting the Theory of Planned Behavior With the Value-Belief-Norm Model in Explaining Conservation Behavior. J Appl Soc Psychol. 2005; 35: 2150–2170.
78. Baierl T, Bonine K, Johnson B, Bogner FX. Effects of informal learning on science motivation, fascination, and system knowledge at Biosphere 2.
79. Maurer M, Koulouris P, Bogner FX. Green Awareness in Action—How Energy Conservation Action Forces on Environmental Knowledge, Values and Behaviour in Adolescents' School Life. Sustainability. 2020; 12: 955. https://doi.org/10.3390/su12030955

F.3 Teilstudie C

Studies in Educational Evaluation 65 (2020) 100863

Contents lists available at ScienceDirect

Studies in Educational Evaluation

journal homepage: www.elsevier.com/locate/stueduc

Modelling environmental literacy with environmental knowledge, values and (reported) behaviour

Michaela Maurer*, Franz X. Bogner

University of Bayreuth, Z-MNU (Centre of Math & Science Education), Department of Biology Education, D-95477, Bayreuth, Germany

ARTICLE INFO

Keywords:
Environmental literacy model
Environmental knowledge
Attitudes and values
Reported behaviour
Assessment of educational modules

ABSTRACT

Environmental literacy integrates the variables cognitive knowledge, environmental values and ecological behaviour. We used three factors in our study: the first includes item-sets monitoring system-, action-related and effectiveness knowledge; the second examined the "Two Major Environmental Value model (2-MEV)"; and the third analysed General Ecological Behaviour (GEB) *via* an established behaviour scale. All participants were Greek sixth graders (N = 223, M = 11.7, SD ± 1.3, 49.8 % = males). Results of the Confirmatory Factor Analysis (CFA) indicated a linear relationship between environmental knowledge and values (ξ = 0.69, $p > .001$), values and (reported) behaviour (ξ = 0.80, $p > .001$), as well as between environmental knowledge and (reported) behaviour (ξ = 0.37, p = .001). We primarily used the theoretical environmental literacy model to holistically evaluate environmental education instead of applying isolated sales.

1. Introduction

"Skills", "environmental attitudes" and "environmental behaviour" were integrated into formal and informal syllabi around the globe after Rio (IUCN, 1970; UN (United Nation) (1992); UNESCO, 1972), transforming Environmental Education "EE" into 'Education for Sustainable Development "ESD". The original definition of EE refers to the following: environmental education is the process of recognising values and clarifying concepts in order to develop skills and attitudes necessary to understand and appreciate the interrelatedness among man, his culture and his biophysical surroundings. Environmental education also entails practice in decision-making and self-formulating of a code of behaviour about issues concerning environmental quality (IUCN, 1970).

Following the UN Decade of Education for Sustainable Development (2005–2014), the United Nations defined 17 Sustainable Development Goals (SDGs) and 169 goals for all nations – not exclusively industrial countries – in their Agenda 2030 (Rieckmann, 2017). The agenda promotes sustainable development to protect the environment and to save the planet. Modern education, therefore, is no longer restricted to formal education in classroom settings. National parks, zoos and botanical gardens have become popular outreach destinations. To assess the impact of such initiatives, valid measuring instruments, evaluating variables such as "attitudes", "awareness", or "ability", are required. There are numerous, individually or in combination, that test for factors like:

- environmental knowledge [*e.g.* Frick, Kaiser, & Wilson, 2004 – knowledge types: system- (SYS), action-related (ACT) and effectiveness knowledge (EFF)],
- attitudes/values *e.g.* New Environmental Paradigm (NEP) for adults (Dunlap & Van Liere, 1978); Two Major Environmental Value model (2-MEV) with its two higher order factors: Preservation (PRE), Utilization (UTL) and Appreciation of Nature (APR) for adolescents' (Bogner & Wiseman, 1999; Bogner, 2018) and
- environmental behaviour General Ecological Behaviour (GEB) (Kaiser, Oerke, & Bogner, 2007).

Recently, (Geiger, Dombois, & Funke, 2018) have trialled all three factors ("general environmental knowledge", "NEP" and "GEB") in one study focusing on intercultural predictors. Not long ago, (Fah & Sirisena, 2014) have analysed the relationship between the three factors using The Environmental Literacy Survey (ELS) measuring instrument. The three factors were sub-categories of environmental literacy regardless of any interventions. Fifteen knowledge items referring to three different topics (scores: four = correct answer; zero = incorrect answer) were used as well as 15 attitude items evaluated by means of a 5-point Likert scale and 15 behavioural items. We have analysed a mutual interaction – comparison using the environmental literacy model to assess environmental knowledge, values and, general

* Corresponding author.
E-mail address: Michaela.Maurer@uni-bayreuth.de (M. Maurer).

https://doi.org/10.1016/j.stueduc.2020.100863
Received 20 January 2019; Received in revised form 25 February 2020; Accepted 26 February 2020

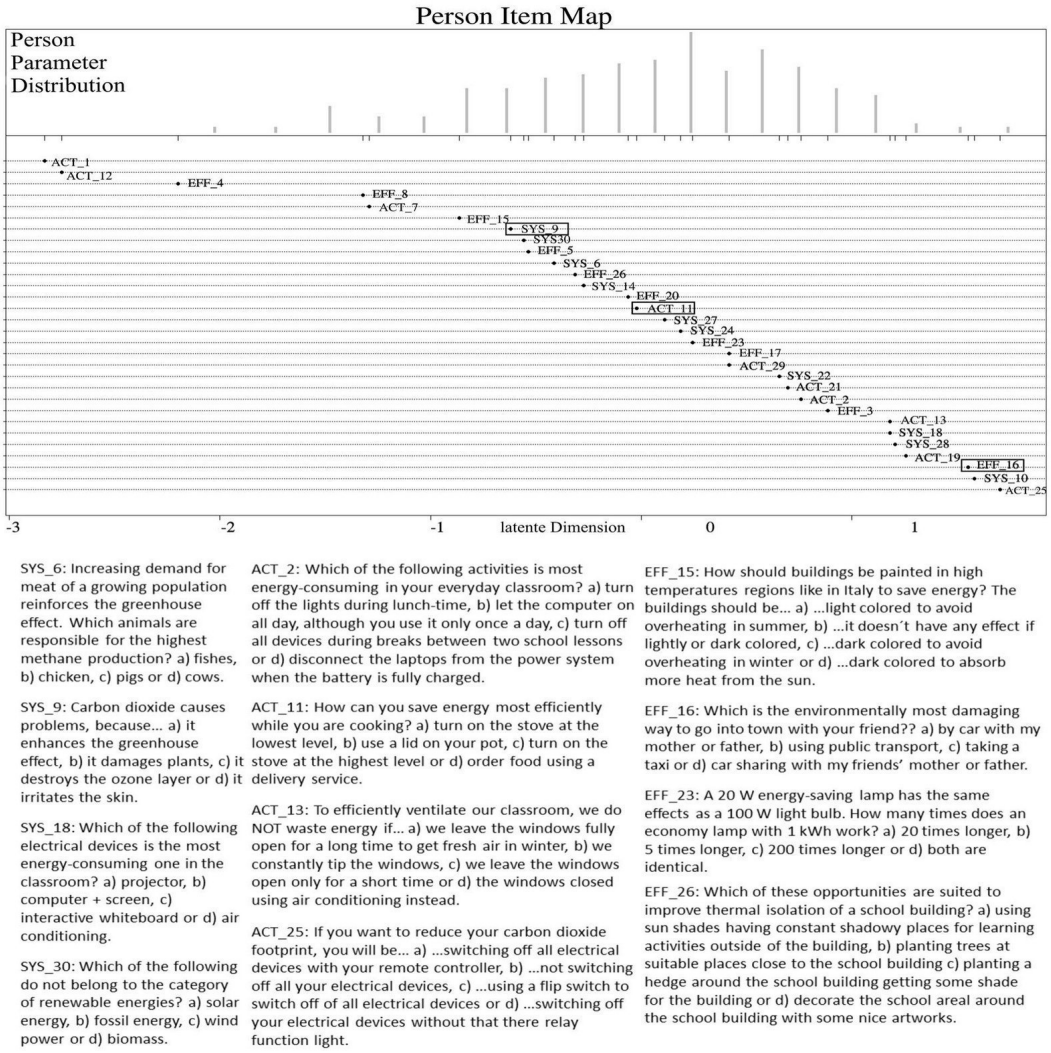


Fig. 1. Person-Item Map of "environmental knowledge". Black dots: knowledge items. Grey bars: estimated person composite distribution.

ecological behaviour (adjusted from (Roczen, Kaiser, & Bogner, 2014; Bissinger & Bogner, 2016). Compared to Geiger et al. (2018), we linked the above-mentioned variables, using our model to illustrate their various correlations, and recorded them for others to use. The model itself evaluates education programs like long-term interventions and, accordingly, constitutes an innovative large-scale approach.

1.1. Environmental Literacy (EL) and competence

The term "literacy" etymologically derives from an 18th-century word describing the general ability to read and write. Nowadays, literacy encompasses several fields of study such as science, politics and journalism. In environmental education, literacy mostly occurs in connection with the term Environmental Literacy (EL), which focuses on four main aspects:

i "affect" (environmental sensitivity, attitudes and values) and
ii "behaviour" (personal investment, responsibility and active involvement) (Roth, 1992; Scholz & Binder, 2011) as well as
iii "knowledge" (*e.g.* question about the relationship to environmental behaviour) (Maloney & Ward, 1973) and
iv "skills" (*e.g.* derived from the Tbilisi document) (UNESCO UNEP, 1978).

Together, they represent the four cornerstones of EL (Roth, 1992) and cover essential goals in science education, reaching beyond common conceptions of scientific literacy (physical-/living- and earth systems). To identify and measure scientific understanding, knowledge, and abilities (using public transport instead of driving into the city centre or buying local and seasonal instead of imported products) (Ribes, 1990) is easier than to qualitatively assess abstract scientific competency proficiency.

Proficiency competency in different areas like increase in knowledge, communication, expert knowledge and evaluation is an essential

part of education. Environmental knowledge, however, is not explicitly mentioned although it also influences and forms the levels of proficiency as well as personal attitudes (*e.g.* interest, responsibility, and intention to act) towards the environment. Both factors are required to assess environmentally responsible behaviour (Hollweg et al., 2011). Since 2000, PISA (Programme for International Student Assessment) is one way to evaluate students' general competence on international levels regarding "science literacy", "maths literacy" and "reading literacy". Participants, mostly 15-year old-pupils, received low scores in science literacy across many European countries *e.g.* Greece, Italy and Spain (Gurria, 2016). Tests like PISA primarily focus on assessing general competency and basic understanding in the above-mentioned areas, whereas the environment literacy model tests cognitive aspects of environmental knowledge and additional factors including values and (reported) behaviour.

1.2. Environmental knowledge

Environmental movements in the early 1970s raised the crucial question among educators, sociologists and psychologists why knowledge about environmental hazards alone does not affect environmental action. Until today, this question has remained unanswered. Current environmental problems are still largely ignored or not taken seriously enough (*e.g.* microplastic, Mintenig, Int-Veen, Löder, Primpke, & Gerdts, 2017); light pollution, Davies, Duffy, Bennie, & Gaston, 2016; species extinction, Valiente-Banuet et al., 2015), although initial environmental movements contributed to a broader public understanding (Carson, 1962 - global ban of DDT). Therefore, it is necessary to know what environmental knowledge actually is. Frick et al. (2004) discovered different types of knowledge, which they named "factual knowledge", "action-related knowledge" and "effectiveness knowledge". Their relationship has recently been tested on a group of adolescents using a competency model (Roczen et al., 2014). Factual knowledge (SYS) refers to basic knowledge in terms of recognising environmental problems *e.g.* those caused by humans *(e.g.* SYS_9 item of our knowledge questionnaire: *"Carbon dioxide causes problems, because… a) it enhances the greenhouse effect, b) it damages plants, c) it destroys the ozone layer or d) it irritates the skin."*, Fig. 1). While factual knowledge is not expected to influence behaviour (*e.g.* Grob, 1995; Levy, Orion, & Leshem, 2018), action-related knowledge (*e.g.* Díaz-Siefer, Neaman, Salgado, Celis-Diez, & Otto, 2015) and effectiveness knowledge do (Kim, Yun, Lee, & Ko, 2016). Thus, action-related knowledge (ACT) refers to the ability to act pro-environmentally based on environmental knowledge (Kaiser, 2003) *e.g.* ACT_11: *"How can you save energy most efficiently while you are cooking? a) turn on the stove at the lowest level, b) use a lid on your pot, c) turn on the stove at the highest level or d) order food using a delivery service."* (Fig. 1). Factual knowledge and action-related knowledge were assumed to provide the basis for effectiveness knowledge (EFF) (*e.g.* Frick et al., 2004), which includes the ability to assess the potential of different behaviours to protect the environment (Vicente-Molina, Fernandez-Sainz, & Izagirre-Olaizola, 2013). It is certainly more comfortable to take a taxi or to get a lift in someone else's car than to use public transport, *e.g.* EFF_16 item from the questionnaire: *"Which is the environmentally most damaging way to go into town with your friend?? a) by car with my mother or father, b) using public transport, c) taking a taxi or d) car sharing with my friends' mother or father."* (Fig. 1). Restrictions to mobility do not exclude choosing the most ecologically sustainable way to get from one place to another. Thus, additional variables should be included (*e.g.* Kaiser, Roczen, & Bogner, 2008). Many researchers agree that different knowledge types influence pro-environmental behaviour (Díaz-Siefer et al., 2015; Kaiser, 2003). Meinhold and Malkus (2005) revealed that environmental knowledge played an important role in assessing the relationship between environmental attitudes and environmental behaviour. "Education" as well as "social and cultural factors" may also contribute to pro-environmental knowledge (Geiger et al., 2018; Kollmuss & Agyeman, 2002; Levy et al., 2018; Meyer, 2015). Recently, Geiger, Geiger, and Wilhelm (2019) outlined the importance of general knowledge compared to environmental knowledge. Gardner and Stern (1996) described knowledge as a necessary but not essential contributor.

1.3. Environmental values

Various attitude scales developed before the 1970s often lacked reliability, validity, or replication studies (Dunlap & Jones, 2003). The measuring instrument "New Ecological Paradigm (NEP)" (Dunlap & Van Liere, 1978) was widely used to assess values in adults, whereas a suitable instrument for adolescents was still lacking. In the early 1990s, the "Two Environmental Value Model (2-MEV)" was developed to fill this gap. It proposed two orthogonal factors: preservation (PRE) and utilization (UTL) (Bogner & Wiseman, 1999) which were independently confirmed at different times (*e.g.* Boeve-de Pauw & Van Petegem, 2011; Borchers et al., 2014; Braun, Cottrell, & Diekers, 2018; Johnson & Manoli, 2010; Milfont & Duckitt, 2004). PRE is more biocentric than ecocentric as it encompasses not only environmental protection but also appreciation for nature (Thompson & Barton, 1994). UTL has an anthropocentric focus describing humans who tend to exploit natural resources (Wiseman & Bogner, 2003). The variant "appreciation" (APR) has recently been added to 2-MEV (Bogner, 2018), confirmed by Manoli and colleagues (Manoli, Johnson, Buxner, & Bogner, 2019). They discovered positive correlations between APR and PRE, using only 20 items in their analysis. Moreover, they proved the NEP's, the 2-MEV's and the APR's reliability. Higher NEP scores correlate with 2-MEV's preservation dimensions whereas lower NEP scores correspond to UTL.

1.4. Environmental behaviour

"The ultimate aim of education is to shape human behaviour" (Hungerford & Volk, 1990). There are numerous measuring scales but hardly any reliably measure behaviour. An adequate and valid measuring scale was, therefore, developed by Kaiser and colleagues (Kaiser et al., 2007): the "General Ecological Behaviour (GEB)". The scale contains 40 items separated into six sub-scales: consumerism, energy, mobility and transport, recycling, vicarious behaviour and waste avoidance. The measuring instrument was adapted for adolescents following Kaiser's (1999) probabilistic measurement based on self-report. Thereby, a person's attitude is linked to their behaviour. This, however, causes problems as environmentally friendly behaviour is not automatically associated with environmental awareness: a person might use a bike to stay healthy, to protect the environment, or simply to save money. Diekmann and Franzen (1997) and Diekmann and Preisendörfer (1992) developed similar sub-scales for consumer behaviour ("consumerism", "waste behaviour", "energy consumption "and "traffic behaviour"). Generally, the ability to protect the environment requires environmental knowledge (Hungerford & Volk, 1990). Numerous studies linked behaviour to other variables such as knowledge or attitude (*e.g.* Geiger et al., 2018), supplemented by individual subjective norms (individual perception and social pressure extended by related persons) and behavioural intentions (Ajzen, 2005).

1.5. Research goals

Our main aim was to apply "the competence model", an extension of the 2-MEV scale, adding GEB environmental knowledge items and an appreciation measure. We had three objectives: (i) to observe the environmental knowledge items and the distribution of person parameters along the latent dimension, (ii) to test the 2-MEV and APR scale and (iii) to observe the relationship between the inserted value variable, knowledge, and behaviour using a Confirmatory Factor Analysis (CFA).

2. Method

2.1. Sample

Our study encompassed 223 Greek students from upper primary classes (mainly sixth graders, $M = 11.7$, $SD \pm 1.3$, 49.8 % = male). We measured students' environmental literacy, before the GAIA (green awareness in action) project group conducted educational interventions. They are currently running a one-year program to test new teaching approaches for sixth graders, which aim at informing students about energy saving opportunities at school. Our paper and pencil questionnaires assessed: (i) an individual item set of system- (SYS), action-related (ACT) and effectiveness (EFF) knowledge, (ii) the 2-MEV and APR scales (Bogner, 2018) and (iii) General Ecological Behaviour (GEB) (Kaiser et al., 2007).

2.2. Instruments

(i) knowledge: to measure environmental knowledge, we adapted a set of 30 multiple-choice questions (ten each: SYS, ACT and EFF, one correct answer for each question), by focusing on issues of "energy "(items below, see Fig. 1).
(ii) values: using a five-point Likert scale: "1 = strongly disagree", "2 = disagree", "3 = partially agree", "4 = agree", "5 = totally agree", we added 20 items of the 2-MEV and APR (items below, see Table 1).
(iii) behaviour: using a five-point Likert-scale: "1 = never, 2 = seldom, 3 = sometimes, 4 = often, 5 = very often", we added 40 items for the GEB (examples, see Table 2).

Table 1
Factor loadings after analysis of 20 selected items for factors: preservation (PRE), utilization (UTL) and appreciation (APR). Score loadings below 0.3 were suppressed for reasons of simplicity.

	components		
	APR	PRE	UTL
APR_4: I take time to consciously smell flowers.	,720		
APR_3: I deliberately take time to watch stars at night.	,706		
APR_2: I take time to watch the clouds pass by.	,677		
APR_1: I consciously watch or listen to birds.	,637		
APR_15: Listening to the sounds of nature makes me relax.	,554		
APR_7: I enjoy gardening.	,553		
APR_5: I personally take care of plants.	,547		
PRE_17: Humans don't have the right to change nature as they see fit.		,558	
PRE_11: Dirty industrial smoke from chimneys makes me angry.		,539	
PRE_9: Humankind will die out if we don't live in tune with nature.		,529	
PRE_6: I save water by taking a shower instead of a bath (in order to spare water).		,522	
PRE_10: Not only plants and animals of economic importance need to be protected.		,511	,412
PRE_19: Human beings are not more important than other creatures.		,491	
UTL_21: The quiet nature outdoors makes me anxious.		-,356	,430
UTL_16: We don't need to set aside areas to protect endangered species.		-,525	
UTL_12: Nature is always able to restore itself.			,635
UTL_14: Our planet has unlimited resources.			,573
UTL_20: We need to clear forests in order to grow crops.			,559
UTL_18: People worry too much about pollution.			,481
UTL_8: We must build more roads so people can travel to the countryside.			,462

N = 223.

Table 2
Mean scores of two sub-scales (mobility and transport [M&T], recycling [R]) for General Ecological Behaviour (GEB).

Item	mean score
GEB_1: I ride a bicycle, take public transportation or walk to school. [M&T]	2.9
GEB_4: I am driven around by car. [M&T]	3.9
GEB_10: For short distances (within 15 minutes), I walk or ride a bike. [M&T]	2.7
GEB_8: I separate waste. [R]	3.8
GEB_14: I put empty batteries in the garbage. [R]	1.7
GEB_17: I collect and recycle used paper. [R]	3.6
GEB_20: I keep gift wrapping paper for reuse. [R]	2.8
GEB_27: I bring empty glass bottles to a recycling bin. [R]	3.8
GEB_40: For making notes, I take paper that is already used on one side. [R]	3.9

5 Likert scale (1) never, (2) seldom, (3) sometimes, (4) often, (5) very often ($N = 223$).

2.3. Statistical analysis

We conducted statistical tests using R (The R Foundation for Statistical Computing for Windows; Version 3.5.1 for Windows; www.r-project.org).

To assess our 30 knowledge items, a simple "Rasch-model" was applied. A "Person Item Map" (package *eRM*, method see Mair, Hatzinger, & Maier, 2009) indicated the location of knowledge items parameters and distribution of person parameters on the latent dimension (Fig. 1).

We used box plots (Figs. 2 and 3) to display values (2-MEV and APR: APR, PRE and UTL) and behaviour (GEB: mobility and transport, recycling, energy, waste avoidance, consumerisms and vicarious behaviours). We examined the structure of values (Bogner, 2018) using a factor analysis which was calculated in R combined with the respective *psych* packages (Revelle, 2012) before conducting a principal components' analysis (PCA) and oblimin rotation. Sampling adequacy was assessed using the Kaiser-Meyer-Olkin (KMO) test (> 0.6 for moderate, > 0.7 intermediate, > 0.8 good or > 0.9 for very good) (Kaiser, 1974).

"Confirmatory Factor Analysis (CFA)" used a maximum likelihood estimation (packages *lavaan*, method see Rosseel, 2012; packages *semPlot*, Epskamp, Eskamp, & MplusAutomation, 2019) to examine factor structures of knowledge, values (2-MEV and APR) and behaviour (GEB). Our model contains three factors: (i) knowledge (including sub-scales: SYS, ACT, EFF), (ii) values based on 2-MEV and APR (including sub-scales: APR, PRE, UTL) and (iii) behaviour based on GEB (including sub-scales: mobility and transport, recycling, energy, waste avoidance, consumerism and vicarious behaviours). We calculated participants' mean scores for each sub-scale. Chi-square, was used to assess

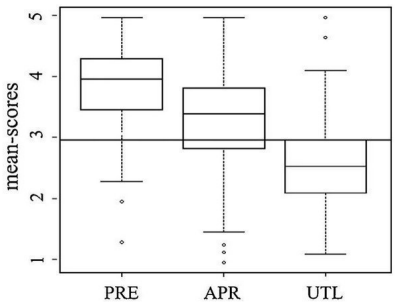


Fig. 2. Box and whiskers plot (n = 223) of mean scores for preservation (PRE), appreciation (APR) and utilization (UTL) of the 2-MEV and APR scale (Bogner, 2018).

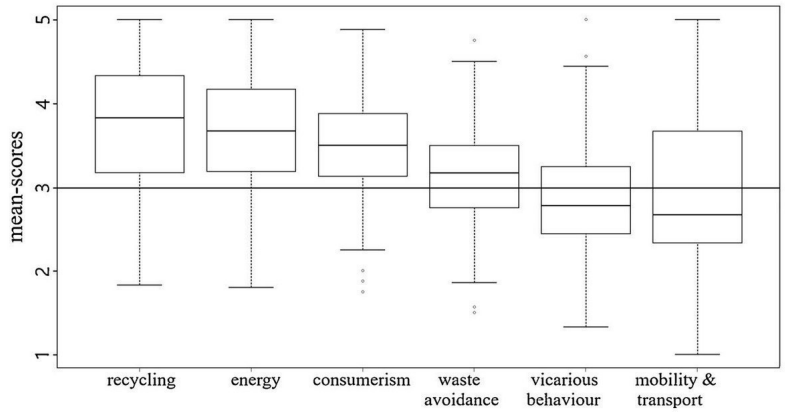


Fig. 3. Box and whiskers plot reflecting mean scores for GEB sub-scales (Kaiser et al., 2007): mobility and transport, recycling, energy, waste avoidance, consumerism and vicarious behaviours.

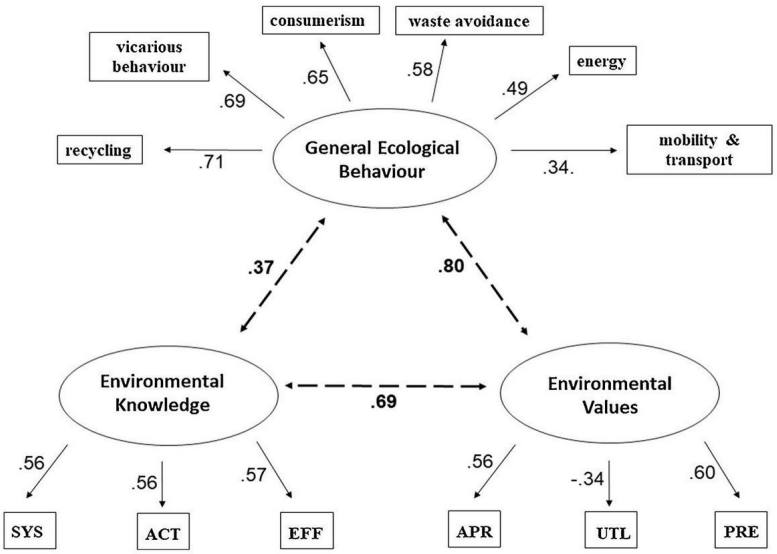


Fig. 4. Path analysis of pro-environmental competence for knowledge as well as value-related and behavioural levels in adolescents (N = 223). Arrows represent the standardised latent variable between levels and respective sub-scales. Dashed arrows indicate covariance's between those levels.

acceptability (RMSEA < .08, SRMR < .08 and CFI ≥ .90 (*e.g.* Browne & Cudeck, 1993; Hooper, Coughlan, & Mullen, 2008). The CFA is based on mean scores. The relationship between the latent factors "ξ" [environmental knowledge, values and (reported) behaviour] was measured *via* observed variables (*e.g.* ξ_{values} = APR + PRE + UTL), which are summarised in Fig. 4.

3. Results

3.1. Knowledge

To test our knowledge scale's quality, we applied a simple "Rasch-model" to three different knowledge types (30 items): system- (SYS), action-related (ACT) and effectiveness knowledge (EFF). All environmental knowledge items are within acceptable range of the weighted fit mean square (wMNSQ) between 0.80 and 1.20 for multiple-choice tests (0.84 ≤ wMNSQ 1.10 ≤) (Bond & Fox, 2001; Boone, Staver, & Yale, 2013). The histogram shows a broad distribution of person parameters and the bars placed below reflect the complexity of item formation. All 30 knowledge items are levelled, ranging from "fairly easy" (-3) on the left to "more difficult" (+2) on the right side of the latent dimension (Fig. 1).

The structural equation model (SEM) displays correlations between knowledge types: SYS and ACT (r = 0.313, p > .001), SYS and EFF (r = 292, p > 0.001) as well as ACT and EFF (r = 0.320, p > .001).

3.2. Environmental values

The MEV sub-scales show mean scores for preservation (PRE) M = 3.87, SD = ± 0.71; appreciation (APR) M = 3.36, SD = ± 0.79 and utilization (UTL) M = 2.58, SD = ± 0.68 including all participants. Thus, PRE and APR, in contrast to UTL scores, range above average (Fig. 2). Preservation (PRE) shows a clear asymmetry to the right whereas appreciation (APR) only indicates a slight asymmetry to the

right. Males and females do not differ significantly (less than 0.2).

Kaiser-Meyer-Olkin (KMO) (Kaiser, 1974) values for 2 MEV and APR were 0.8 and are, thus acceptable for factor analysis. A principal component analysis (PCA) 2 MEV's and APR's 20 items with Bogner (Bogner, 2018) (Table 1) revealed a three factor structure for PRE, APR and UTL. One item, however, showed unexpected factor loadings within two contrary factors: PRE and UTL (PRE_10). Cronbach's alpha = .78 for APR (n_{Items} = 6), alpha = .57 for PRE (n_{Items} = 7) and alpha = 0.59 for UTL (n_{Items} = 7) values were adequate.

Structural equation modelling (SEM) reveals correlations between APR and PRE (r = 0.354, p > .001) as well as between PRE and UTL (r = -0.185, p = .006). Correlations were observed between the factors "values" and "knowledge" (for APR: with ACT; for PRE: with SYS, ACT and EFF; for UTL: negative with SYS, ACT and EFF).

3.3. Environmental behaviour (GEB)

All six GEB sub-scales' (Kaiser et al., 2007) mean scores for *consumerism (M = 3.45, SD = ± 0.58), energy* (M = 3.64, SD = ± 0.64), *mobility and transport* (M = 2.89, SD = ± 0.96), *recycling* (M = 3.72, SD = ± 0.76), *vicarious behaviour* (M = 2.87, SD = ± 0.68) and *waste avoidance (M = 3.18, SD = ± 0.59)* (Fig. 3).

Within each sub-scale, some items indicate environmentally friendly behaviour if "never" or "seldom" was selected (like GEB_4). Other items indicate environmentally damaging behaviour if participants selected "often" or "very often" (like GEB_10) in *e.g.* the sub-category "mobility and transport". In sub-scales like "recycling" it would, however, indicate environmentally friendly behaviour (Table 2). For such "environmentally unfriendly items" (*e.g.* GEB_10, GEB_14, Table 2), we used reverse scores for statistical analysis.

Cronbach's alpha values were α = .70 for "vicarious behaviour" (n_{Items} = 9), α = .57 for "recycling" (n_{Items} = 6), and α = .53 for "consumerism" (n_{Items} = 8) in contrast to alpha values of α = .47 for "waste avoidance" (n_{Items} = 8), α = .36 for "mobility & transport" (n_{Items} = 3) and α = 0.33 for "energy" (n_{Items} = 6).

Structural equation modelling (SEM) yielded correlations between "behaviour" sub- scales (consumerism, energy, mobility and transport, recycling, vicarious behaviour and waste avoidance): *e.g.* "vicarious behaviour" and "recycling" (r = 0.37, p > 0.001), "energy" and "waste avoidance" (r = 0.27, p > 0.001), "vicarious behaviour" and "consumerism" (r = 0.26, p > 0.001). Between "behaviour" and "values" as well as "knowledge", correlations between the sub- scales: *e.g.* effectiveness knowledge and "energy" (r = 0.36, p > 0.001), "appreciation" and "vicarious behaviour" (r = 0.42, p > 0.001) were detected. To consider each individual sub-scale in relation to other relevant sub-scales *via* regression analysis, many connections of variable importance were identified. Appreciation (APR), for instance, contains all (reported) behaviour sub-scales except for mobility and transport. Between APR and environmental knowledge, we observed only one connection to action-related knowledge.

Confirmatory analysis (CFA) showed positive correlations between three factors: (i) environmental knowledge and values (ξ = 0.685, p > 0.001), (ii) environmental values and behaviour (ξ = 0.802, p > 0.001) and (iii) environmental knowledge and behaviour (ξ = 0.370, p > 0.001) (Fig. 4). Each factor sub-scale's load differs.

We evaluated model fit *via* chi-square: 117.288 (p > 0.001), RMSEA = 0.076 (p = .010), SRMR = 0.069 and CFI = 0.873 (*e.g.* Beauducel & Wittmann, 2005; Browne & Cudeck, 1993).

In contrast to (reported) behaviour (t = 1.586, df = 110, p = .124), participants' median split ($n_{high\text{-}achievers}$ = 110, $n_{low\text{-}achievers}$ = 110) displayed significant differences in environmental knowledge (t = 51.589, df = 110, p < .001) and values (t = 4.219, df = 110, p < .001). Across all three environmental knowledge types, high achievers attained higher scores than low achievers (SYS: $M_{high\text{-}achievers}$ = 0.57, $M_{low\text{-}achievers}$ = 0.33, t = 14.143, df = 110, p < 0.001; ACT: $M_{high\text{-}achievers}$ = 0.58, $M_{low\text{-}achievers}$ = 0.42, t = 10.923, df = 110, p < 0.001; EFF: $M_{high\text{-}achievers}$ = 0.66, $M_{low\text{-}achievers}$ = 0.45, t = 12.066, df = 110, p < 0.001). For values, we discovered two significant differences between PRE ($M_{high\text{-}achievers}$ = 4.09, $M_{low\text{-}achievers}$ = 3.67, t = 5.025, df = 110, p < 0.001) and UTL ($M_{high\text{-}achievers}$ = 2.35, $M_{low\text{-}achievers}$ = 2.82, t = -5.544, df = 110, p < 0.001).

4. Discussion

Numerous studies have proven that knowledge, attitude, behaviour and other variables are influenced or changed through specific interventions in formal and informal education (*e.g.* outreach activity) (*e.g.* Azeiteiro, Bacelar-Nicolau, Caetano, & Caeiro, 2015; Braun et al., 2018; Fančovičová & Prokop, 2011). We were interested in the factors' connectedness and their causal relationship with different sub-scales. Additionally, we assessed differences between low- and high achievers. In terms of environmental literacy and competence, our model covers (i) affect (using the example of 2-MEV and APR), (ii) behaviour (using the example of GEB) and (iii) cognitive knowledge (not conceptions).

4.1. Knowledge

As observed (Fig. 1), our knowledge scale displays a broad range of knowledge types: factual knowledge (SYS), action-related knowledge (ACT), and effectiveness knowledge (EFF) including the respective levels. Most items were neither too easy nor too difficult for our participants to answer and, thus, serve our model's purpose. There were only few outliers in our sample (*e.g.* too easy: ACT_1, 12 and EFF_4 or difficult: EFF_15, ACT_10 and SYS_25) that we did not delete for analysis. Some authors, however, are critical of specific environmental knowledge types (Geiger et al., 2019), as they lack replication. We partly understand their concerns as knowledge items are mostly tailored to individual target groups and topics *e.g.* "energy" (in our case). Knowledge constitutes the basis of many interventions (*e.g.* Díaz-Siefer et al., 2015; Otto & Pensini, 2017) which is why our model examines different knowledge types and their manifold values' sub-scales. As it also includes (reported) behaviour our model is suited for evaluating long term interventions, like eco-schools and green-school projects. Between high-achievers and low-achievers, we discovered significant values for all three knowledge types: system-related knowledge ($M_{high\text{-}achievers}$ = 0.57, $M_{low\text{-}achievers}$ = 0.33, p = > 0.001), action-related knowledge ($M_{high\text{-}achievers}$ = 0.58, $M_{low\text{-}achievers}$ = 0.42, p = > 0.001) and effectiveness knowledge ($M_{high\text{-}achievers}$ = 0.66, $M_{low\text{-}achievers}$ = 0.45, p = > 0.001).

4.2. Values

Measuring environmental attitudes ignited intense discussion with disappointing results: (Leeming, William, Porter, & Cobern, 1993) demonstrated in a meta-analysis that approaches to measure environmental attitudes may prove unsuccessful due to experimenting design, data analysis errors or inadequate psychometrics. Unfortunately, in our case, this applies to item_10 ("Not only plants and animals of economic importance need to be protected", Table 1) which showed substantial cross-loadings due to translation errors. Kibbe and colleagues have proven that rephrasing PRE-items produced negatively phrased UTL meanings and vice-versa (Kibbe, Bogner, & Kaiser, 2014). Although some studies contradict interconnectedness between environmental attitudes and environmental knowledge (*e.g.* Liefländer & Bogner, 2018) or, at best, show limited correlations (*e.g.* Boeve-de Pauw & Van Petegem, 2011), our analysis discovered such links (Fig. 4). Kaiser et al. (2008) emphasised the positive relationship between PRE, appreciative UTL and nature. Brick and Lewis (2014) confirmed that environmental attitudes may predict environmental behaviour, an essential goal of ESD (Environmental for Sustainable Development) (UNESCO, 2007; 2017). In contrast to the NEP's one-dimensional scale, the 2-MEV and APR consist of multiple sub-scales: appreciation, preservation and

utilization, which are suited for a more precise analysis. Additionally, while comparing values of low- and high achievers, we discovered that high achievers receive higher scores for preservation ($M_{high\text{-}achievers}$ = 4.09, $M_{low\text{-}achievers}$ = 3.67, p = > 0.001) and lower scores for utilization than low-achievers ($M_{high\text{-}achievers}$ = 2.35, $M_{low\text{-}achievers}$ = 2.82, p = > 0.001). Thus, high-achievers tend to be more environmentally friendly than low achievers (in this case). There is, however, no significant gender effect in contrast to studies of *e.g.* Boeve-de Pauw, Jacobs, & Van Petegem, 2014.

4.3. Behaviour

"General Ecological Behaviour (GEB)", an established measuring instrument with six sub-scales assessing ecological behaviour (mobility and transport, recycling, energy, waste avoidance, consumerisms and vicarious behaviours) (Kaiser et al., 2007) was extended to include sustainability goals. Several studies have shown that attitudes/values may predict behaviour and *vice versa* (Kaiser, Hübner, & Bogner, 2005). In our model, we identified several correlations between sub-categories of environmental knowledge, environmental values and (reported) behaviour. However, we do not list all. Co-variances of environmental values are higher for (reported) behaviour (r = 0.802, p > 0.001) than for environmental knowledge (r = 0.685, p > 0.001). Focussing on (reported) behaviour and environmental values, we observed the highest significant correlation for value sub-categories: (i) appreciation (APR) and vicarious behaviour (Std.all = 0.415, p = 0.000), (ii) preservation (PRE) and consumerism (Std.all = 0.262, p = 0.000) and (iii) utilization (UTL) and energy (Std.all = - 0.178, p = 0.009). Interactions between several categories, not just a single one, and different weightings (the highest variable is recycling, whereas the lowest variable is mobility and transport – Fig. 4) may explain relationships between values and (reported) behaviour. The sub-category "mobility and transport" scored lowest for levels of (reported) behaviour. We suggest that such levels may be owed to our participating sixth graders' decision-making influenced by their parents' decision. Additionally, most pupils lived in town and had to commute to our target schools, which were in remote areas and difficult to reach by public transportation. Each factor sub-scale of environmental knowledge has similar loadings compared to (reported) behaviour. Co-variances of environmental knowledge are higher in contrast to environmental values (r = 0.685, p > 0.001) and (reported) behaviour (r = 0.370, p > 0.001). For data considering (reported) behaviour and environmental knowledge, we observed the highest significant correlations for all three sub-categories of environmental knowledge between (i) system knowledge and energy (*Std. all* = 0.192, p = 0.005), (ii) action- related knowledge and recycling (*Std.all* = 0.1742, p = 0.010) and (iii) effectiveness-related knowledge and recycling (*Std.all* = 0.144, p = 0.033).

4.4. Limitation

For reasons of comparability, we have limited the sample to those students' who filled in all three parts of the paper and pencil questionnaires. A Rasch analysis was applied to all environmental knowledge items as a whole, not separately for all three dimensions. Our results are exemplary for one selected target group, that is, sixth graders from a South-Eastern European country. Furthermore, path analysis represents a total value of overall participants. In the next step, resulting profiles of an intervention will help to analyse different groups for different recommendations. According to literature, there are variances between different class levels or school types regarding the implementation. Further studies would need to show similarities or differences of the model.

4.5. Environmental Literacy model and conclusion

The "Environmental Literacy Model" encompasses three levels: cognitive knowledge types, values, and individual behaviour. Thus, it provides a valid framework to assess formal and informal education initiatives in the future. Path analysis showed that (reported) behaviour is more closely related to environmental values than to environmental knowledge. Knowledge, on the other hand, is considered to be the basis of values (Roczen et al., 2014) as its correlation with values is higher than to (reported) behaviour (Fig. 4). This is in line with literature since *e.g.* knowledge has a positive effect on attitudes/values and (reported) behaviour (Duerden & Wit, 2010; Falk & Balling, 1982). In contrast to structural equation analysis' (SEM) results, Lay & Anuthra (2014) identified only one correlation between attitudes and behaviour, suggesting more advance statistical analysis such as SEM to reflect EE programmes. The model offers possibilities to observe changes across different factors (environmental knowledge, values and (reported) behaviour) and their sub-categories, but it does not explain individual items. Our calculations with mean score levels do not offer such distinctions. Results of this study are only valid for this model and reflect a representative cross section of the population in a south-eastern European country. To apply the model to a new target group or content, environmental knowledge should be redesigned and re-examined (*e.g.* Rasch analysis) as it is unique for each intervention regarding the two factors values and (reported) behaviour. An appropriate sample size is required to perform a path analysis. We have calculated the Confirmatory Factor Analysis at mean score level which is why we cannot make any statements about individual items of each factor level. It is possible to extend the model with other factors like "emotions" [*e.g.* "Science Motivation Questionnaire (SMQ)" (Glynn, Taasoobshirazi, & Brickman, 2009)] or "motivation" [*e.g.* "The Motivation Toward the Environment Scale (MTE)" (Boeve-de Pauw & Van Petegem, 2017; Pelletier, Tuson, Green-Demers, Noels, & Beaton, 1998)]. This example has been already tested in environmental education.

As an after-school initiative for one year, the GAIA project appears to be an excellent opportunity to assess variables such as knowledge, values and /or individual behavioural regarding energy consumption and sustainability awareness in a pre-post design. In the end, children might actually learn how to save energy effectively.

Acknowledgements

We are grateful to all students involved in this study for their time and engagement. This project was funded by the "Qualitätsoffensive Lehrerbildung" (Grant: 01JA1601, https://www.qualitaetsoffensive-lehrerbildung.de/) and two European Horizon 2020 projects, "OSOS" (Open School For Open Society: grant agreement No. 741572, https://www.openschools.eu/) and "GAIA" (Green Awareness In Action: grant agreement No. 696029) as well as by the University of Bayreuth. Finally, this publication was funded by the German Research Foundation (DFG) and the University of Bayreuth too. We also thank Michael Wiseman for discussing earlier stages of our paper, Pavlos Koulouris for initiating the study and collaborating with us. We also thank Tamara Roth for proofreading. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the position of the founding institutions.

References

Ajzen, I. (2005). *Attitudes, personality, and behaviour* (second edi). McGraw-Hill Education (UK): Open University Press.

Azeiteiro, U. M., Bacelar-Nicolau, P., Caetano, F. J. P., & Caeiro, S. (2015). Education for sustainable development through e-learning in higher education: Experiences from Portugal. *Journal of Cleaner Production, 106*, 308–319. https://doi.org/10.1016/j.jclepro.2014.11.056.

Beauducel, A., & Wittmann, W. W. (2005). Simulation study on fit indexes in CFA based on data with slightly distorted simple structure. *Structural Equation Modeling A Multidisciplinary Journal, 12*(1), 41–75.

Bissinger, K., & Bogner, F. X. (2016). Environmental literacy in practice: Education on the tropical rainforest and climate change. *11th Conference of the European Researchers in*

Didactics of Biology (ERIDOB) 58.
Boeve-de Pauw, J., & Van Petegem, P. (2011). The effect of Flemish eco-schools on student environmental knowledge, attitudes, and affect. *International Journal of Science Education, 33*(11), 1513–1538. https://doi.org/10.1080/09500693.2010.540725.
Boeve-de Pauw, J., & Van Petegem, P. (2017). Because my friends insist or because it makes sense? Motivation towards the Environment. *Sustainability, 9*(5), https://doi.org/10.3390/su9050750.
Boeve-de Pauw, J., Jacobs, K., & Van Petegem, P. (2014). Gender differences in environmental values: an issue of measurement? *Environment and Behavior, 46*(3), 373–397. https://doi.org/10.1177/0013916512460761.
Bogner, F. X. (2018). Environmental values (2-MEV) and appreciation of nature. *Sustainability, 10*(2), https://doi.org/10.3390/su10020350.
Bogner, F. X., & Wiseman, M. (1999). Toward measuring adolescent environmental perception. *European Psychologist, 4*(3), https://doi.org/10.1027//1016-9040.4.3.139.
Bond, T. G., & Fox, C. M. (2001). *Applying the Rasch model.* Psychology Press.
Boone, W., Staver, J., & Yale, M. (2013). *Rasch analysis in the human science.* Springer Science & Business Media.
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.
Braun, T., Cottrell, R., & Diekers, 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.
Brick, C., & Lewis, G. J. (2014). Unearthing the "green" personality: Core traits predict environmentally friendly behavior. *Environment and Behavior, 48*(5), 635–658. https://doi.org/10.1177/0013916514554695.
Browne, M. W., & Cudeck, R. (1993). Alternative ways of assessing model fit. In K. A. Bollen, & J. S. Long (Eds.). *Testing structural equation models* (pp. 136–162). Newbury Park, CA: Sage.
Carson, R. (1962). *Silent spring.* Boston, MA: Houghton Mifflin Co.
Davies, T. W., Duffy, J. P., Bennie, J., & Gaston, K. J. (2016). Stemming the tide of light pollution encroaching into marine protected areas. *Conservation Letters, 9*(3), 164–171. https://doi.org/10.1111/conl.12191.
Díaz-Siefer, P., Neaman, A., Salgado, E., Celis-Diez, J. L., & Otto, S. (2015). Human-environment system knowledge: A correlate of pro-environmental behavior. *Sustainability, 7*(11), 15510–15526. https://doi.org/10.3390/su71115510.
Diekmann, A., & Franzen, A. (1997). CO2-Eine Herausforderung für die Menschheit [Co2-a human challenge]. In A. D. G. Kaufmann, & R. Hayoz (Eds.). *Einsicht in ökologische Zusammenhänge und Umweltverhalten [View of ecological interdependencies and environmental behaviour]* (pp. 120–138). Berlin, Heidelberg, Germany: Springer.
Diekmann, A., & Preisendörfer, P. (1992). Persönliches Umweltverhalten. Diskrepanzen zwischen Anspruch und Wirklichkeit [Personal environmental issues: discrepancy between expectations and reality]. *Kölner Zeitschrift Für Soziologie Und Sozialpsychologie, 44*, 2226–2251.
Duerden, M., & Wit, P. A. (2010). The impact of direct and indirect experiences on the development of environmental knowledge, attitudes, and behavior. *Journal of Environmental Psychology, 30*(4), 379–392. https://doi.org/10.1016/j.jenvp.2010.03.007.
Dunlap, R. E., & Jones, R. E. (2003). Environmental attitudes and values. *Encyclopaedia of Psychological Assessment, 1*, 364–369.
Dunlap, R. E., & Van Liere, K. D. (1978). The "new environmental paradigm". *The Journal of Environmental Education, 9*(4), 10–19.
Epskamp, S., Eskamp, M. S., & MplusAutomation, S. (2019). *Package 'semPlot'. Retrieved 25 February 2020.* fromhttps://cran.r-project.org/web/packages/semPlot/semPlot.pdf.
Fah, L. Y., & Sirisena, A. (2014). Relationships between the knowledge, attitudes, and behaviour dimensions of environmental literacy: A structural equation modelling approach using smartpls. *Jurnal Pemikir Pendidikan, 5*, 119–144.
Falk, J. H., & Balling, J. D. (1982). The field trip milieu: Learning and behavior as a function of contextual events. *The Journal of Educational Research, 76*(1), 22–28. https://doi.org/10.1080/00220671.1982.10885418.
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.
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.
Gardner, G. T., & Stern, P. C. (1996). *Environmental problems and human behavior.* NeedhamHeights, MA: Allyn and Bacon.
Geiger, S. M., Dombois, C., & Funke, J. (2018). The role of environmental knowledge and attitude: Predictors for ecological behavior across cultures. An analysis of argentinean and german students. *Environmental Psychology, 22*(1), 69–87.
Geiger, S. M., Geiger, M., & Wilhelm, O. (2019). Environment-Specific vs. General Knowledge and Their Role in Pro-environmental Behavior. *Frontiers in Psychology, 10*, 1–12. https://doi.org/10.3389/fpsyg.2019.00718.
Glynn, S. M., Taasoobshirazi, G., & Brickman, P. (2009). Science motivation questionnaire: Construct validation with nonscience majors. *Journal of Research in Science Teaching, 46*(2), 127–146. https://doi.org/10.1002/tea.20267.
Grob, A. (1995). A structural model of environmental attitudes and behavior. *Journal of Environmental Psychology, 15*, 209–220.
Gurria, A. (2016). PISA 2015 results in focus. *PISA in Focus, 67*(1).
Hollweg, K. S., Taylor, J. R., Bybee, R. W., Marcinkowski, T. J., McBeth, W. C., & Zoido, P. (2011). *Developing a framework for assessing environmental literacy: Executive summary*.
Hooper, D., Coughlan, J., & Mullen, M. R. (2008). Structural equation modeling: Guidelines for determining model fit. *Electronic Journal of Business Research Methods, 6*(1), 53–60.
Hungerford, H. R., & Volk, T. L. (1990). Changing learner behavior - through environmental education. *The Journal of Environmental Education Research, 21*(3), 8–21.
IUCN (1970). *International working meeting on environmental education in the school curriculum, final report*Gland, Switzerland: IUCN.
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*. https://doi.org/10.1080/00958964.2010.503716.
Kaiser, F. G., Roczen, N., & Bogner, F. X. (2008). Competence formation in environmental education : Advancing ecology-specific rather than general abilities. *Umweltpsychologie [Environmental Psychology], 12*(2), 56–70.
Kaiser, M. O. (1974). Kaiser-Meyer-Olkin measure for identity correlation matrix. *Journal of the Royal Statistical Society, 52*, 296–298.
Kaiser, F. G., Hübner, G., & Bogner, F. X. (2005). Contrasting the theory of planned behavior with the value-belief-norm model in explaining conservation behavior. *Journal of Applied Social Psychology, 35*(10), https://doi.org/10.3390/su11051286.
Kaiser, F. G., Oerke, B., & Bogner, F. X. (2007). Behavior-based environmental attitude: Development of an instrument for adolescents. *Journal of Environmental Psychology, 27*(3), 242–251. https://doi.org/10.1016/j.jenvp.2007.06.004.
Kaiser, F. G. (1999). A general measure of ecological behavior. *Journal of Applied Social Psychology, 28*(5), 395–422. https://doi.org/10.1111/j.1559-1816.1998.tb01712.x.
Kaiser, F. G. (2003). Ecological behavior's dependency on different forms of knowledge. *Applied Psychology, 52*(4), 598–613.
Kibbe, A., Bogner, F. X., & Kaiser, F. G. (2014). Exploitative vs. appreciative use of nature–Two interpretations of utilization and their relevance for environmental education. *Studies in Educational Evaluation, 41*, 106–112. https://doi.org/10.1016/j.stueduc.2013.11.007.
Kim, Y., Yun, S., Lee, J., & Ko, E. (2016). How consumer knowledge shapes green consumption: An empirical study on voluntary carbon offsetting. *International Journal of Advertising, 35*(1), 23–41. https://doi.org/10.1080/02650487.2015.1096102.
Kollmuss, A., & Agyeman, J. (2002). Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behaviour? *Environmental Education Research, 8*(3), 239–260. https://doi.org/10.1080/13504620220145401.
Leeming, F. C., William, O. D., Porter, B. E., & Cobern, M. (1993). Outcome research in environmental education: A critical review.pdf. *The Journal of Environmental Education, 24*(4), 8–21.
Levy, A., Orion, N., & Leshem, Y. (2018). Variables that influence the environmental behavior of adults. *Environmental Education Research, 24*(3), 307–325. https://doi.org/10.1080/13504622.2016.1271865.
Liefländer, A., & Bogner, F. X. (2018). Educational impact on the relationship of environmental knowledge and attitudes. *The Environmental Education Research, 24*(4), 611–624. https://doi.org/10.1080/13504622.2016.1188265.
Mair, P., Hatzinger, R., & Maier, M. J. (2009). *Extended Rasch modeling: The R package eRM.* Retrieved 25 February 2020, fromhttps://cran.r-project.org/web/packages/eRm/vignettes/eRm.pdf.
Maloney, M. P., & Ward, M. P. (1973). Ecology: Let's hear from the people: An objective scale for the measurement of ecological attitudes and knowledge. *The American Psychologist, 28*(7), 583–586.
Manoli, C. C., Johnson, B., Buxner, S., & Bogner, F. X. (2019). Measuring environmental perceptions grounded on different theoretical models: The 2-Major Environmental Values (2-MEV) model in comparison with the New Ecological Paradigm (NEP) scale. *Sustainability, 11*(5), https://doi.org/10.3390/su11051286.
Meinhold, J. L., & Malkus, A. J. (2005). Adolescent environmental behaviors: Can knowledge, attitudes and self-efficacy make a difference? *Environment and Behavior, 37*(4), 511–532. https://doi.org/10.1177/0013916504269665.
Meyer, A. (2015). Does education increase pro-environmental behavior? Evidence from Europe. *Ecological Economics, 116*, 108–121. https://doi.org/10.1016/j.ecolecon.2015.04.018.
Milfont, T. L., & Duckitt, J. (2004). The structure of environmental attitudes: A first- and second-order confirmatory factor analysis. *Journal of Environmental Psychology, 24*(3), 289–303.
Mintenig, S. M., Int-Veen, I., Löder, M. G. J., Primpke, S., & Gerdts, G. (2017). Identification of microplastic in effluents of waste water treatment plants using focal plane array-based micro-Fourier-transform infrared imaging. *Water Research, 108*, 365–372. https://doi.org/10.1016/j.watres.2016.11.015.
Otto, S., & Pensini, P. (2017). Nature-based environmental education of children: Environmental knowledge and connectedness to nature, together, are related to ecological behaviour. *Global Environmental Change, 47*, 88–94. https://doi.org/10.1016/j.gloenvcha.2017.09.009.
Pelletier, L. G., Tuson, K. M., Green-Demers, I., Noels, K., & Beaton, A. M. (1998). Why are you doing things for the environment? The motivation toward the environment scale (MTES). *Journal of Applied Social Psychology, 28*(5), 437–468. https://doi.org/10.1111/j.1559-1816.1998.tb01714.x.
Revelle, W. (2012). *). Procedures for psychological, psychometric, and personality research. Retrieved 25 February 2020.* fromhttps://doi.org/10.1007/s11336-008-9102-z.
Ribes, I. E. (1990). *Psicología general [General psychology].* Mexico: Editorials Trillas.
Rieckmann, M. (2017). *Education for sustainable development goals: Learning objectives.* Paris, France: UNESCO.
Roczen, N., Kaiser, F. G., & Bogner, F. X. (2014). A competence model for environmental education. *Environment and Behavior, 46*(8), 972–992. https://doi.org/10.1177/0013916513492416.

Rosseel, Y. (2012). lavaan: an R package for structural equation modeling and more Version 0. 3-1 (BETA). *Journal of Statistical Software, 48*(2), 1–36. https://doi.org/10.1002/jae.767.

Roth, C. E. (1992). *Environmental literacy: Its roots, evolution and directions in the 1990s.* Columbus, OH: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

Scholz, R. W., & Binder, C. R. (2011). *Environmental literacy in science and society: From knowledge to decisions.* Cambridge, UK: Cambridge University Press.

Thompson, S. C. G., & Barton, M. A. (1994). Ecocentric and anthropocentric attitudes toward the environment. *Journal of Environmental Psychology, 14*, 149–157.

UN (United Nation) (1992). Rio declaration on environment and development - Preamble. In S. M. Wheeler, & T. Beatley (Eds.). *The sustainable Urban development reader* (pp. 79–86). (3rd ed.). Taylor & Francis.

UNESCO (1972). *The Stockholm declaration.* Stockholm, Sweden.

UNESCO (2007). *The UN Decade for Education for Sustainable Development (DESD 2005–2014): The first two years.* Paris, France.

UNESCO UNEP (1978). *Recommendations of the intergovernmental conference on environmental education Tbilisi.* USSR. France: UNESCO.

Valiente-Banuet, A., Aizen, M. A., Alcantara, J. M., Arroyo, J., Cocucci, A., Galetti, M., ... Zamora, R. (2015). Beyond species loss: The extinction of ecological interactions in a changing world. *Functional Ecology, 29*(3), 299–307. https://doi.org/10.1111/1365-2435.12356.

Vicente-Molina, M. A., Fernandez-Sainz, A., & Izagirre-Olaizola, J. (2013). Environmental knowledge and other variables affecting pro-environmental behaviour: Comparison of university students from emerging and advanced countries. *Journal of Cleaner Production, 61*, 130–138. https://doi.org/10.1016/j.jclepro.2013.05.015.

Wiseman, M., & Bogner, F. X. (2003). A higher-order model of ecological values and its relationship to personality. *Personality and Individual Differences, 34*(5), 783–794.

F.4 Teilstudie D

sustainability

MDPI

Article

Green Awareness in Action—How Energy Conservation Action Forces on Environmental Knowledge, Values and Behaviour in Adolescents' School Life

Michaela Maurer [1,*], Pavlos Koulouris [2] and Franz X. Bogner [1]

[1] Didactics of Biology, Z-MNU (Centre of Math & Science Education), University of Bayreuth, NW-1, Campus, D-95447 Bayreuth, Germany; franz.bogner@uni-bayreuth.de
[2] Research and Development Department, Ellinogermaniki Agogi, GR-15351 Athens/Pallini, Greece; pkoulouris@ea.gr
* Correspondence: Michaela.Maurer@uni-bayreuth.de

Received: 28 December 2019; Accepted: 24 January 2020; Published: 28 January 2020

Abstract: Affordable, reliable, sustainable and modern energy consumption is a crucial goal of the Agenda 2030. To raise each citizen's awareness for more effective energy consumptions, proper education is necessary. The classroom project GAIA (Green Awareness in Action) was designed to change energy consumption patterns to pursue green behaviour. The class-wise aim was to improve schools' CO_2-balance and to promote environmentally sustainable behaviour without impacting school life quality. Our target group were sixth graders (N = 132, M = 11.03, SD ± 0.23, 53.4% = girls) of one Greek school. To monitor the project's effect, a pre- and post-test design was applied to measure environmental literacy regarding environmental knowledge, attitudes/values and behaviour. A regression analysis revealed that students with poor previous knowledge reached higher learning effects compared to those with good previous knowledge. Related to the environmental knowledge types, an ANCOVA analysis revealed a knowledge gain in action-related and effectiveness knowledge. The overall learning effect correlates positively with pro-environmental preference (high scores in preservation, low scores in utilisation) and negatively with weak pro-environmental preferences. Anthropocentric (utilitarian) preferences primarily focussing on nature exploitation have considerably decreased. The project illustrates how far individual behaviour can be targeted in green educational initiatives.

Keywords: Environmental Education (EE); Education for Sustainable Development (ESD); environmental knowledge types and values; Environmental Literacy (EL); moderated regression; sustainability

1. Introduction

1.1. Green Educational Initiatives

Conferences in Stockholm [1] and Rio de Janeiro [2] strongly recommended that conservation efforts should integrate cognitive, affective and psychometric aspects in formal and informal settings [3]. Developing Agenda 21, Environmental Education (EE) was formally turned into Education for Sustainable Development (ESD) retaining its initial aim to support environmental protection. ESD comprises three components: environmental, economic and social sustainability (three-pillar model of sustainability) [4], raising awareness for worldwide sustainability with respect to present and future generations [5,6]. In 2015, the United Nations updated the Agenda 2030's expectations, including peace and international cooperation with all nations [7]. The Foundation for Environmental Education (FEE), a non-governmental, non-profit organisation founded in 1981, promotes educational programmes for young people who approach an environmentally sustainable lifestyle. Its programmes comprise Blue

Flag, Eco-Schools, Learning about Forests (LEAF), Young Reporters for the Environment and Green Key, although the latter does not include in-class teaching. Eco-schools are the most popular among all programs, acting at a global level with an action-based learning plan. Today, over 59,000 schools in 68 countries are taking part [8]. Current topics are water, waste avoidance, saving energy, biodiversity, transport as well as sustainable mobility, health, noise and climate change.

Green education initiatives are also offered outside FEE for conventional schools in formal and informal education contexts for half a day or even several days long settings. Some schools additionally work together with organizations. This raises the question of the extent to which green education initiatives actually contribute to environmental awareness regarding EE or ESD. Thus, there should be room for discussing such green education initiative' applications. A valid and reliable psychometric measuring instrument could point out some benefits.

Various conferences and agreements of global and historical relevance [1,2] have the common goal to raise citizens' awareness for a more conscious handling of problems associated with environmental and natural resources. Environmental awareness comprises three components: environmental knowledge, values and behaviour. Usually, the examination of knowledge, attitude, behaviour components and other variables are compared using psychometric measuring instruments to assess if they are influenced by such green educational initiatives. When applying bioenergy-modules [9], for example, 10th graders revealed a knowledge gain after a half-day long intervention. That gain, in turn, depended on (reported) behaviour and desirable attitude-set preferences (preservation and utilisation). Knowledge gains for girls were positively correlated with preservation and (reported) behaviour scores, whereas for boys there were only positive correlations with low utilisation's scores. Another intervention using a climate change module has shown significant short-term and long-term knowledge gain for 10th graders, while connectedness with nature and environmental attitude-sets played a substantial role for that gain [10,11]. A one-week environmental education outreach program on water issues reported similar changes regarding environmental knowledge and values for fourth and sixth graders [12].

GAIA (Green Awareness in Action) was a related green education initiative realised as part of a European research project on achieving behavioural changes for sustainability and energy awareness in schools. At one particular school in Greece, GAIA initiatives promoted problem-based learning, case-based teaching and discovery learning to increase sustainable behaviour of sixth-graders. Our analysis of this intervention included the sub-scale 'energy' which enabled us to detect changes in behaviour and to apply behaviour as a moderator of other variables (e.g., values). A first pilot testing [13] revealed close links between environmental behaviour and values. For environmental behaviour and environmental knowledge, there were only weak correlations. Taking cooperative action to change schools' energy consumption patterns was the key role of the intervention explained in the following.

1.2. Green Awareness in Action (GAIA) Intervention

The GAIA project, which was carried out by a multidisciplinary consortium consisting of nine partners from five European countries, involved in-class activities to foster sustainability awareness and energy saving. The major aim was to help students understand the impact of individual energy consumption and to promote changes in their habits. Deploying an Internet of Things (IoT) infrastructure in the participating schools, the project gathered data of energy consumption and sustainable infrastructure of classrooms. The GAIA Internet of Things (IoT) platform combines sensing, web-based tools and gamification elements, allowing the educational community to work with data produced by school buildings (e.g., temperature, relative humidity, illuminance, motion detection, noise level, electrical power consumption). The IoT installation in each school consists of a multitude of IoT nodes (sensors and meters) communicating with cloud-based services via gateway devices [14]. Access to this data, combined with tailor-made educational methods (e.g., computer-based learning, ta 1a), tools and materials enabled school communities to monitor energy efficiency results.

The overall learning aims of GAIA, using the project's developed infrastructure and methodologies, were: (i) to raise awareness regarding the need to save energy and possibilities to implement energy-saving methods in everyday school life (students, educators, other staff) and wider communities (families, local communities); and (ii) to encourage environmentally-friendly behaviour, which can contribute to increased energy efficiency. The project was designed and implemented as an educational initiative beyond merely informing about energy efficiency, and involved students, teachers, and building managers in monitoring and reducing energy consumption in schools. Thereby, all decisions based on their previously set goals were not forcefully implemented, but carried out voluntarily. Everyone was encouraged to experiment with and adopt behaviours that proved effective.

The GAIA project was considered to stimulate three actions. First, to understand and monitor their own and others' behaviours affecting energy consumption in their school building; second, based on this, to make informed decisions and take action to increase energy efficiency; and third, to observe and analyse the impact of their actions on energy consumption and their effect on comfort, functionality and smooth functioning of school life.

GAIA initiatives were realized in 25 schools in Greece, Italy and Sweden. Our study focuses on the activities realized in the seven classes of the sixth grade (11-year-old students) of one of the participating Greek schools, in the greater area of Athens, led by the environmental education teacher.

Subjects were sixth graders (N = 132 students) who attended learning activities embedded in their regular environmental education course, for about 19 teaching hours over a period of 10 weeks in the first term of school year 2018–2019. Through observation, simple calculations and accessing as well as interpreting data provided by the GAIA infrastructure, they systematically monitored their use of electricity in the classroom. In consequence, students analysed how energy consumption changed throughout a fixed time slot and how it differed among classrooms (Figure 1b). After having discussed their data and shared decisions, they reconsidered their use of electric lightning (e.g., switching it off during daytime or when leaving the classroom). In addition, the building's orientation was taken into account to use daylight as effectively as possible. At the end of the week, students reduced their overall energy consumption by 50% and shared their success with the rest of the school community (Figure 1c).

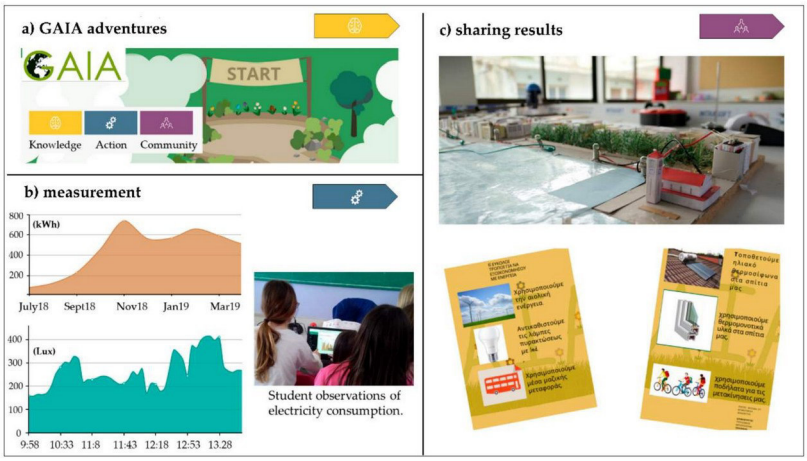


Figure 1. Green Awareness in Action (GAIA) progression: (**a**) knowledge generates awareness (e.g., through an independent tutorial program [15]), (**b**) action regarding observation of energy consumption and light intensity, including aberrations related to classroom conditions, and (**c**) engagement via hands-on in-class activities and sharing ideas. Diagrams and pictures are offered by the GAIA project (P. Koulouris).

1.3. Environmental Literacy (EL) Cornerstones

A variety of definitions for environmental literacy (EL) exists [16]. The term literacy initially referred solely to the ability to read and write. However, EL was specifically developed for environmental education and comprises four cornerstones: knowledge (relationships to environmental behaviour), attitudes/values, behaviour and skills. According to Weinert [17], competencies are described as the sum of skills and abilities to cope with everyday situations. Extensive research was conducted to find suitable measuring instruments for competencies. Roczen and colleagues [18] defined a competency model applying three pillars of EL: (i) copying skills, referring to the knowledge structure model [19], (ii) values as attitude-sets, linked to the Two Major Environmental Value model (2-MEV) scale [20] and (iii) individual behaviour covered by the General Ecological Behaviour (GEB) scale [21]. This competency model with its three pillars was pilot-tested within the GAIA context [13], by accompanying appreciation (APR) [22] to the attitude-set. The following sections give a brief outline of the instruments we used.

(i) Since the 1990s, programme assessments have shown varying environmental knowledge gains (e.g., [23,24]). Various studies assumed that environmental knowledge alone is insufficient to measure an ecological lifestyle, as it does not automatically lead to action (e.g., [25]). Frick and colleagues [19] have already described different types of knowledge, namely system (SYS), action-related (ACT) and effectiveness knowledge (EFF); the first one is considered weak whereas the others may have a high impact [25,26]. Moreover, SYS and ACT together are supposed to form the basis of EFF [18,19]. Some researchers agree that different knowledge types can be influenced by pro-environmental behaviour (e.g., [26,27]), but not exclusively [28]. Using the three knowledge types, Thorn and Bogner [29] revealed a knowledge gain after six months, observing, for example, cognitive knowledge acquisition regarding nature conservation after tenth graders had visited an ecosystem forest. Similar results could be obtained six weeks after participation in an outreach drinking water module for seventh-graders [30]. Despite increasing numbers of green- and eco-school initiatives, environmental knowledge types are still not sufficiently examined (e.g., [31–33]). The GAIA intervention provides an opportunity to analyse relationships between knowledge types (as we revealed in an earlier pilot study [13]) and how much they are influenced by a pre- and post-test design.

(ii) Attitudes/values are an important part of environmental knowledge (e.g., [34]). For years, a suitable, reliable and valid instrument [35] to measure adolescents' attitudes has been lacking. Bogner and colleagues developed the Two Major Environmental Value model (2-MEV) [20,23] with two orthogonal factors: preservation (PRE) and utilisation (UTL). Over the last decades, the pilot instrument with more than 60 items has subsequently been cross-tested within bi-national studies (e.g., [36]) and further validated with other scales, such as the individual risk-taking preferences [37]. Finally, a 20 items version was agreed upon [38]. Moreover, what is the instrument was subsequently confirmed by independent groups at different times (e.g., [39–43]) accepting its ecocentric and anthropocentric views. The scale was frequently used to analyse the effectiveness of educational programs to provide recommendations for educational implementation efforts [44,45]. Based on green initiatives, Boeve-de Pauw and Van Petegem [46] reported that utilisation tendencies were lower in eco-school students than control school students. In consequence, values can also be a predictor of environmental knowledge as well as their willingness to learn (e.g., [47,48]). Relationships between other variables are expected [42]. Although further research will have to be conducted, green educational initiatives such as GAIA may support relationships between values, knowledge and environmental behaviour.

(iii) Various studies (e.g., [49,50]) describe that pro-environmental behaviours improve with growing environmental knowledge and attitudes. Other studies displayed changes, though not always significant, in environmental behaviour after educational interventions (e.g., [41]) or green educational initiatives (e.g., [46]). Nevertheless, one has to keep in mind that most cited examples refer to different measuring scales and, thus, do not allow for the comparability. Demographic factors (age, sex and social status) or external factors (e.g., economic, social and cultural reasons), as well as internal factors (e.g., motivation, values and responsibilities and priorities), could be the underlying cause [51].

In the late 1990s, the General Ecological Behaviour (GEB) scale was established for adults [52] and subsequently adapted for adolescents in 2007 [21]. It comprises six pro-environmental sub-scales (consumerism, energy, mobility and transport, recycling, vicarious behaviour and waste avoidance) and was confirmed independently at different times (e.g., [53]). Using this instrument across national borders, we could observe various outcomes [50,54]. The GEB categories are all based on a possible relationship between attitudes and behaviour as an expression of motivation [55].

1.4. Research Goals

The objectives of our study were three-fold:

(i) to analyse the individual person estimate of each student, expressed in logits (natural logarithm of the ratio of correct to incorrect answer), for environmental knowledge and (reported) behaviour compared to differences between pre- (T0) and post-test (T1),
(ii) to observe how individual preferences (preservation and utilisation) interact with environmental knowledge/(reported) behaviour and differ after participation, and
(iii) to analyse the interaction of (reported) behaviour with environmental knowledge as a moderator.

2. Methods and Procedures

2.1. Sample

Our subjects were 132 Greek sixth-graders (seven school classes), in their last year of primary school ($M = 11.03$, $SD \pm 0.23$, 53.4% = female), completing a paper and pencil questionnaires twice: first, after the beginning of the school year (pre-test, T0) and another time four months after intervention at the very end of the project (post-test, T1).

2.2. Instruments

Altogether three psychometric constructs were assessed:

(i) an individual environmental knowledge item set of 15 multiple choice question, adapted from the pilot study [13], including three different types (covariates) of system knowledge (SYS), action-related knowledge (ACT) and effectiveness knowledge (EFF) concerning the issues of "energy" (one correct answer for each multiple-choice question and five items of each knowledge type) (see Table 1),
(ii) 20 items regarding 2-MEV and APR scales [56], based on a five-point Likert scale ("1 = strongly disagree", "2 = disagree", "3 = partially agree", "4 = agree", "5 = totally agree") and
(iii) 21 items regarding the General Ecological Behaviour (GEB) scale containing four sub-categories: "energy", "mobility & transport", "recycling" and "vicarious behaviour" [21], based on a five-point Likert scale ("1 = never", "2 = seldom", "3 = sometimes", "4 = often", "5 = very often").

2.3. Statistical Analysis

Statistical tests were conducted using R (The R Foundation for Statistical Computing for Windows; Version 3.6.0 for Windows; www.r-project.org). The probabilistic Rasch model describes the likelihood to solve items via item difficulty and person ability. To estimate each person's attitudinal level, a dichotomous Rasch model for environmental knowledge and (reported) behaviour was developed, expressing results in logits (package eRM; for method, see [57]). Logits represent the ratio's natural logarithm between correct and incorrect answers. If logits were positive, the ratio shifted towards correct answers and vice versa. For this purpose, all polytomous items were converted into a dichotomous format. Response pattern followed a 5-point Likert scale (see instruments) ranging from 'strongly disagree (1)', 'disagree (2)' and 'partially agree (3)'. To represent unreliable pro-environmental preferences, we used 'zero' as the code. Analogous, 'agree (4)' and 'totally agree (5)', to represent pro-environmental preferences, we used 'one' as the code. For instance, we coded the item "I personally

take care of plants" as one if the student ticked the item as 'totally agree'. For utilisation, we coded 'strongly disagree (1)' and 'disagree (2)' with 'one' to represent pro-environmental preferences. For example, we coded the item "Nature is always able to restore itself" as one if the student ticked the item as strongly disagree.

Table 1. Item examples for three different knowledge types: system (SYS), action-related (ACT) and effectiveness knowledge (EFF).

Item Examples:
SYS_6: Increasing demand for meat in a growing population reinforces the greenhouse effect. Which animals are responsible for the highest methane production? (a) fishes, (b) chicken, (c) pigs or (d) cows
SYS_18: Which of the following electrical devices is the most energy-consuming one in the classroom? (a) projector, (b) computer + screen, (c) interactive whiteboard or (d) air conditioning.
ACT_11: How can you save energy while cooking? (a) turn the stove to the lowest level, (b) use a lid on your pot, (c) turn the stove to the highest level or (d) order food using a delivery service.
ACT_21: How do you not save energy in the classroom? (a) do not use long curtains to prevent heat from escaping, (b) keep classroom doors closed, (c) close the windows in winter while heating the classroom or (d) during night time, turn the thermostat of the heating on its highest stage.
EFF_5: You urgently need new pants. How would you harm the environment most? (a) buy the article in a second-hand shop, (b) considering its origin and buy the article locally, (c) buy your article in an online shop choosing over-night express delivery or (d) going to the next store and buy new pants that please you.
EFF_15: How should buildings be painted in hot sunny areas like Italy to save energy? The buildings should be … (a) … lightly coloured to avoid overheating in summer, (b) … light or dark colours do not have any effect, (c) … dark colours to prevent overheating in winter or (d) … dark colours absorb the sun's heat.

For 'partially agree (3)', 'agree (4)' and 'totally agree (5)', we coded unreliable preferences with 'zero'. All other items representing unreliable pro-environmental (reported) behaviour like 'never (1)', 'seldom (2)' and 'sometimes (3)' were also coded with 'zero'. Polytomous items such as 'often (4)' and 'very often (5)' which represent unreliable pro-environmental engagement were coded with 'one' (e.g., "I buy beverages in cans."). Reversed items were then used for coding (e.g., "In hotels, I have the towels changed daily.").

A simple regression analysis was applied to observe differences between person estimates in adolescents regarding environmental knowledge items. We also examined differences between girls and boys. Multivariate analyses of covariance's (ANCOVA) were used to determine group differences between covariates (packages effects). To test the homogeneity of variance between covariates, we applied Levene's test (packages car; for method, see [58]).

3. Results

3.1. Analyses of Quality and Environmental Knowledge

To analyse and visualise knowledge items (5 system- (SYS), 5 action-related (ACT) and 5 effectiveness knowledge (EFF)), we used a dichotomous Rasch model (eRm package, [57]). The likelihood ratio (LR) test confirmed the model's application (T0: LR = 9.045, df = 14, p = 0.828; T1: = LR = 14.235, df = 14, p = 0.432). The Wald test indicates one-dimensionality at item level without breaking the rules for T0's ($T0_{minimum}$ = −1.093, $T0_{maximum}$ = 1.29), whereas for T1 one item does. For other items, one-dimensionality is given ($T1_{minimum}$ = −1.82 $T1_{maximum}$ = 1.43). The weighted fit mean square (wMNSQ), which should range between 0.80 and 1.20 for multiple-choice tests [59,60], was acceptable for pre- (T0) and post-test (T1): T0 0.83 ≤ wMNSQ 1.09 ≤, T1 0.79 ≤ wMNSQ ≤ 1.17. The item map illustrates that infit t-statistics applied to all items—except for one item in T0 (Figure 2A) and three items in T1—within the limits of ±1.95 against the latent dimension. According to Wang & Wilson [61], an item is only misfit, if wMNSQ and the infit t-statistic did not fit both. The joint Item Charateristic Curve-Plot (ICC plot) displayed a broad range of probability for environmental

knowledge items as was plotted against the latent dimension (Figure 2B). The items' discriminatory power was comparable for each item, although it slightly shifted relative to item difficulties.

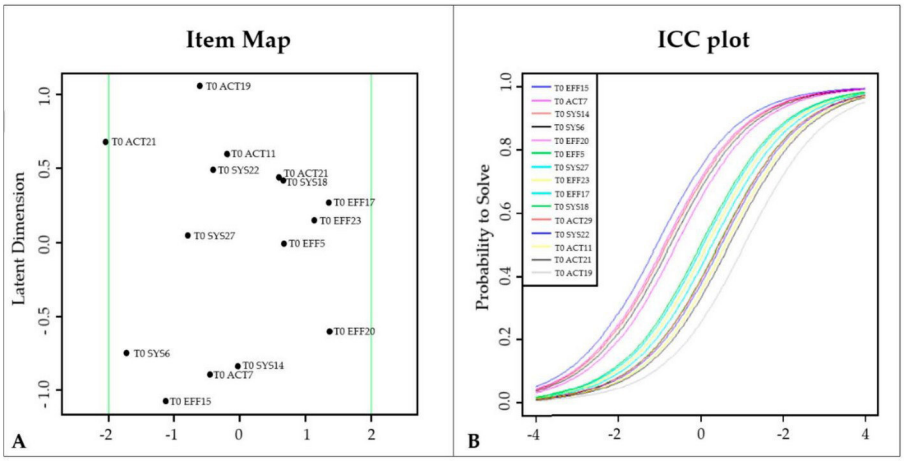


Figure 2. Visualising the infit t-statistic for knowledge items of the pre-test (**A**) and their characteristic item curves (**B**).

3.2. Person Estimate Promoting Environmental Knowledge

The person estimate indicates person performance and item difficulty based on pre- (T0) and post-tests (T1). To visualise differences, we used a simple regression analysis to observe variances of person estimate scores (logits) ($F = 12.66$, $df = 130$, $r^2 = 0.09$, $p = 0.001$) (Figure 3A).

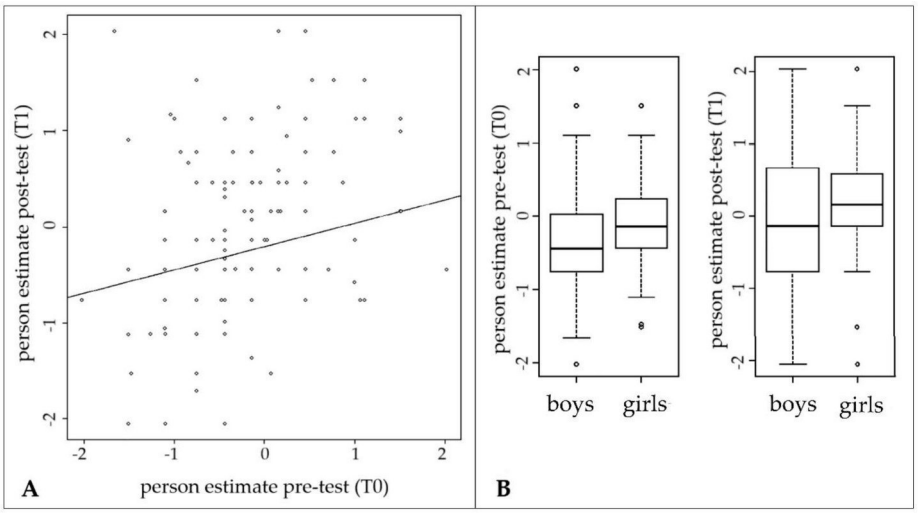


Figure 3. Environmental knowledge regression line in relation to participants' personal estimate ($N = 132$) (**A**) and correctly answered environmental knowledge items (**B**) for person estimate of boys and girls with regard to pre- and post-tests.

All participants were divided into two groups with respect to their logit scores to measure a possible increase in knowledge. Those with lower logit scores (group one, $N = 66$) answered about five items in the pre-test correctly and about seven in the post-test. Groups with higher logit scores ($N = 66$) solved approximately eight items in T0 and T1. Comparison between girls and boys showed that both sexes increased their knowledge after participation (Figure 3B), but that girls knew more than boys did.

To verify our assumptions, we applied multivariate tests of ANCOVA. For analyses of all three covariates (system (SYS), action-related (ACT) and effectiveness knowledge (EFF)), we used sum-scores (Figure 4A). Results are not based on a specific lesson; they refer to the 10 weeks after the intervention. While system knowledge decreased after having participated in the intervention, action-related and effectiveness knowledge increase. The test quality was acceptable (Figure 4B).

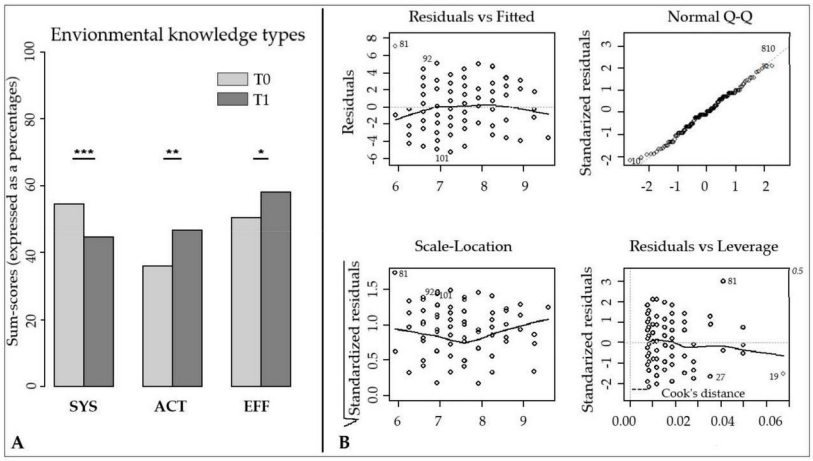


Figure 4. Correlation between the three knowledge types for pre- and post-tests (**A**) and test quality for analysis (**B**).

Levene's test indicates no homogeneity of variance between covariates ($SYS_{T0,\,T1}$: $df = 126$, $F = 1.27$, $p = 0.28$; $ACT_{T0,\,T1}$: $df = 126$, $F = 0.82$, $p = 0.54$ and $EFF_{T0,\,T1}$: $df = 126$, $F = 0.21$, $p = 0.96$). Classification of the person estimate as dependent factor for environmental knowledge did not reveal violations of homogeneity for regression slopes ($SYS_{T0,\,T1}$: $Sum\ Sq = 0.49$, $F = 0.14$, $p = 0.94$; $ACT_{T0,\,T1}$: $Sum\ Sq = 3.50$, $F = 0.83$, $p = 0.48$; and $EFF_{T0,\,T1}$: $Sum\ Sq = 4.01$, $F = 0.96$, $p = 0.41$).

ANCOVA analysis (type III) showed that person estimate significantly affected covariates comparing single covariates of T0 and T1 with each other ($SYS_{T0,\,T1}$: $Sum\ Sq = 16.02$, $F = 26.13$, $p > 0.001$; $ACT_{T0,\,T1}$: $Sum\ Sq = 21.92$, $F = 39.90$, $p > 0.001$; and $EFF_{T0,\,T1}$: $Sum\ Sq = 7.02$, $F = 9.01$, $p = 0.003$) whereas for individual covariates two showed learning effects and one even a loss of knowledge ($SYS_{T0,\,T1}$: $r = 0.30$, $t = 3.65$, $df = 130$, $p > 0.001$; $ACT_{T0,\,T1}$: $r = 0.24$, t = 2.80, $df = 130$, $p = 0.006$ and $EFF_{T0,\,T1}$: $r = 0.19$, $t = 2.24$, $df = 130$, $p = 0.03$).

3.3. Nature Conservation Preferences and (Reported) Behaviour

In terms of attitudes, both groups (lower and higher values) displayed a significant knowledge gain (Table 2).

Table 2. Environmental knowledge mean scores ($N = 15$ items) for pre- and post-test dependent on adolescents environmental values (lower and higher).

Values		T0	T1	Difference
Appreciation (APR)	Low	6.85	7.73	+0.88
	High	6.55	7.26	+0.71
Preservation (PRE)	Low	6.50	7.30	+0.80
	High	6.89	7.68	+0.79
Utilisation (UTL)	Low	6.38	7.11	+0.73
	High	7.02	7.88	+0.86

$N = 66$ for each measurement.

Classifying preservation as dependent factor for environmental knowledge indicates assumptions of homogeneity for regression slopes are not violated ($SYS_{T0, T1}$: *Sum Sq* = 1.79, *F* = 0.73, *p* = 0.48; $ACT_{T0, T1}$: *Sum Sq* = 3.00, *F* = 1.07, *p* = 0.35; and $EFF_{T0, T1}$: *Sum Sq* = 1.10, *F* = 0.42, *p* = 0.66). The same applies to appreciation ($SYS_{T0, T1}$: *Sum Sq* = 1.75, *F* = 0.15, *p* = 0.69; $ACT_{T0, T1}$: *Sum Sq* = 0.59, *F* = 0.51, *p* = 0.48; and $EFF_{T0, T1}$: *Sum Sq* = 1.40, *F* = 1.27, *p* = 0.26) and utilisation ($SYS_{T0, T1}$: *Sum Sq* = 0.77, *F* = 0.66, *p* = 0.42; $ACT_{T0, T1}$: *Sum Sq* = 0.001, *F* = 0.007, *p* = 0.98; and $EFF_{T0, T1}$: *Sum Sq* = 2.94, *F* = 2.80, *p* = 0.10).

ANCOVA analysis (type III) show that preservation did not significantly affect covariates ($SYS_{T0, T1}$: *Sum Sq* = 0.62, *F* = 0.54, *p* = 0.46; $ACT_{T0, T1}$: *Sum Sq* = 0.92, *F* = 0.78, *p* = 0.38; and $EFF_{T0, T1}$: *Sum Sq* = 0.33, *F* = 0.30, *p* = 0.58). The same applies to appreciation ($SYS_{T0, T1}$: *Sum Sq* = 1.75, *F* = 0.15, *p* = 0.70; $ACT_{T0, T1}$: *Sum Sq* = 0.59, *F*0.51, *p* = 0.48; and $EFF_{T0, T1}$: *Sum Sq* = 1.39, *F* = 1.27, *p* = 0.26) and utilisation ($SYS_{T0, T1}$: *Sum Sq* = 0.77, *F* = 0.66, *p* = 0.42; $ACT_{T0, T1}$: *Sum Sq* = 0.001, *F* = 0.007, *p* = 0.10; and $EFF_{T0, T1}$: *Sum Sq* = 2.94, *F* = 2.80, *p* = 0.10). We obtained comparable results for difference analyses of pre- and post-test mean values which distinguished between adolescents' lower and higher values (appreciation, preservation and utilisation) (Table 2).

Ecocentric tendencies remained at an almost equal level after having participated in our intervention for preservation ($T0_{preservation}$ = 62%, $T1_{preservation}$ = 63%), and slightly decreased for appreciation ($T0_{appreciation}$ = 37%, $T1_{appreciation}$ = 31%). Anthropocentric tendencies focused on exploiting nature did, however, not decrease ($T0_{utilisation}$ = 37%, $T1_{utilisation}$ = 47%, see methods).

Analysing item preferences of preservation regarding (reported) behaviour, participants with lower logit scores (group one) increased their environmental values after the intervention and were almost at the same level as participants with higher scores (group two) (Figure 5A). We observed similar effects for anthropocentric preferences (utilisation): Here, scores assessing tendencies to exploit nature decreased (Figure 5B). More items of 'disagree' and 'strongly disagree' were ticked in T1 than in T0 (see methods). No differences between pre-test and post-test were identified for appreciation preferences.

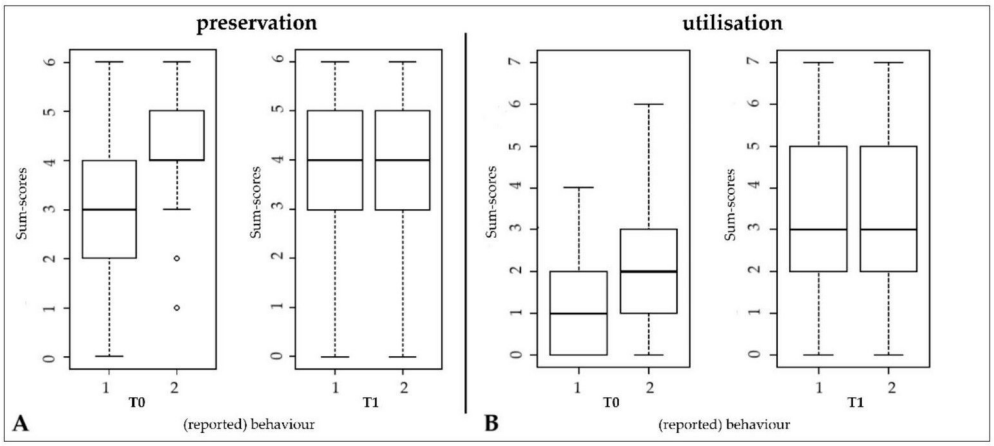


Figure 5. Ability to assess nature preferences (**A**) preservation and (**B**) utilisation via dependent logits displaying (reported) behaviour. 1 (x-axis) represents the group with the lower logit scores whereas 2 (x-axis) represents the group with the higher logit scores for both figures.

GEB as moderator shows an increased learning curve for environmental knowledge as its main interaction effect. Adolescents with lower logit scores have learned more compared to those with higher logit scores (Figure 6).

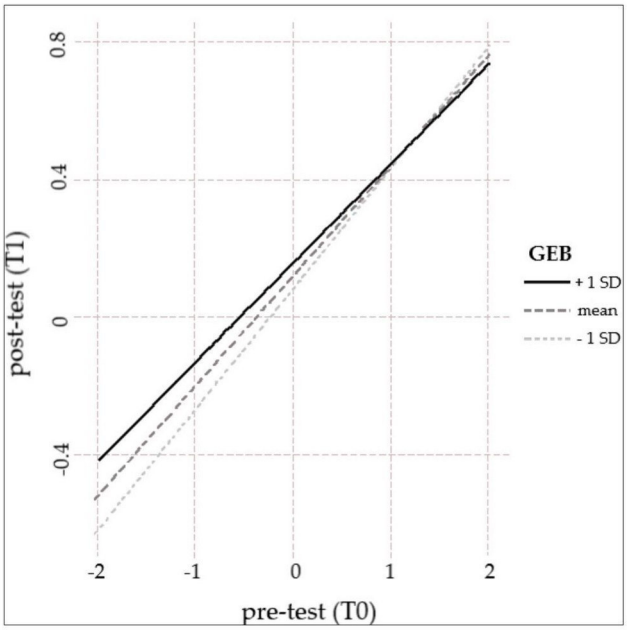


Figure 6. Conditional effect of the general ecological behaviour as moderator to solve environmental knowledge items between pre- and post-test.

4. Discussion

The major goal of our "green" module was affecting behaviour, promoting attitudes/values and fostering cognitive learning. Although this expectancy is in line with the literature [41,62], the GAIA (Green Awareness in Action) intervention did not meet all expectations: the overall environmental knowledge improved while values and behaviour did not. However, a detailed overview of the analyses could be of use.

4.1. Efficacy of Environmental Knowledge

Regarding the implementation of an environmental education program about water issues by Liefländer and colleagues [12], the highest increase in knowledge was observed for system knowledge and is much higher than in our study. Other researchers identified knowledge gains across all three knowledge types [33,41]. Poor basic pre-knowledge levels in system knowledge may provide a possible explanation for the discrepancy in our study [63,64]. After extensive analysis of energy consumption in the classroom, an increase in knowledge for action-related and effectiveness knowledge was the logical outcome of our study (Figure 4), although the actual increase was not particularly high. Action-related knowledge was the explicit goal of our intervention as it could potentially impact students' daily life. However, groups with lower logit scores (N = 66) increased their environmental knowledge scores whereas groups with higher logit scores (N = 66) did not. Of course, it would be desirable to specifically facilitate action-related knowledge as it could potentially impact students' daily life. In any case, it will be difficult to intrinsically motivate students to change their habits. Studies about adult consumers are already pointing out that most are unwilling to adjust their consumption patterns unless it is beneficial [65,66]. Grønhøj and Thøgersen [67] described motivation of young people as rooted in family descriptive norms. Generally, that some people are more motivated to protect the environment (e.g., consuming and acting sustainably or saving energy) than others is explained by psychological factors of intrinsic motivation.

4.2. Environmental Values and Behaviour Preferences

Attitudes and informal education, although often critically discussed, do not impact pro-environmental behaviour [52]. In our case, we could show an interaction between pre- and post-test for environmental knowledge with (reported) behaviour as moderator (Figure 6). Poor motivation, thereby, seems to have an effect on learning as low-achievers (students who score below the baseline level were at a comparable level in the post-test) although they received lower environmental knowledge scores in the pre-test. This confirms our assumption, that action-related and effectiveness knowledge have a specific impact on low achievers. The respective attitudes/values seem to influence behavioural decisions [47,48]. Depending on higher and lower scores for preservation, appreciation and utilisation, it only affected cognitive achievement. In contrast to educational interventions in natural outreach setting [11,68], our in-class initiative focusing on energy consumption did not change attitudes toward nature. A possible explanation might be our target group's age: many participants were probably too young to understand the complex context of energy consumption patterns and CO_2 emissions and its impact on climate change. Boeve-de Pauw and Van Petegem [39] reported that environmental knowledge and utilisation preferences correlate negatively. Regarding environmental attitudes, their study displays an impact of social acceptability, not utilisation preferences, on preservation preferences. Our results suggest that tendencies to exploit nature (utilisation) significantly decreased throughout the intervention (Figure 5): utilizers may see an advantage in saving energy. Therefore, utilisation preferences had a larger effect than preservation or appreciation did. Our long-term intervention has influenced attitude but did not produce changes of attitudes which other interventions were able to achieve [24]. Eco-school projects, which mostly involve only a few classes, follow a similar pattern. Green educational initiatives will help to support raising awareness, but the decision to protect the environment should be an individual choice [67].

4.3. Limitation and Directions for Future Research

For reasons of comparability, we have limited the sample to one school (same teachers, same activities). We only included paper and pencil questionnaires filled in at both testing points despite considerably reducing the number of questionnaires through non-participants (reason of illness or non-participating). Rasch analysis was applied to all environmental knowledge items compared to behavioural items but was not carried out for each sub-scale. Unlike other interventions with three-fold testing cycles (pre-tests a few weeks before the intervention started, post-tests directly after the intervention and retention tests usually more than six weeks after the intervention), our testing schedule did not allow further insight into the knowledge acquisition. After participation in green initiatives, students have the largest knowledge gain which usually decreases shortly thereafter. In consequence, our monitoring procedure was limited to the beginning and end of the entire intervention phase. This is different from other studies and may indicate long time learning. Rasch analysis was applied to all environmental knowledge items versus behavioural items analyses but was not carried out for each sub-scale.

The GAIA project is an example of how to raise student's awareness of more sustainable energy consumption. Our results displayed that GAIA was a successful intervention. As it only entails minor technical effort and provides an application of materials [15,68], teachers in other schools can easily adapt its concept. Previous studies have already revealed [69] that interventions implemented in different classes or schools, but with similar school types and age groups, still produce different results. Differences within heterogeneous classes are quite usual. Furthermore, personal moderators (difficulties), situational moderators (social pressure) and subjective versus social norms (expectation) can impact the outcome [70]. Green initiatives regarding ESD do not specifically aim at changing awareness and behavioural preferences. Their focus is on shaping students' skills including other factors (knowledge, motivation, attitudes, values and take action) [71] to provide space for own decisions (e.g., self-efficacy according to Bandura's self-beliefs) [72].

5. Conclusions

Based on the three pillars of Education for Sustainable Development (ESD) (as outlined in the above), GAIA (Green Awareness in Action) specifically considered the economic pillar, as reducing energy consumption in schools was the main goal of the project. Participation encouraged school classes to compete with each other with regard to saving energy. Applied measuring devices confirmed that energy consumption patterns changed measurably throughout the intervention [68]. Unfortunately, our study was not able to connect the empirical data with the on-site measurement of hardware data in classrooms. Potential reasons for behavioural change may be two-fold: (i) it is related to the values of preservation and utilisation and (ii) it functions as a moderator for environmental knowledge. Furthermore, levels of action-related and effectiveness knowledge improved throughout the intervention. At the same time, behavioural decisions should not be the only factor taken into account. The social pillar, based on cooperation between students, teachers and stakeholders, was equally represented in the GAIA project. The impact of educational projects exceeds the boundaries of school (e.g., family, friends, open-source internet of Facebook, Instagram or Twitter) also included the ecological pillar, to protect the environment by changing energy consumption patterns and minimising CO_2 emissions.

Green education initiatives such as GAIA (or e.g., eco-schools) attempt to optimise energy consumption by various methods (e.g., improving students' knowledge levels). Potential expenses for in-class activities within the GAIA project mostly involve one-off payments (e.g., Internet of Things techs (IoT) like power meters, environmental sensors and weather stations)) and sensing hardware which are not expensive and applicable in other contexts. Moreover, we should keep in mind that the individual benefit of educational interventions highly differs within heterogeneous student communities. Projects like GAIA can only act as extrinsic operators. Still, it is possible that values and behaviour do not change despite extrinsic operators. Everyone must intrinsically motivate themselves. Creating individual learning tools and assessing their impact on competency could be subject to further research.

Author Contributions: M.M. initiated the first draft. All authors subsequently worked on the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This project through by the "Qualitätsoffensive Lehrerbildung" (Grant: 01JA1901, https://www.qualitaetsoffensive-lehrerbildung.de/) and European project 'GAIA' (Green Awareness in Action: grant agreement No. 696029) as well as by the University of Bayreuth. Additionally, the German Research Foundation (DFG) and the University of Bayreuth in the funding program Open Access Publishing funded this publication.

Acknowledgments: The authors are very grateful to all students and teachers involved in this study for their time and engagement. We also thank Florian G. Kaiser for valuable statistics advice and Tamara Roth for proofreading.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. UNESCO. *The Stockholm Declaration*; UNESCO: Stockholm, Sweden, 1972.
2. UN (United Nation). Rio Declaration on Environment and Development —Preamble. In *The Sustainable Urban Development Reader*; Wheeler, S.M., Beatley, T., Eds.; Taylor & Francis: London, UK, 1992; pp. 79–86.
3. DeKock, A.; Sleegers, P.; Voeten, M.J.M. New Learning and the Classification of Learning Environments in Secondary Education. *Rev. Educ. Res.* **2004**, *74*, 141–170. [CrossRef]
4. UN (United Nation). *The Sustainable Development Goals Report 2017*; United Nation: New York, NY, USA, 2017.
5. McKeown, R.; Hopkins, C. EE p ESD: Defusing the worry. *Environ. Educ. Res.* **2003**, *9*, 117–128. [CrossRef]
6. UNESCO. *United Nations Decade of Education for Sustainable Development (2005-2014): International Implementation Scheme*; UNESCO: Paris, France, 2005.
7. UNGA. *Transforming our world: The 2030 agenda for sustainable development*; UN General Assembly: New York, NY, USA, 2016.

8. Foundation for Environmental Education Eco-Schools. Available online: https://www.fee.global/eco-schools-1. (accessed on 26 January 2020).
9. Schumm, M.F.; Bogner, F.X. The impact of science motivation on cognitive achievement within a 3-lesson unit about renewable energies. *Stud. Educ. Eval.* **2016**, *50*, 14–21. [CrossRef]
10. Sellmann, D.; Bogner, F.X. Effects of a 1-day environmental education intervention on environmental attitudes and connectedness with nature. *Eur. J. Psychol. Educ.* **2013**, *28*, 1077–1086. [CrossRef]
11. Sellmann, D.; Bogner, F.X. Climate change education: Quantitatively assessing the impact of a botanical garden as an informal learning environment. *Environ. Educ. Res.* **2013**, *19*, 415–429. [CrossRef]
12. Liefländer, A.K.; Bogner, F.X.; Kibbe, A.; Kaiser, F.G. Evaluating Environmental Knowledge Dimension Convergence to Assess Educational Programme Effectiveness. *Int. J. Sci. Educ.* **2015**, *37*, 684–702. [CrossRef]
13. Maurer, M.; Bogner, F.X. Modelling Environmental Literacy with environmental knowledge, values and (reported) behaviour. *Stud. Educ. Eval.* **2020**, in press.
14. Mylonas, G.; Chatzigiannakis, I.; Amaxilatis, D.; Paganelli, F.; Anagnostopoulos, A. Enabling Energy Efficiency in Schools based on IoT and Real-World Data. *IEEE Pervasive Comput.* **2018**, *17*. [CrossRef]
15. GAIA, GAIA challenge. Available online: http://gaia-challenge.com (accessed on 26 January 2020).
16. Roth, C.E. *Environmental Literacy: Its Roots, Evolution and Directions in the 1990s*; ERIC Clearinghouse for Science, Mathematics, and Environmental Education: Columbus, OH, USA, 1992.
17. Weinert, F.E. Concept of competence: A conceptual clarification. In *Defining and selecting key competencies*; Rychen, D.S., Salganik , L.H., Eds.; Göttingen, Germany, 2001; pp. 45–66.
18. Roczen, N.; Kaiser, F.G.; Bogner, F.X.; Wilson, M. A Competence Model for Environmental Education. *Environ. Behav.* **2014**, *46*, 972–992. [CrossRef]
19. Frick, J.; Kaiser, F.G.; Wilson, M. Environmental knowledge and conservation behavior: Exploring prevalence and structure in a representative sample. *Pers. Individ. Differ.* **2004**, *37*, 1597–1613. [CrossRef]
20. Bogner, F.X.; Wiseman, M. Toward Measuring Adolescent Environmental Perception. *Eur. Psychol.* **1999**, *4*, 139–151. [CrossRef]
21. Kaiser, F.G.; Oerke, B.; Bogner, F.X. Behavior-based environmental attitude: Development of an instrument for adolescents. *J. Environ. Psychol.* **2007**, *27*, 242–251. [CrossRef]
22. Kaiser, F.G.; Brügger, A.; Hartig, T.; Bogner, F.X.; Gutscher, H. Appreciation of nature and appreciation of environmental protection: How stable are these attitudes and which comes first? *Eur. Rev. Appl. Psychol.* **2014**, *64*, 269–277. [CrossRef]
23. Wiseman, M.; Bogner, F.X. A higher-order model of ecological values and its relationship to personality. *Pers. Individ. Differ.* **2003**, *34*, 783–794. [CrossRef]
24. Bogner, F.X. The influence of a residential outdoor education programme to pupil's environmental perception. *Eur. J. Psychol. Educ.* **2002**, *17*, 19–34. [CrossRef]
25. Kaiser, F.G.; Wölfing, S.; Fuhrer, U. Environmental attitude and ecological behaviour. *J. Environ. Psychol.* **1999**, *19*, 1–19. [CrossRef]
26. Kaiser, F.G. Ecological behavior's dependency on different forms of knowledge. *Appl. Psychol.* **2003**, *52*, 598–613. [CrossRef]
27. Díaz-Siefer, P.; Neaman, A.; Salgado, E.; Celis-Diez, J.L.; Otto, S. Human-environment system knowledge: A correlate of pro-environmental behavior. *Sustainability* **2015**, *7*, 15510–15526. [CrossRef]
28. Gardner, G.T.; Stern, P.C. *Environmental problems and human behavior*; Allyn and Bacon: NeedhamHeights, MA, USA, 1996.
29. Thorn, C.; Bogner, F.X. How Environmental Values Predict Acquisition of Different Cognitive Knowledge Types with Regard to Forest Conservation. *Sustainability* **2018**, *10*, 2188. [CrossRef]
30. Fremerey, C.; Bogner, F.X. Cognitive learning in authentic environments in relation to green attitude preferences. *Stud. Educ. Eval.* **2015**, *44*, 9–15. [CrossRef]
31. Clark, W.C.; Van Kerkhoff, L.; Lebel, L.; Gallopin, G.C. Crafting usable knowledge for sustainable development. *Proc. Natl. Acad. Sci.* **2016**, *113*, 4570–4578. [CrossRef] [PubMed]
32. Sauvé, L. Currents in Environmental Education: Mapping a Complex and Evolving Pedagogical Field. *Can. J. Environ. Educ.* **2005**, *10*, 11–37.
33. Fremerey, C.; Bogner, F.X. Learning about Drinking Water: How Important are the Three Dimensions of Knowledge that Can Change Individual Behavior? *Educ. Sci.* **2014**, *4*, 213–228. [CrossRef]

34. Meinhold, J.L.; Malkus, A.J. Adolescent environmental behaviors: Can knowledge, attitudes and self-efficacy make a difference? *Environ. Behav.* **2005**, *37*, 511–532. [CrossRef]
35. Dunlap, R.E.; Jones, R.E. Environmental attitudes and values. *Encycl. Psychol. Assess.* **2003**, *1*, 364–369.
36. Bogner, F.X.; Wiseman, M. Environmental perspectives of Danish and Bavarian pupils: Towards a methodological framework. *Scand. J. Educ. Res.* **1997**, *41*, 53–71. [CrossRef]
37. Bogner, F.X.; Brengelmann, J.C.; Wiseman, M. Risk-taking and environmental perception. *Environmentalist* **2000**, *20*, 49–62. [CrossRef]
38. Bogner, F.X.; Wiseman, M. Adolescents' attitudes towards nature and environment: Quantifying the 2-MEV model. *Environmentalist* **2006**, *26*, 247–254. [CrossRef]
39. Boeve-de Pauw, J.; Van Petegem, P. The effect of Flemish eco-schools on student environmental knowledge, attitudes, and affect. *Int. J. Sci. Educ.* **2011**, *33*, 1513–1538. [CrossRef]
40. Borchers, C.; Boesch, C.; Riedel, J.; Guilahoux, H.; Ouattara, D.; Randler, C. Environmental Education in Côte d'Ivoire/West Africa: Extra-Curricular Primary School Teaching Shows Positive Impact on Environmental Knowledge and Attitudes. *Int. J. Sci. Educ. Part B* **2014**, *4*, 240–259. [CrossRef]
41. Braun, T.; Cottrell, R.; Diekers, P. Fostering changes in attitude, knowledge and behavior: Demographic variation in environmental education effects. *Environ. Educ. Res.* **2018**, *24*, 899–920. [CrossRef]
42. Johnson, B.; Manoli, C.C. The 2-MEV scale in the United States: a measure of children's environmental attitudes based on the theory of ecological attitude. *J. Environ. Educ.* **2010**, *42*, 84–97. [CrossRef]
43. Milfont, T.L.; Duckitt, J. The structure of environmental attitudes: A first- and second-order confirmatory factor analysis. *J. Environ. Psychol.* **2004**, *24*, 289–303. [CrossRef]
44. Glaab, S.; Heyne, T. Green classroom vs. classroom–Influence of teaching approaches, learning settings, and state emotions on environmental values of primary school children. *Appl. Environ. Educ. Commun.* **2019**, *18*, 179–190. [CrossRef]
45. Johnson, B.; Činčera, J. Development of the ecological concepts of energy flow and materials cycling in middle school students participating in earth education programs. *Stud. Educ. Eval.* **2019**, *63*, 94–101. [CrossRef]
46. Boeve-de Pauw, J.; Van Petegem, P. The effect of eco-schools on children's environmental values and behaviour. *J. Biol. Educ.* **2013**, *47*, 96–103. [CrossRef]
47. Schmitz, G.L.; Rocha, J.B.T. Environmental Education Program as a Tool to Improve Children's Environmental Attitudes and Knowledge. *Education* **2018**, *8*, 15–20. [CrossRef]
48. Zelenika, I.; Moreau, T.; Lane, O.; Zhao, J. Sustainability education in a botanical garden promotes environmental knowledge, attitudes and willingness to act. *Environ. Educ. Res.* **2018**, *24*, 1581–1596. [CrossRef]
49. Hungerford, H.R.; Volk, T.L. Changing learner behavior through environmental education. *J. Environ. Educ.* **1990**, *21*, 8–21. [CrossRef]
50. Geiger, S.M.; Dombois, C.; Funke, J. The role of environmental knowledge and attitude: Predictors for ecological behavior across cultures. An analysis of argentinean and german students. *Environ. Psychol.* **2018**, *22*, 69–87.
51. Kollmuss, A.; Agyeman, J. Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behaviour? *Environ. Educ. Res.* **2002**, *8*, 239–260. [CrossRef]
52. Kaiser, F.G. A general measure of ecological behavior. *J. Appl. Soc. Psychol.* **1998**, *28*, 395–422. [CrossRef]
53. Urban, J. Are we measuring concern about global climate change correctly? Testing a novel measurement approach with the data from 28 countries. *Clim. Chang.* **2016**, *3–4*, 397–411. [CrossRef]
54. Kaiser, F.G.; Biel, A. Assessing general ecological behavior: A cross-cultural comparison between Switzerland and Sweden. *Eur. J. Psychol. Assess.* **2000**, *16*, 44–52. [CrossRef]
55. Kaiser, F.G.; Hübner, G.; Bogner, F.X. Contrasting the Theory of Planned Behavior With the Value-Belief-Norm Model in Explaining Conservation Behavior. *J. Appl. Soc. Psychol.* **2005**, *35*, 2150–2170. [CrossRef]
56. Bogner, F.X. Environmental Values (2-MEV) and Appreciation of Nature. *Sustainability* **2018**, *10*, 350. [CrossRef]
57. Mair, P.; Hatzinger, R.; Maier, M.J. Extended Rasch Modeling: The R Package eRM. Available online: https://cran.r-project.org/web/packages/eRm/vignettes/eRm.pdf. (accessed on 26 January 2020).
58. Fox, J.; Weisberg, S.; Adler, D.; Bates, D.; Baud-Bovy, G.; Ellison, S. Packages car. Available online: https://cran.microsoft.com/snapshot/2017-06-17/web/packages/car/car.pdf. (accessed on 26 January 2020).
59. Bond, T.G.; Fox, C.M. *Applying the Rasch Model*, 2nd ed.; Psychology Press: New York, NY, USA, 2007.

60. Boone, W.; Staver, J.; Yale, M. *Rasch Analysis in the Human Science*; Springer: Dordrecht, The Netherlands, 2014.
61. Wang, W.-C.; Wilson, M. The Rasch testlet model. *Appl. Psychol. Meas.* **2005**, *29*, 126–149. [CrossRef]
62. Fančovičová, J.; Prokop, P. Plants have a chance: Outdoor educational programmes alter students' knowledge and attitudes towards plants. *Environ. Educ. Res.* **2011**, *17*, 537–551. [CrossRef]
63. Makki, M.H.; Abd-El-Khalick, F.; BouJaoude, S. Lebanese secondary school students' environmental knowledge and attitudes. *Environ. Educ. Res.* **2003**, *9*, 21–33. [CrossRef]
64. Randler, C.; Ilg, A.; Kern, J. Cognitive and emotional evaluation of an amphibian conservation program for elementary school students. *J. Environ. Educ.* **2005**, *37*, 43–52. [CrossRef]
65. Henn, L.; Taube, O.; Kaiser, F.G. The role of environmental attitude in the efficacy of smart-meter-based feedback interventions. *J. Environ. Psychol.* **2019**, *63*, 74–81. [CrossRef]
66. Rieger, A.; Thummert, R.; Fridgen, G.; Kahlen, M.; Ketter, W. Estimating the benefits of cooperation in a residential microgrid: A data-driven approach. *Appl. Energy* **2016**, *180*, 130–141. [CrossRef]
67. Grønhøj, A.; Thøgersen, J. Why young people do things for the environment: The role of parenting for adolescents' motivation to engage in pro-environmental behaviour. *J. Environ. Psychol.* **2017**, *54*, 11–19. [CrossRef]
68. GAIA Green awareness in action. Available online: http://gaia-project.eu (accessed on 26 January 2020).
69. Liefländer, A.K.; Bogner, F.X. Educational impact on the relationship of environmental knowledge and attitudes. *Environ. Educ. Res.* **2018**, *24*, 611–624. [CrossRef]
70. Wallace, D.S.; Paulson, R.M.; Lord, C.G.; Bond, C.F., Jr. Which behaviors do attitudes predict? Meta-analyzing the effects of social pressure and perceived difficulty. *Rev. Gen. Psychol.* **2005**, *9*, 214–227. [CrossRef]
71. Marcinkowski, T.; Reid, A. Reviews of research on the attitude–behavior relationship and their implications for future environmental education research. *Environ. Educ. Res.* **2019**, *25*, 459–471. [CrossRef]
72. Bandura, A. Self-efficacy mechanism in human agency. *Am. Psychol.* **1982**, *37*, 122–147. [CrossRef]

G Anhang

G.1 Fragebogen: Vorstellungen von Studierende

Fragen mit * gekennzeichnet - Teilstudie A, nicht gekennzeichnet Teilstudie B.

Didaktik der Biologie Februar 2017

Im Folgenden werden Ihnen einige Frage zum Themengebiet Umwelt gestellt.
Beachten Sie bitte:

- Es wird nach **Ihrer persönlichen Meinung** gefragt.
- **Beantworten** Sie die Fragen **spontan** und ohne lange zu überlegen.
- Die Auswertung der Daten erfolgt **streng vertraulich** und wird nicht an Dritte weitergegeben.

Semester: _____ Alter: _____ Geschlecht: Männlich ☐

Studiengang: _____ Weiblich ☐

1. Bildung für Nachhaltige Entwicklung (BNE) *

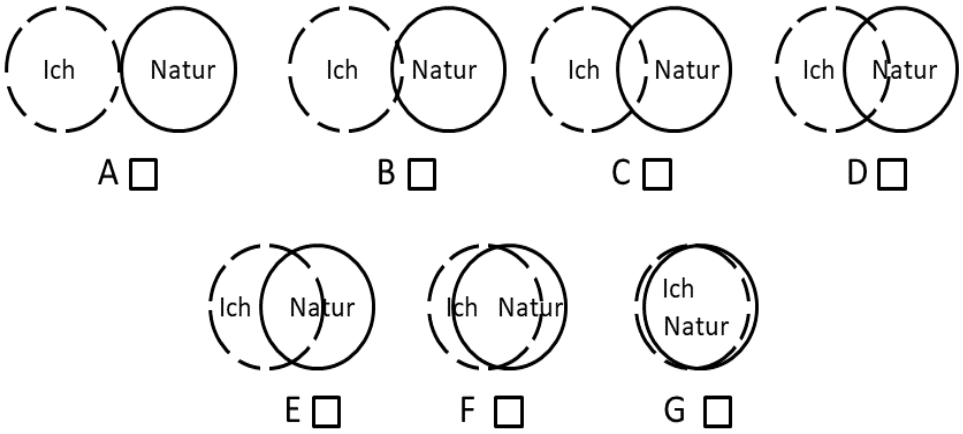
Was verstehen Sie darunter?

2. Ökologischer Fußabdruck

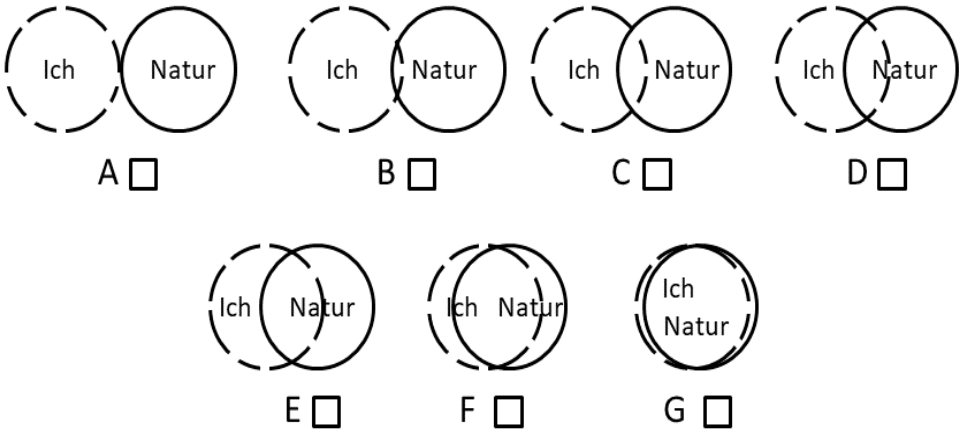
Was können Sie dazu beitragen, um Ihren ökologischen Fußabdruck zu verringern?

3. Natur

a) Betrachten Sie folgende Kreise. Wie eng sollte Ihrer Meinung nach der Mensch mit der Natur verbunden sein? Kreuzen Sie nur ein Kästchen an. *



b) Wie eng sehen Sie sich mit der Natur verbunden? Kreuzen Sie nur ein Kästchen an. *



c) **Natur:** Welche persönlichen Gefühle/Emotionen verbinden Sie damit?

4. Umweltbildung *

a) Was verstehen Sie darunter? *

b) Wie stark trug in Ihrem Fall die folgenden Kategorien zur Umweltbildung bei:

	schwach	mittelmäßig	stark	sehr stark
Schule	□	□	□	□
Außerschulische Lernorte (Zoo, Botanischer Garten, Museum)	□	□	□	□
Medien (TV, Zeitschriften, Bücher)	□	□	□	□
Werbung (Plakate, Flyer)	□	□	□	□
Elternhaus, Familie, Freunde	□	□	□	□
Politik	□	□	□	□

C) Zu welchem Themengebiet in der Umweltbildung wünschen Sie sich mehr Informationen?

5. Umwelt

a) Wofür steht für Sie der Begriff Umwelt?

b) Wodurch wird Ihrer Meinung nach die Umwelt am stärksten gefährdet?

G.2 Schülerfragebogen Energiesparen im Klassenzimmer

Englisch

UNIVERSITÄT BAYREUTH

Open Schools for Open Societies

Dear students

Thank for your participation in this science project.

This **questionnaire** is part of scientific and the applied data is treated **strictly confidence**.

Your **teacher** will **not read or mark** your answers.

Please **work on your own.**

Read and **answer** each question **carefully**.

Please **use a dark pen**, not a pencil.

Please tick only one box for each question. In case you have ticked the wrong box, please fill out the whole box and tick another box.

When you are finished, please **check your questionnaire** if you **answered all questions**.

date ☐☐ ☐☐ ☐☐☐☐

day **month** **year**

Personal code:

This code is important to match the questionnaires to each other but not personally, who fills it out.

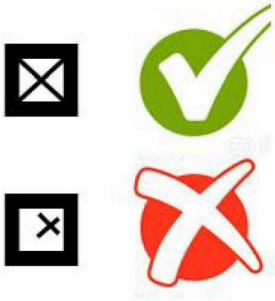
1. Reduce your **gender** for males as **M** or female as **W**.
2. In which **month** are **you born**? (example: **08** for August, **12** for December).
3. In which **year** are **you born**? (example: **99** for 1999, **00** for 2000).
4. Which are the two first letters of your **mother's name**? (example. **AL** for Aliki).
5. In which **house number** do you live? (example: **003** for house number 3, 012 for house number 12).

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

1. gender **2. month of birth** **3. year of birth** **4. mothers name** **5. house number**

Example: Aliki, female, born in September 2001, her mothers name is Anastacia and Aliki lives in house number 7. ***<u>*Alikis code number*</u>: ***F0901AN007***

A) Answer the following question by tick only one case for each question.



1	Which activity does not require fossil energy?
☐	transport
☐	ride a bicycle
☐	lighting of rooms
☐	using computers

2	Which of the following activities is most energy-consuming in your everyday classroom?
☐	turn off the lights during lunch-time
☐	let the computer on all day, although you use it only once a day
☐	turn off all devices during breaks between two school lessons
☐	disconnect the laptops from the power system when the battery is fully charged

3	What kind of lamps would you choose to get possible energy savings and the most economical solution for your classroom?
☐	LED lamps, 18 watts, 10€
☐	light bulb, 100 watts, 0,75€
☐	energy-saving lamps, 20 watts, 5€
☐	fluorescent lamp, 18 watt, 3,50€

4	Which operation will be the best opportunity to dry your clothes environmentally friendly?
☐	using electricity from natural gases in operation of the tumble-dryer
☐	using a tumble-dryer in an efficiency category
☐	drying on a clothesline instead of using a tumble-dryer
☐	using green electricity for the tumble-dryer

5	You urgently need new pants. How would you harm the environment most?
☐	buy the article in a second-hand shop
☐	considering its origin and buy the article locally
☐	buy your article in an online shop choosing over-night express delivery
☐	going to the next store and buy new pants that please you

6	Increasing demand for meat in a growing population reinforces the greenhouse effect. Which animals are responsible for the highest methane production?
☐	fishes
☐	chicken
☐	pigs
☐	cows

7	**Which of the following opportunities is NOT good to save energy?**
☐	good isolation of the building to protect from cold
☐	using an energy-efficient light bulb
☐	using an air conditioner in summer day and night
☐	turn off the air conditioner in winter

8	**Which of the following opportunity waste the most energy during a lesson in your classroom?**
☐	your teacher using a whiteboard
☐	your teacher using a flip chart
☐	your teacher using the board
☐	your teacher using a visualizer connected to a projector

9	**Carbon dioxide causes problems, because…**
☐	…it enhances the greenhouse effect
☐	…it damages plants
☐	…it destroys the ozone layer
☐	…it irritates the skin

10	**Which compass direction of photovoltaic cells is the best?**
☐	north
☐	south
☐	east
☐	west

11	**How can you save energy while cooking?**
☐	turn the stove to the lowest level
☐	use a lid on your pot
☐	turn the stove to the highest level
☐	order food using a delivery service

12	**Where should you throw away old used energy-saving lamps?**
☐	waste glass container
☐	nature
☐	household waste
☐	special recycling bin for used lamps

13	**To efficiently ventilate our classroom, we do NOT waste energy if…**
☐	…we leave the windows fully open for a long time to get fresh air in winter
☐	…we constantly tip the windows
☐	…we leave the windows fully open and only for a short time
☐	…keeping windows closed and using air conditioning

14	**How is it possible to reduce carbon dioxide from the atmosphere?**
☐	plant trees
☐	ride a bicycle
☐	wearing clothes from natural fibres
☐	using wood as fuel

15	How should buildings be painted in hot sunny areas like Italy to save energy? The buildings should be…
☐	… light coloured to avoid overheating in summer
☐	… light or dark colours do not have any effect
☐	… dark colours to prevent overheating in winter
☐	… dark colours absorb the sun's heat

16	Which is the environmentally most damaging way to go into town with your friend?
☐	by car with my mother or father
☐	using public transport
☐	take a taxi
☐	car sharing with my friends' mother or father

17	Two people travel from Athens to Saloniki. Person A takes a car, person B a bus (including 30 passengers).
☐	person B using 6 time less energy for the route than person A.
☐	person B using only the half of energy than person A.
☐	person A using only the half of energy than person B.
☐	both person using the same amount of energy.

18	Which of the following electrical devices is the most energy-consuming one in the classroom?
☐	projector
☐	computer + screen
☐	interactive whiteboard
☐	air conditioning

19	What kind of building are NOT energy efficient in hot areas?
☐	building with many small windows
☐	building with many big windows
☐	building with double glassing
☐	building consisting only from natural materials

20	For heating water, energy are required. For which action you need warm water most?
☐	hand washing
☐	brush your teeth
☐	bike or car washing
☐	washing dishes

21	How do you not save energy in the classroom?
☐	do not use long curtains to prevent heat from escaping
☐	keep classroom doors closed
☐	close the windows in winter while heating the classroom
☐	during night time, turn the thermostat of the heating on its highest stage

22	For a sustainable development…
☐	…ecological trade measures are needed that our grand-children still have an intact environment
☐	…economical trade measures are needed that our grand-children will not living in poverty
☐	…aspects of environment, social and economic need equal weighing
☐	…social trade measures are needed that our grandchildren will live in freedom

23	**A 20 W energy-saving lamp has the same effects as a 100 W light bulb. How many times does an economy lamp with 1 kWh work?**
☐	20 times longer
☐	5 times longer
☐	200 times longer
☐	both are identical

24	**Coal, mineral oil and natural gases were originally developed million years ago from…**
☐	sand
☐	stones
☐	plant material
☐	bacteria

25	**If you want to reduce your carbon dioxide footprint, you will be…**
☐	… switching off all electrical devices with your remote controller
☐	… not switching off all your electrical devices
☐	… using a flip switch to switch off of all electrical devices
☐	… switching off your electrical devices without that there relay function light

26	**Which of these opportunities are suited to improve thermal isolation of a school building?**
☐	using sun shades having constant shadow places for learning activities outside the building
☐	planting trees at suitable places close to the school building
☐	planting a hedge around the school building getting some shade for the building
☐	decorate the school areal around the school building with some nice artworks

27	**What will NOT be the long-term effect of the greenhouse effect?**
☐	…glacier will melt
☐	…sea level will rises
☐	…sea temperature will sink in all oceans
☐	…changing climate zone around the globe

28	**If a room has 50% humidity and 20°C temperature, the humidity-temperature relationship is considered…**
☐	it does not matter
☐	satisfactory
☐	not good – dry air
☐	not good – too much moisture

29	**You would like to save energy. Which action is NOT useful?**
☐	take a shower instead of a bath
☐	charge your cell phone in school
☐	wearing warm clothes inside the room in winter
☐	using LED for lighting

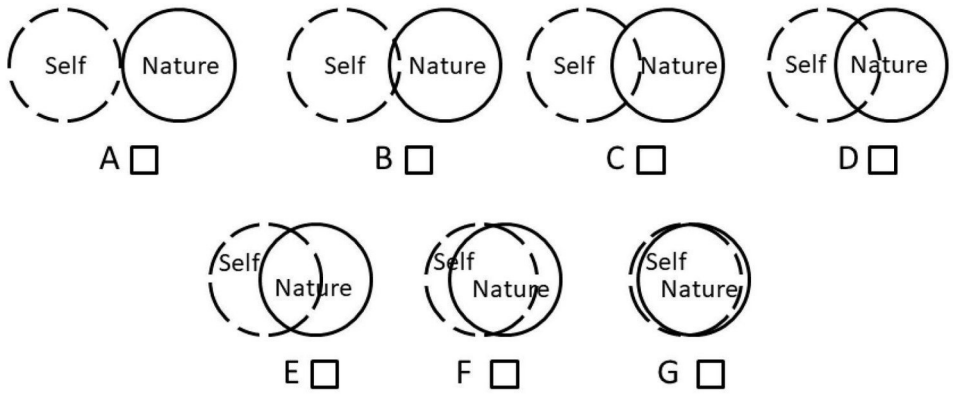
30	**Which of the following does not belong to the category of renewable energies?**
☐	solar energy
☐	fossil energy
☐	wind power
☐	biomass

	B) How often have you done this outside (of the) school? (GEB, Kaiser 2007)	never	seldom	sometimes	often	very often
1.	I ride a bicycle, take public transportation or walk to school.	☐	☐	☐	☐	☐
2.	After one day of use, my sweaters or trousers go into the laundry.	☐	☐	☐	☐	☐
3.	I buy beverages in cans.	☐	☐	☐	☐	☐
4.	I am driven around by car.	☐	☐	☐	☐	☐
5.	I read books, publications, and other materials about environmental problems.	☐	☐	☐	☐	☐
6.	I buy beverages in returnable bottles.	☐	☐	☐	☐	☐
7.	In hotels, I have the towels changed daily.	☐	☐	☐	☐	☐
8.	I separate waste.	☐	☐	☐	☐	☐
9.	In the winter, it is warm enough in my room to only wear a T-shirt.	☐	☐	☐	☐	☐
10.	For short distances (within 15 minutes), I walk or ride a bike.	☐	☐	☐	☐	☐
11.	After a picnic, I leave the place as clean as it was before.	☐	☐	☐	☐	☐
12.	When shopping, I prefer products with eco-labels.	☐	☐	☐	☐	☐
13.	If I am offered a plastic bag in a store, I take it.	☐	☐	☐	☐	☐
14.	I put empty batteries in the garbage.	☐	☐	☐	☐	☐
15.	I buy products in refillable packages.	☐	☐	☐	☐	☐

	B) How often have you done this outside (of the) school?	never	seldom	sometimes	often	very often
16.	I refrain from battery-operated appliances.	☐	☐	☐	☐	☐
17.	I collect and recycle used paper.	☐	☐	☐	☐	☐
18.	I buy certified organic foods.	☐	☐	☐	☐	☐
19.	On excursions, I take along beverages in single-use packages (e.g.Sunkist, Capri-Sonne).	☐	☐	☐	☐	☐
20.	I keep gift wrapping paper for reuse.	☐	☐	☐	☐	☐
21.	I contribute financially to environmental organizations.	☐	☐	☐	☐	☐
22.	I reuse my shopping bags.	☐	☐	☐	☐	☐
23.	I insist on holidays close to home.	☐	☐	☐	☐	☐
24.	I eat seasonal produce.	☐	☐	☐	☐	☐
25.	At my parties, we use plastic silverware and paper cups.	☐	☐	☐	☐	☐
26.	In the winter, I turn down the heat when I leave my room for more than 4 hours.	☐	☐	☐	☐	☐
27.	I bring empty glass bottles to a recycling bin.	☐	☐	☐	☐	☐
28.	I use writing pads from recycled paper.	☐	☐	☐	☐	☐
29.	I try to persuade my parents to buy an energy-efficient car.	☐	☐	☐	☐	☐
30.	I order take-out pizza.	☐	☐	☐	☐	☐

	B) How often have you done this outside (of the) school?	never	seldom	sometimes	often	very often
31.	I eat in fast-food restaurants, such as McDonalds and Burger King.	☐	☐	☐	☐	☐
32.	I have pointed out unecological behavior to someone.	☐	☐	☐	☐	☐
33.	I ask my parents to buy seasonal produce.	☐	☐	☐	☐	☐
34.	As the last person to leave a room, I switch off the lights.	☐	☐	☐	☐	☐
35.	I learn about environmental issues in the media (newspapers, magazines, and TV).	☐	☐	☐	☐	☐
36.	I leave electrically powered appliances (TV, stereo, printer) on standby.	☐	☐	☐	☐	☐
37.	I am a member of an environmental organization.	☐	☐	☐	☐	☐
38.	I kill insects with a chemical insecticide.	☐	☐	☐	☐	☐
39.	I prefer markers to crayons for drawing.	☐	☐	☐	☐	☐
40.	For making notes, I take paper that is already used on one side.	☐	☐	☐	☐	☐

C) Please, circle the picture below that describes your relationship with the natural environment best. (INS, Schultz 2004)



D) How often have you done this outside (of the) school? (2-MEV, Bogner 2018)		never	seldom	sometimes	often	very often
1.	I consciously watch or listen to birds	☐	☐	☐	☐	☐
2.	I take time to watch the clouds pass by	☐	☐	☐	☐	☐
3.	I deliberately take time to watch stars at night	☐	☐	☐	☐	☐
4.	I take time to consciously smell flowers	☐	☐	☐	☐	☐
5.	I personally take care of plants	☐	☐	☐	☐	☐

D) To what extent do you agree with the following statements?		strongly disagree	disagree	partially agree	agree	totally agree
6.	I save water by taking a shower instead of a bath (in order to spare water).	☐	☐	☐	☐	☐
7.	I enjoy gardening	☐	☐	☐	☐	☐
8.	We must build more roads so people can travel to the countryside.	☐	☐	☐	☐	☐
9.	Humankind will die out if we don't live in tune with nature.	☐	☐	☐	☐	☐
10.	Not only plants and animals of economic importance need to be protected.	☐	☐	☐	☐	☐
11.	Dirty industrial smoke from chimneys makes me angry.	☐	☐	☐	☐	☐
12.	Nature is always able to restore itself.	☐	☐	☐	☐	☐
13.	Pets are part of the family.	☐	☐	☐	☐	☐
14.	Our planet has unlimited resources	☐	☐	☐	☐	☐

	D) To what extent do you agree with the following statements?	strongly disagree	disagree	partially agree	agree	strongly agree
15.	Listening to the sounds of nature makes me relax	☐	☐	☐	☐	☐
16.	We don't need to set aside areas to protect endangered species.	☐	☐	☐	☐	☐
17.	Humans don't have the right to change nature as they see fit.	☐	☐	☐	☐	☐
18.	People worry too much about pollution.	☐	☐	☐	☐	☐
19.	Human beings are not more important than other creatures.	☐	☐	☐	☐	☐
20.	We need to clear forests in order to grow crops.	☐	☐	☐	☐	☐
21.	The quiet nature outdoors makes me anxious.	☐	☐	☐	☐	☐

Thank you to fill out this questionnaire. Please check, if you have answered all the questions.

Griechisch

Κωδικός μαθητή: _____

Ηλικία _____

Φύλο _____

Σας ευχαριστούμε που συμμετέχετε στην έρευνά μας!

Οι απαντήσεις σας σε αυτό το ερωτηματολόγιο είναι ανώνυμες και εμπιστευτικές. Δεν θα τις διαβάσουν και δε θα τις βαθμολογήσουν οι δάσκαλοι και οι δασκάλες σας!
Παρακαλούμε απαντήστε πολύ προσεκτικά - ο καθένας μόνος του και η καθεμία μόνη της. Χρησιμοποιήσετε μπλε ή μαύρο στυλό. Σημειώστε την απάντησή σας με ένα καθαρό X μέσα στο πλαίσιο. Αν κάνετε λάθος, γεμίστε ολόκληρο το λάθος κουτί και βάλτε X στο σωστό.

Α) Απάντησε τις παρακάτω ερωτήσεις κάνοντας μόνο μια επιλογή ανά ερώτηση.

1	**Ποια δραστηριότητα δεν απαιτεί σε καμία περίπτωση ενέργεια από ορυκτά καύσιμα;**
☐	Μετακίνηση με αυτοκίνητο
☐	Μετακίνηση με ποδήλατο
☐	Φωτισμός του δωματίου
☐	Χρήση του υπολογιστή

2	**Με ποια συνήθεια σπαταλάτε περισσότερη ενέργεια στη σχολική τάξη;**
☐	Σβήνετε τα φώτα κατά τη διάρκεια του μεγάλου διαλείμματος.
☐	Αφήνετε τον υπολογιστή αναμμένο όλη μέρα, ενώ τον χρησιμοποιείτε μόνο για λίγο.
☐	Σβήνετε όλες τις συσκευές στο διάλειμμα μεταξύ δύο μαθημάτων.
☐	Βάζετε το φορητό υπολογιστή στην πρίζα, όταν η μπαταρία είναι πλήρως φορτισμένη.

3	**Τι είδους λάμπες θα επιλέγατε για να εξοικονομήσετε ενέργεια στην τάξη σας με τον πιο οικονομικό τρόπο;**
☐	Λάμπες LED, 18 watt, 10€
☐	Παραδοσιακές λάμπες, 100 watt, 0,75€
☐	Λάμπες εξοικονόμησης ενέργειας, 20 watt, 5€
☐	Λάμπες φθορισμού, 18 watt, 3,50€

4	**Ποιος είναι ο πιο φιλικός προς το περιβάλλον τρόπος για να στεγνώνετε τα ρούχα σας;**
☐	Χρησιμοποιώντας ηλεκτρική ενέργεια από φυσικό αέριο για το στεγνωτήριο.
☐	Χρησιμοποιώντας στεγνωτήριο που ανήκει σε καλή κατηγορία ενεργειακής απόδοσης.
☐	Στεγνώνοντας τα ρούχα σε σκοινί αντί να χρησιμοποιούμε στεγνωτήριο.
☐	Χρησιμοποιώντας «πράσινη» ηλεκτρική ενέργεια για το στεγνωτήριο.

5	**Χρειάζεστε επειγόντως καινούργιο παντελόνι. Πώς θα βλάπτατε περισσότερο το περιβάλλον;**
☐	Αγοράζοντας το παντελόνι σε κατάστημα μεταχειρισμένων ειδών.
☐	Μαθαίνοντας για την προέλευσή του και επιλέγοντας ένα τοπικό προϊόν.
☐	Αγοράζοντας το παντελόνι στο ίντερνετ με επείγουσα παράδοση την επόμενη μέρα.
☐	Πηγαίνοντας σε ένα κατάστημα ρούχων και αγοράζοντας ένα παντελόνι που σας αρέσει.

6	**Η αύξηση της ζήτησης κρέατος από τον παγκόσμιο πληθυσμό ενισχύει το φαινόμενο του θερμοκηπίου. Ποια ζώα παράγουν περισσότερο μεθάνιο;**
☐	Τα ψάρια
☐	Τα κοτόπουλα
☐	Οι χοίροι
☐	Οι αγελάδες

7	**Ποια από τις παρακάτω ΔΕΝ είναι καλή πρακτική για την εξοικονόμηση ενέργειας;**
☐	Καλή μόνωση του κτηρίου για προστασία από το κρύο
☐	Χρήση ενεργειακά αποδοτικών λαμπτήρων
☐	Χρήση του κλιματιστικού το καλοκαίρι, μέρα και νύχτα
☐	Σβήσιμο του κλιματιστικού το χειμώνα
9	**Το διοξείδιο του άνθρακα είναι πρόβλημα, γιατί...**
☐	...ενισχύει το φαινόμενο του θερμοκηπίου.
☐	... βλάπτει τα φυτά.
☐	... καταστρέφει τη στιβάδα του όζοντος.
☐	...ερεθίζει το δέρμα.
11	**Πώς μπορείτε να εξοικονομήσετε ενέργεια ενώ μαγειρεύετε;**
☐	Ανάβοντας την εστία της ηλεκτρικής κουζίνας στο χαμηλότερο επίπεδο.
☐	Βάζοντας το καπάκι στη κατσαρόλα.
☐	Ανάβοντας την εστία στον πιο ψηλό επίπεδο.
☐	Παραγγέλνοντας έτοιμο φαγητό που θα σας παραδοθεί στο σπίτι.
13	**Για να αερίσετε καλά την τάξη μας, ΔΕΝ σπαταλάτε ενέργεια αν...**
☐	...αφήνετε το χειμώνα τα παράθυρα εντελώς ανοιχτά για πολλή ώρα.
☐	...κρατάτε συνεχώς μισάνοιχτα τα παράθυρα.
☐	...αφήνετε τα παράθυρα εντελώς ανοιχτά μόνο για μικρό χρονικό διάστημα.
☐	...κρατάτε τα παράθυρα κλειστά και χρησιμοποιείτε τον κλιματισμό.

8	**Σε ποια από τις παρακάτω περιπτώσεις υπάρχει μεγαλύτερη σπατάλη ενέργειας κατά τη διάρκεια του μαθήματος στην τάξη;**
☐	Ο δάσκαλος χρησιμοποιεί λευκό πίνακα.
☐	Ο δάσκαλος χρησιμοποιεί πίνακα με μεγάλα χαρτιά για σημειώσεις (flip chart).
☐	Ο δάσκαλος χρησιμοποιεί απλό πίνακα.
☐	Ο δάσκαλος χρησιμοποιεί προβολέα (προτζέκτορα).
10	**Ποια είναι η καλύτερη κατεύθυνση για τα φωτοβολταϊκά;**
☐	Βόρεια
☐	Νότια
☐	Ανατολικά
☐	Δυτικά
12	**Πού πρέπει να πετάτε παλιούς λαμπτήρες εξοικονόμησης ενέργειας;**
☐	Σε κάδο απορριμμάτων γυαλιού
☐	Στη φύση
☐	Στα οικιακά απορρίμματα
☐	Σε ειδικό κάδο ανακύκλωσης για χρησιμοποιημένους λαμπτήρες
14	**Πώς βοηθάτε να μειωθεί το διοξείδιο του άνθρακα στην ατμόσφαιρα;**
☐	Φυτεύοντας δέντρα
☐	Κάνοντας ποδήλατο
☐	Φορώντας ρούχα από φυσικές ίνες
☐	Χρησιμοποιώντας ξύλα ως καύσιμο

15	**Πώς πρέπει να χρωματίζονται τα κτήρια σε περιοχές με θερμό κλίμα για να εξοικονομείται ενέργεια;**
☐	Ανοιχτόχρωμα, για να αποφεύγεται η υπερθέρμανση το καλοκαίρι.
☐	Είτε ανοιχτόχρωμα είτε σκουρόχρωμα, δεν έχει σημασία.
☐	Σκουρόχρωμα για να αποφεύγεται η υπερθέρμανση το χειμώνα.
☐	Σκουρόχρωμα για να απορροφούν περισσότερη θερμότητα από τον ήλιο.
17	**Δύο άτομα ταξιδεύουν από την Αθήνα στη Θεσσαλονίκη. Το άτομο Α πηγαίνει με αυτοκίνητο, το άτομο Β παίρνει λεωφορείο με 30 επιβάτες.**
☐	Το άτομο Β χρησιμοποιεί 6 φορές λιγότερη ενέργεια για τη διαδρομή από το άτομο Α.
☐	Το άτομο Β χρησιμοποιεί μόνο τη μισή ενέργεια σε σχέση με το άτομο Α.
☐	Το άτομο Α χρησιμοποιεί μόνο τη μισή ενέργεια σε σχέση με το άτομο Β.
☐	Και τα δύο άτομα χρησιμοποιούν την ίδια ποσότητα ενέργειας.
19	**Τι είδους κτήριο ΔΕΝ είναι ενεργειακά αποδοτικό σε περιοχές με θερμό κλίμα;**
☐	Κτήριο με πολλά μικρά παράθυρα
☐	Κτήριο με πολλά μεγάλα παράθυρα
☐	Κτήριο με παράθυρα με διπλά τζάμια
☐	Κτήριο φτιαγμένο μόνο από φυσικά υλικά
21	**Με ποια ενέργεια ΔΕΝ εξοικονομείτε ενέργεια στη σχολική τάξη;**
☐	Χρησιμοποιείτε μακριές κουρτίνες για να αποφύγετε τη διαφυγή θερμότητας.
☐	Κρατάτε την πόρτα της αίθουσας κλειστή.
☐	Κλείνετε το παράθυρο το χειμώνα, όταν χρησιμοποιείτε τη θέρμανση.
☐	Για το βράδυ, γυρίζετε το θερμοστάτη της θέρμανσης στο υψηλότερο επίπεδο.

16	**Ποιος είναι ο χειρότερος για το περιβάλλον τρόπος για να πάτε βόλτα στο κέντρο της πόλης με ένα φίλο σας;**
☐	Σας πηγαίνει η μητέρα σας ή ο πατέρας σας με το αυτοκίνητο.
☐	Χρησιμοποιείτε τη δημόσια συγκοινωνία.
☐	Παίρνετε ταξί.
☐	Μοιράζεστε με το φίλο σας το αυτοκίνητο της μητέρας ή του πατέρα του.
18	**Ποια από τις ακόλουθες ηλεκτρικές συσκευές καταναλώνει περισσότερη ενέργεια στη σχολική τάξη;**
☐	Προβολέας (προτζέκτορας)
☐	Υπολογιστής και οθόνη
☐	Διαδραστικός πίνακας
☐	Κλιματιστικό
20	**Για τη θέρμανση του νερού απαιτείται ενέργεια. Για ποια δουλειά χρειάζεστε περισσότερο ζεστό νερό;**
☐	Πλύσιμο των χεριών
☐	Βούρτσισμα των δοντιών
☐	Πλύσιμο του αυτοκινήτου ή του ποδήλατου
☐	Πλύσιμο πιάτων
22	**Για να πετύχουμε βιώσιμη ανάπτυξη ...**
☐	...χρειάζεται να πάρουμε οικολογικά μέτρα, για να διατηρήσουμε και για τα εγγόνια μας ανέπαφο το φυσικό περιβάλλον.
☐	...χρειάζεται να πάρουμε οικονομικά μέτρα, για να μην ζουν σε συνθήκες φτώχειας τα εγγόνια μας.
☐	...χρειάζεται να δώσουμε ίσο βάρος στο περιβάλλον, την κοινωνία και την οικονομία.
☐	...χρειάζεται να πάρουμε κοινωνικά μέτρα, για να ζουν τα εγγόνια μας σε συνθήκες ελευθερίας.

23	**Μια λάμπα εξοικονόμησης ενέργειας 20 W δίνει ίδιο φως με μια συμβατική λάμπα των 100 W. Πόσες φορές περισσότερο χρόνο λειτουργεί η λάμπα οικονομίας σε σύγκριση με τη συμβατική λάμπα, καταναλώνοντας ενέργεια 1 kWh;**
☐	20 φορές περισσότερο
☐	5 φορές περισσότερο
☐	200 φορές περισσότερο
☐	Και οι δυο είναι το ίδιο.
25	**Για να μειώσετε το διοξείδιο του άνθρακα που εκλύεται στην ατμόσφαιρα λόγω της δραστηριότητάς σας...**
☐	...απενεργοποιείτε τις ηλεκτρικές συσκευές με το τηλεχειριστήριο.
☐	...δεν απενεργοποιείτε τις ηλεκτρικές συσκευές σας.
☐	....χρησιμοποιείτε τον κεντρικό διακόπτη για να απενεργοποιήσετε τις συσκευές σας.
☐	...απενεργοποιείτε τις συσκευές σας, πάνω στις οποίες δεν υπάρχει κάποιο φως.
27	**Ποιο από τα παρακάτω ΔΕΝ θα αποτελέσει μακροπρόθεσμη συνέπεια του φαινομένου του θερμοκηπίου;**
☐	Θα λιώσουν οι παγετώνες.
☐	Θα ανεβεί η στάθμη της θάλασσας.
☐	Η θερμοκρασία της θάλασσας θα μειωθεί σε όλους τους ωκεανούς.
☐	Θα αλλάξουν οι κλιματικές ζώνες σε ολόκληρο τον πλανήτη.
29	**Ποιο από τα παρακάτω ΔΕΝ βοηθάει για να εξοικονομήσετε ενέργεια;**
☐	Να κάνετε ντους, αντί για μπάνιο σε γεμάτη μπανιέρα.
☐	Να φορτίζετε το κινητό σας στο σχολείο.
☐	Να φοράτε ζεστά ρούχα μέσα στο κτήριο το χειμώνα.
☐	Να χρησιμοποιείτε λάμπες LED για το φωτισμό.

24	**Οι γαιάνθρακες, το πετρέλαιο και το φυσικό αέριο δημιουργήθηκαν πριν από εκατομμύρια χρόνια από...**
☐	...άμμο
☐	...πέτρες
☐	...φυτικά υλικά
☐	...βακτήρια
26	**Ποιος είναι καλύτερος τρόπος για τη βελτίωση της θερμομόνωσης του σχολείου;**
☐	Η δημιουργία περιοχών με μόνιμη σκιά για εκπαιδευτικές δραστηριότητες εκτός του σχολικού κτηρίου.
☐	Η φύτευση δέντρων σε κατάλληλα σημεία κοντά στο σχολικό κτήριο.
☐	Η φύτευση θάμνων γύρω από το σχολικό κτήριο, για να κάνει κάποια σκιά στο κτήριο.
☐	Η διακόσμηση του περιβάλλοντος γύρω από το σχολικό κτήριο με ωραία έργα τέχνης.
28	**Αν ένα δωμάτιο έχει υγρασία 50% και θερμοκρασία 20° C, η σχέση υγρασίας-θερμοκρασίας θεωρείται...**
☐	Ασήμαντη
☐	Ικανοποιητική
☐	Όχι καλή, ο αέρας είναι ξηρός.
☐	Όχι καλή, έχει υπερβολικά πολλή υγρασία.
30	**Ποια από τις παρακάτω μορφές ενέργειας δεν είναι ανανεώσιμη;**
☐	Ηλιακή ενέργεια
☐	Ενέργεια από ορυκτά καύσιμα
☐	Αιολική ενέργεια
☐	Ενέργεια από βιομάζα

Β) Πόσο συχνά κάνετε τα παρακάτω εκτός σχολείου;		**Ποτέ**	**Σπάνια**	**Μερικές φορές**	**Συχνά**	**Πολύ συχνά**
1.	Πηγαίνω στο σχολείο με το ποδήλατο, με τα μέσα μαζικής μεταφοράς, ή με τα πόδια.	☐	☐	☐	☐	☐
2.	Φοράω τις μπλούζες και τα παντελόνια μου μια μόνο μέρα και μετά τα βάζω για πλύσιμο.	☐	☐	☐	☐	☐
3.	Αγοράζω αναψυκτικά σε μεταλλικά κουτάκια.	☐	☐	☐	☐	☐
4.	Μετακινούμαι με αυτοκίνητο.	☐	☐	☐	☐	☐
5.	Διαβάζω βιβλία, δημοσιεύσεις και άλλο υλικό για τα προβλήματα του περιβάλλοντος.	☐	☐	☐	☐	☐
6.	Αγοράζω αναψυκτικά σε επιστρεφόμενες φιάλες.	☐	☐	☐	☐	☐
7.	Όταν μένω σε ξενοδοχείο, θέλω να μου αλλάζουν καθημερινά τις πετσέτες.	☐	☐	☐	☐	☐
8.	Διαχωρίζω τα σκουπίδια ανάλογα με το είδος τους.	☐	☐	☐	☐	☐
9.	Το χειμώνα κάνει αρκετή ζέστη στο δωμάτιό μου ώστε να φοράω κοντομάνικο μπλουζάκι.	☐	☐	☐	☐	☐
10.	Για μικρές αποστάσεις (μέχρι 15 λεπτά), πηγαίνω με τα πόδια ή το ποδήλατο.	☐	☐	☐	☐	☐
11.	Μετά από ένα πικνίκ, αφήνω το μέρος τόσο καθαρό όσο ήταν και πριν.	☐	☐	☐	☐	☐
12.	Όταν ψωνίζω, προτιμώ προϊόντα που έχουν στη συσκευασία τους κάποιο οικολογικό σήμα.	☐	☐	☐	☐	☐
13.	Αν μου προσφέρουν πλαστική τσάντα σε ένα κατάστημα, την παίρνω.	☐	☐	☐	☐	☐
14.	Πετάω τις άδειες μπαταρίες στα σκουπίδια.	☐	☐	☐	☐	☐
15.	Αγοράζω προϊόντα σε συσκευασίες που μπορούν να ξαναγεμιστούν.	☐	☐	☐	☐	☐
16.	Αποφεύγω να χρησιμοποιώ συσκευές που λειτουργούν με μπαταρίες.	☐	☐	☐	☐	☐
17.	Μαζεύω και ανακυκλώνω το χρησιμοποιημένο χαρτί.	☐	☐	☐	☐	☐
18.	Αγοράζω πιστοποιημένα βιολογικά τρόφιμα.	☐	☐	☐	☐	☐
19.	Στις εκδρομές, παίρνω μαζί αναψυκτικά σε συσκευασίες μιας χρήσης.	☐	☐	☐	☐	☐
20.	Κρατάω το χαρτί από τις συσκευασίες των δώρων για να το ξαναχρησιμοποιήσω.	☐	☐	☐	☐	☐
21.	Υποστηρίζω οικονομικά περιβαλλοντικές οργανώσεις.	☐	☐	☐	☐	☐

Β) Πόσο συχνά κάνετε τα παρακάτω εκτός σχολείου;		**Ποτέ**	**Σπάνια**	**Μερικές φορές**	**Συχνά**	**Πολύ συχνά**
22.	Ξαναχρησιμοποιώ τις σακούλες από τα ψώνια μου.	☐	☐	☐	☐	☐
23.	Επιμένω να κάνουμε διακοπές κοντά στο σπίτι.	☐	☐	☐	☐	☐
24.	Τρώω εποχιακά φυσικά προϊόντα (δηλαδή, τα τρώω την εποχή που παράγονται κανονικά).	☐	☐	☐	☐	☐
25.	Στα πάρτι χρησιμοποιώ πλαστικά σερβίτσια και ποτήρια.	☐	☐	☐	☐	☐
26.	Το χειμώνα χαμηλώνω τη θέρμανση όταν φεύγω από το χώρο μου για περισσότερο από 4 ώρες.	☐	☐	☐	☐	☐
27.	Πετάω τα άδεια γυάλινα μπουκάλια σε κάδο ανακύκλωσης.	☐	☐	☐	☐	☐
28.	Χρησιμοποιώ τετράδια από ανακυκλωμένο χαρτί.	☐	☐	☐	☐	☐
29.	Προσπαθώ να πείσω τους γονείς μου να αγοράσουν ενεργειακά αποδοτικό αυτοκίνητο.	☐	☐	☐	☐	☐
30.	Παραγγέλνω πίτσα στο σπίτι.	☐	☐	☐	☐	☐
31.	Τρώω σε εστιατόρια fast-food.	☐	☐	☐	☐	☐
32.	Επισημαίνω σε κάποιον ότι η συμπεριφορά του δεν είναι φιλική προς το περιβάλλον.	☐	☐	☐	☐	☐
33.	Ζητώ από τους γονείς μου να αγοράζουν εποχιακά προϊόντα (την εποχή που παράγονται κανονικά).	☐	☐	☐	☐	☐
34.	Όταν είμαι το τελευταίο άτομο που φεύγει από ένα δωμάτιο, σβήνω τα φώτα.	☐	☐	☐	☐	☐
35.	Μαθαίνω για τα περιβαλλοντικά προβλήματα από τα μέσα ενημέρωσης (εφημερίδες, τηλεόραση,…).	☐	☐	☐	☐	☐
36.	Αφήνω τις ηλεκτρικές συσκευές (π.χ. τηλεόραση, εκτυπωτή, κτλ.) σε κατάσταση αναμονής.	☐	☐	☐	☐	☐
37.	Είμαι μέλος κάποιας περιβαλλοντικής οργάνωσης.	☐	☐	☐	☐	☐
38.	Σκοτώνω έντομα χρησιμοποιώντας χημικά εντομοκτόνα.	☐	☐	☐	☐	☐
39.	Προτιμώ μαρκαδόρους αντί για μπογιές όταν ζωγραφίζω.	☐	☐	☐	☐	☐
40.	Για να κρατήσω σημειώσεις, παίρνω χαρτί που έχει ήδη χρησιμοποιηθεί στη μία πλευρά.	☐	☐	☐	☐	☐

Ευχαριστούμε για τη συμμετοχή σας! Παρακαλούμε ελέγξτε ότι έχετε απαντήσει σε όλες τις ερωτήσεις.

Κωδικός μαθητή: _____

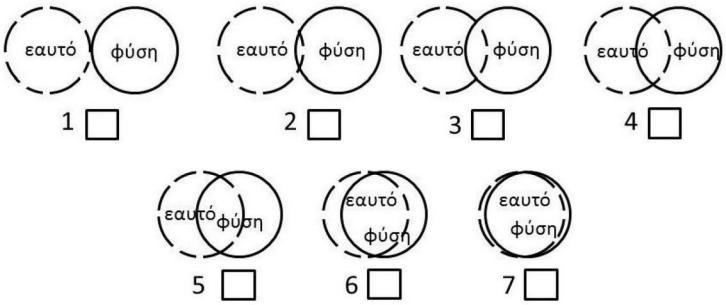
Ηλικία _____

Φύλο _____

Σας ευχαριστούμε που συμμετέχετε στην έρευνά μας!

Οι απαντήσεις σας σε αυτό το ερωτηματολόγιο είναι ανώνυμες και εμπιστευτικές. Δεν θα τις διαβάσουν και δε θα τις βαθμολογήσουν οι δάσκαλοι και οι δασκάλες σας!
Παρακαλούμε απαντήστε πολύ προσεκτικά - ο καθένας μόνος του και η καθεμία μόνη της. Χρησιμοποιήσετε μπλε ή μαύρο στυλό. Σημειώστε την απάντησή σας με ένα καθαρό Χ μέσα στο πλαίσιο. Αν κάνετε λάθος, γεμίστε ολόκληρο το λάθος κουτί και βάλτε Χ στο σωστό.

Γ) Σημειώστε παρακάτω την εικόνα που περιγράφει καλύτερα τη σχέση σας με το φυσικό περιβάλλον.



Δ) Πόσο συχνά κάνετε τα παρακάτω εκτός σχολείου;		**Ποτέ**	**Σπάνια**	**Μερικές φορές**	**Συχνά**	**Πολύ συχνά**
1.	Παρατηρώ ή ακούω προσεκτικά τα πουλιά.	☐	☐	☐	☐	☐
2.	Αφιερώνω χρόνο για να παρατηρώ τα σύννεφα που περνούν.	☐	☐	☐	☐	☐
3.	Αφιερώνω χρόνο για να παρατηρώ τα αστέρια.	☐	☐	☐	☐	☐
4.	Αφιερώνω χρόνο για να μυρίσω ένα λουλούδι.	☐	☐	☐	☐	☐
5.	Φροντίζω τα φυτά.	☐	☐	☐	☐	☐

Δ) Πόσο συμφωνείτε ή διαφωνείτε με τις ακόλουθες προτάσεις;		**Διαφωνώ απόλυτα**	**Διαφωνώ**	**Συμφωνώ κάπως**	**Συμφωνώ**	**Συμφωνώ απόλυτα**
6.	Εξοικονομώ νερό κάνοντας ντους, αντί να κάνω μπάνιο σε γεμάτη μπανιέρα.	☐	☐	☐	☐	☐
7.	Μου αρέσει η κηπουρική.	☐	☐	☐	☐	☐
8.	Πρέπει να κατασκευάσουμε περισσότερους δρόμους, για να μπορούν οι άνθρωποι να ταξιδεύουν στην εξοχή.	☐	☐	☐	☐	☐

9.	Η ανθρωπότητα θα εξαφανιστεί, αν δεν ζούμε σε αρμονία με τη φύση.	☐	☐	☐	☐	☐
10.	Δε χρειάζονται προστασία μόνο τα φυτά και τα ζώα που έχουν ιδιαίτερη σημασία για την οικονομία.	☐	☐	☐	☐	☐
11.	Ο βρόμικος καπνός από τις καμινάδες των βιομηχανιών με θυμώνει.	☐	☐	☐	☐	☐
12.	Η φύση μπορεί πάντοτε να αποκαθιστά τον εαυτό της (να αυτο-διορθώνεται).	☐	☐	☐	☐	☐
13.	Τα κατοικίδια ζώα είναι μέλη της οικογένειας.	☐	☐	☐	☐	☐
14.	Ο πλανήτης μας έχει απεριόριστους πόρους.	☐	☐	☐	☐	☐
15.	Το να ακούω τους ήχους της φύσης, με κάνει να χαλαρώνω.	☐	☐	☐	☐	☐
16.	Δε χρειάζονται περιοχές αφιερωμένες στην προστασία απειλούμενων ειδών.	☐	☐	☐	☐	☐
17.	Οι άνθρωποι δεν έχουν το δικαίωμα να αλλάζουν τη φύση όπως τους βολεύει.	☐	☐	☐	☐	☐
18.	Οι άνθρωποι υπερβάλλουν, όταν ανησυχούν τόσο πολύ για τη ρύπανση.	☐	☐	☐	☐	☐
19.	Οι άνθρωποι δεν είναι πιο σημαντικοί από τα άλλα πλάσματα της φύσης.	☐	☐	☐	☐	☐
20.	Χρειάζεται να μετατρέπουμε δάση σε γη που θα μπορούμε να καλλιεργούμε.	☐	☐	☐	☐	☐
21.	Η ησυχία της φύσης στην ύπαιθρο μου προκαλεί ανησυχία.	☐	☐	☐	☐	☐

Ευχαριστούμε για τη συμμετοχή σας! Παρακαλούμε ελέγξτε ότι έχετε απαντήσει όλες τις ερωτήσεις.

H (Eidesstattliche) Versicherungen und Erklärungen

(§ 8 Satz 2 Nr. 3 PromO Fakultät)
Hiermit versichere ich eidesstattlich, dass ich die Arbeit selbstständig verfasst und keine anderen als die von mir angegebenen Quellen und Hilfsmittel benutzt habe (vgl. Art. 64 Abs. 1 Satz 6 BayHSchG).

(§ 8 Satz 2 Nr. 3 PromO Fakultät)
Hiermit erkläre ich, dass ich die Dissertation nicht bereits zur Erlangung eines akademischen Grades eingereicht habe und dass ich nicht bereits diese oder eine gleichartige Doktorprüfung endgültig nicht bestanden habe.

(§ 8 Satz 2 Nr. 4 PromO Fakultät)
Hiermit erkläre ich, dass ich Hilfe von gewerblichen Promotionsberatern bzw. –vermittlern oder ähnlichen Dienstleistern weder bisher in Anspruch genommen habe noch künftig in Anspruch nehmen werde.

(§ 8 Satz 2 Nr. 7 PromO Fakultät)
Hiermit erkläre ich mein Einverständnis, dass die elektronische Fassung der Dissertation unter Wahrung meiner Urheberrechte und des Datenschutzes einer gesonderten Überprüfung unterzogen werden kann.

(§ 8 Satz 2 Nr. 8 PromO Fakultät)
Hiermit erkläre ich mein Einverständnis, dass bei Verdacht wissenschaftlichen Fehlverhaltens Ermittlungen durch universitätsinterne Organe der wissenschaftlichen Selbstkontrolle stattfinden können.

Bayreuth, den ……..... ……..

Datum Unterschrift