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Das Potenzial außerschulischer Lernorte

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Verzeichnisse

Abkürzungsverzeichnis

FIT	*Fascination with Science*
GEB	*General Ecological Behavior Scale*
NEP	*New Environmental Paradigm*
SMOT	*Science Motivation Scale*
2-MEV	*Two Major Environmental Values Model*

Abbildungsverzeichnis

Nachfolgend sind sämtliche Abbildungen der vorliegenden Arbeit mit einer zusammenfassenden, überblickshaften Beschreibung gelistet. Insofern keine unmittelbaren Referenzen angegeben sind, wurden die Fotografien selbst gemacht und die Abbildungen mithilfe von Informationen aus den jeweils angegebenen Quellen selbst erstellt. Lediglich die Piktogramme in Abbildung 1 entstammen dem Vorlagenrepertoire von Microsoft Word.

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1 Summary

Environmental conservation initiatives adhere to the consensus of a sustainable lifestyle, in which ecological, economical, and social goals resonate and induce persistent pro-environmental behavior (e.g. UN, 2015; UNESCO, 2003). Environmental education at schools thus aims at balancing those three goals so the standard of living and economic growth aligns with environmental preservation. This raises the question as how to promote conservation behavior age-appropriately through teaching. For decades, researchers have strived to derive antecedents of behavior through evaluating educational programs (e.g. Hines et al., 1987; Kollmuss & Agyeman, 2002). Environmental knowledge is a well-known antecedent of environmental education, the latter aiming at pro-environmental behavior (e.g. Heimlich & Ardoin, 2008). From a psychological perspective, environmental attitude has emerged as another established parameter (e.g. Ajzen, 1991; Bogner & Wiseman, 2006; Kraus, 1995; Leeming et al., 1993) though there is yet no measurement standard. Conformity regarding its definition and measurement would however help modify educational programs to strengthen environmental attitude and provide teaching recommendations. This thesis therefore works towards a uniform concept of environmental attitude to derive recommendations for promoting nature conservation.

To meet this purpose, five studies were conducted and students were the target group since schools can reach out to large cohorts, and since ages nine to 14 seem to be particularly sensitive to generate environmental attitude (e.g. Otto et al., 2019). Further, informal and outreach learning – including *earth education*, an established teaching approach in the US – appears to positively contribute to environmental attitude (e.g. Potvin & Hasni, 2014; Rickinson, 2001; Van Matre, 1990).

Study A (N = 227; M_{Age} [SD] = 13.06 [1.01]) contrasted two environmental attitude variables: *Science Motivation* (Glynn et al., 2011) and *Fascination with Science* (Otto et al., 2020). It further evaluated the educational programs at Biosphere 2 in Arizona. The one-day interventions could induce environmental knowledge gains and reveal a positive effect of environmental attitude on knowledge. However, the attitude measurements turned out to be reliable but not valid. Due to the continuing Covid-pandemic, it was not possible to use alternative instruments or to evaluate a program modification based on pre- and post-program activities (**study B**) and further program changes. Therefore, **study C** elaborated on a preexisting, larger dataset (N = 6585; M_{Age} [SD] = 9.96 [0.81]) about the extensive program *Earthkeepers* that has been evaluated for multiple years. The study compared established attitude scales (*Two Major Environmental Values Model* [2-MEV: Bogner & Wiseman, 2002] and *New Environmental Paradigm* [Dunlap & Van

Liere, 1978]) and concluded recommendations for their use, which is mainly their focus on nature preservation as an attitude measurement. Finally, it related the parameters *knowledge*, *attitude* and *behavior*. Results showed that attitude significantly affected knowledge levels, while the latter resonated with pro-environmental behavior.

Study D (N = 1592; M_{Age} [SD] = 14.47 [1.78]) continued restructuring scales for a consensus on nature preservation as an expression of environmental attitude through complementing the 2-MEV's opinion-based items with self-reports of past behaviors aimed at preserving the environment (*General Ecological Behavior* [Kaiser, 1998]). The modified scale sustained several quality tests and helped identify attitude's role in knowledge acquisition. Attitude turned out to explain whether students take learning opportunities and how rigorously they learn. This situated attitude as a motivational force for knowledge acquisition. In a quality test, the scale further depicted the characteristic curve of environmental attitude throughout adolescence, which pointed at a sensitive period in which the formation of attitude primarily occurs. The same scale was used in a new context in **study E** (N = 247; M_{Age} [SD] = 9.38 [0.51]). In a reciprocal process, the outreach setting *Cooper Center* was evaluated, while the attitude scale was confirmed through the learning progress of an educational program that has proven successful in study C. Concurrently, as argued in study D, study E confirmed attitude's role in knowledge acquisition as a factor of conservation behavior.

In conclusion, all evaluated informal, educational programs show potential for environmental education through knowledge, attitude, or behavior changes. Effects are stronger if programs are embedded in pre and post activities. Meanwhile, the environmental attitude scale introduced in study D demonstrates robust validity, reliability, and inter-study comparability to serve as a measurement standard. Moreover, it appears recommendable to strengthen environmental attitude primarily until middle school. Further studies are needed to investigate age-related attitude-trends and to determine precise parameters for enhancing environmental attitude. Those should help develop more concrete curricular guidelines and transmit those findings to teaching in the traditional classroom setting.

2 Zusammenfassung

Umweltschutzinitiativen folgen dem Prinzip einer nachhaltigen Lebensweise, bei der ökologische, ökonomische und soziale Bestrebungen konformgehen und persistentes Umweltschutzverhalten hervorbringen (z.B. UN, 2015; UNESCO, 2003). Umweltbildung an Schulen strebt damit nach einer balancierten Vermittlung dieser drei Säulen, um den menschlichen Lebensstandard mit dem Naturschutz und damit anthropogene und ökologische Bestrebungen besser in Einklang zu bringen. Für Unterrichtskonzeptionen stellt sich dabei die Frage nach konkreter, altersgerechter Förderung adäquaten Umweltschutzverhaltens. Seit Jahrzehnten wird versucht, über Lehrprogrammvergleiche Fördermaßnahmen abzuleiten (z.B. Hines et al., 1987; Kollmuss & Agyeman, 2002). Während das Umweltwissen als unabdingbare Säule der Umweltbildung, deren Ziel Umweltschutzverhalten ist, gilt (z.B. Heimlich & Ardoin, 2008), hat sich aus psychologischer Sicht die Umwelteinstellung als zusätzlich etablierter Einflussfaktor herauskristallisiert (e.g. Ajzen, 1991; Bogner & Wiseman, 2006; Kraus, 1995; Leeming et al., 1993), obgleich kein allgemeiner Messstandard vorliegt. Eine Begriffs- und Messkonformität wäre dagegen hilfreich, um Lehrprogramme zur Herausbildung der Umwelteinstellung und damit der Umweltschutzpräferenz zu modifizieren sowie entsprechende Lehrempfehlungen zu formulieren. Der vorliegende Forschungsansatz arbeitet daher eine einheitliche Definition heraus, um über die Messung von Umwelteinstellung Fördermaßnahmen für Umweltschutzverhalten ableiten zu können.

Hierfür wurden im Rahmen von fünf Teilarbeiten Schüler:innen als Zielgruppe herangezogen, da über Schulen ganze Kohorten erreicht werden können und die Altersspanne von neun bis 14 Jahren als besonders sensible Phase der Umwelteinstellungsgenese gesehen wird (z.B. Otto et al., 2019). Ferner zeigen Besuche außerschulischer Lernorte und dabei der in Amerika etablierte Ansatz *Earth Education* erfolgsversprechende Effekte auf die Umwelteinstellung (z.B. Potvin & Hasni, 2014; Rickinson, 2001; Van Matre, 1990).

Teilarbeit A (N = 227; M_{Alter} [SD] = 13,06 [1,01]) konzentrierte sich auf die Kontrastierung von zwei Einstellungsvariablen, nämlich *Science Motivation* (Glynn et al., 2011) sowie *Fascination with Science* (Otto et al., 2020), und auf die Lehrprogrammevaluation an der Biosphäre 2 in Arizona. Die eintägigen Interventionen konnten Umweltwissen generieren und die Daten einen positiven Einfluss der Einstellung auf den Wissensstand abbilden, allerdings stellten sich die Einstellungsskalen zwar als reliabel, jedoch nicht valide heraus. Aufgrund der anhaltenden Covid-Pandemie konnte dem Einsatz alternativer Instrumente, der Evaluation einer Lehrprogrammmodifikation durch vor- und nachbereitenden Unterricht (**Teilarbeit B**: Unterrichtseinheit) sowie weiteren Programmänderungen nicht nachgegangen werden. In **Teilarbeit C** wurden daraufhin

mithilfe eines umfangreichen Datensatzes (N = 6585; M_{Alter} [SD] = 9,96 [0,81]) im Kontext des extensiveren, über Jahre hinweg evaluierten Programms *Earthkeepers* zwei anerkannte Einstellungsmessinstrumente kontrastiert (*Two Major Environmental Values Model* [2-MEV: Bogner & Wiseman, 2002] und *New Environmental Paradigm* [Dunlap & Van Liere, 1978]). Infolgedessen konnten Nutzungsempfehlungen generiert und hierin der Fokus auf die Umweltschutzpräferenz als Einstellungsentität gelenkt werden. Außerdem wurden die Parameter *Wissen*, *Einstellung* und *Verhalten* in Relation gesetzt. Dabei erwies sich die Einstellungsvariable wiederholt als signifikante Einflussgröße des Umweltwissensstandes, der wiederum mit vermehrtem Umweltschutzverhalten einherging.

Die Restrukturierung der Skalen gemäß des gemeinsamen Konsens' der Umweltschutzpräferenz als Ausdruck der Umwelteinstellung wurde in **Teilarbeit D** (N = 1592; M_{Alter} [SD] = 14,47 [1,78]) fortgeführt, indem die meinungsbasierten Items des 2-MEV durch Verhaltensselbstberichte (*General Ecological Behavior* [Kaiser, 1998]) ergänzt wurden. Die modifizierte Skala hielt zahlreichen Qualitätstests stand und erklärte die Rolle der Einstellung beim Wissenserwerb. Demnach beeinflusst die Einstellung, inwieweit Lernoptionen wahrgenommen werden und wie intensiv gelernt wird, wodurch sich die Einstellung als motivationaler Antrieb des Wissenserwerbs abzeichnete. In einem Qualitätstest der Skala wurde ferner die charakteristische Kurve der Umwelteinstellung im Jugendalter abgebildet, die auf eine sensitive Phase der Einstellungsgenese hindeutet. Diese Einstellungsskala wurde in **Teilarbeit E** (N = 247; M_{Alter} [SD] = 9,38 [0,51]) auf einen neuen Kontext transferiert und in einem reziproken Prozess das Umweltbildungszentrum *Cooper Center* evaluiert sowie die Skala durch das Abbilden der Lernprogression des in Teilarbeit C erfolgreich gezeigten Programms bestätigt. Simultan wurde, wie in Teilarbeit D argumentiert, die Rolle der Einstellung beim Lernen als Komponente des Umweltschutzverhaltens bekräftigt.

Schließlich zeigen die in den Teilarbeiten geprüften außerschulischen Lernorte durch Wissens-, Einstellungs- bzw. Verhaltensänderungen Potenzial für Umweltbildung, wobei stärkere Effekte durch Vor- und Nachbereitung bewirkt werden können. Die in Teilarbeit D konstituierte Einstellungsskala kann hierin durch solide Güte und adressatengerechte Flexibilität als Messstandard dienen. Ferner scheint eine nuancierte Etablierung der Umwelteinstellung besonders bis ins Mittelstufenalter empfehlenswert. Weitere Studien sollen einstellungsbezogenen Alterstrends sowie expliziten Parametern der Einstellungsschärfung nachgehen, sodass die Erkenntnisse zu konkreteren curricularen Empfehlungen führen und auf das Lernen im Klassenzimmer übertragen werden können.

3 Synopsis

3.1 Einleitung

> „One way to describe the current condition of environmental education in America is as a gifted child who has yet to reach his or her full potential." (Coyle, 2005, S. 51)

Das Zitat Coyles (2005) bildet den Anlass, die Intention und die Progression der vorliegenden Arbeit ab. Umweltbildung soll Umweltbewusstsein evozieren, wodurch nicht nur Umweltwissen, sondern eine Sensibilität für Umweltproblematiken und deren -lösungen sowie eine Motivation zur aktiven Problemlösung generiert werden soll (Stapp, 1969). Anthropogene Entwicklungen führten zu einer Neufokussierung des Umweltbildungsbegriffs auf einen nachhaltigen Lebensstil, demzufolge die Schulbildung holistischer, alltagsnäher und handlungsorientierter gestaltet (Tilbury, 1995; UNESCO, 1992) und die Einstellung von Schüler:innen langfristig geschärft werden soll (IUCN/UNEP/WWF, 1980). Einstellungsschärfung meint die Verbesserung der Einstellung zur Umwelt, ergo die Erhöhung der Umweltschutzpräferenz mit einer einhergehenden Reduktion der Naturausnutzungstendenz. Das ultimative Ziel der Umweltbildung ist dabei Umweltschutzverhalten (Pooley & O'Connor, 2000), das jegliche (unterlassene) Handlungen, die die Natur und Umwelt schützen, und damit diverse Facetten vom Klimawandel über das Konsumverhalten (z.B. Energieverbrauch, Tierwohl) bis hin zum Recycling umfasst (Lange & Dewitte, 2019).

Weltweite Bewegungen wie *Fridays for Future* zeigen hingegen, dass das Potenzial für Umweltschutz nicht ausgeschöpft wird (Fridays for Future, 2021). Seit 2018 fungiert Klimaaktivistin Greta Thunberg als Leitfigur der Bewegung, plädiert für Umweltschutz und -bewusstsein, fordert zur Aktivität auf und wurde 2019 von der *Times* zur bisher jüngsten ‚Person des Jahres' gekürt (Spiegel, 2019; Time, 2020). Die zunehmende Wichtigkeit der Umweltschutzdebatte schlägt ebenso auf politischer Ebene Wellen, indem sich beispielsweise bei der 26. Klimakonferenz in Glasgow sämtliche beteiligte Staaten für eine dringend notwendige Energiewende und mehr Tempo beim Klimaschutz ausgesprochen haben (Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz, 2021). Ferner deuten politische Entwicklungen wie ein steigender Umfragewert der *Grünen* in der deutschen Bevölkerung die Relevanz der Thematik an (Der Tagesspiegel, 2021), indem Umweltschutz mehr Bedeutung zugesprochen wird (Schuler, 2021). Stimmen für Umweltbewusstsein und -verhalten werden lauter und der Umwelt- sowie der zugehörige Klimaschutz gehören trotz pandemischer Lage zu den brisantesten Themen (Umweltbundesamt, 2021).

Dabei wird auf vielen Ebenen das noch ausschöpfbare Potenzial via Umweltbildung mit der Forderung nach Nachhaltigkeit und Naturschutz deutlich. Aufgrund nachfolgend exemplarisch angeführter Zahlen wurden in der vorliegenden Arbeit primär Schüler:innen der USA herangezogen, da – wie von Coyle (2005) angemerkt – durch das wirtschaftliche Kapital viel Potenzial gegeben ist. Die USA ist nämlich neben China mit einer durchschnittlichen CO_2-Emission von 15.52 Tonnen pro Kopf der derzeit größte CO_2-Emittent und beansprucht mit einem Anteil von 13,43% eine global gesehen überdurchschnittlich hohe Menge an fossilen Brennstoffen (European Commission, 2021). Dieser Konsum spiegelt sich im ökologischen Fußabdruck wider, der anhand des Konsumverhaltens (Energieverbrauch, Lebensmittelproduktion, etc.) die Fläche zur Deckung des Ressourcenbedarfs angibt und für die USA derzeit bei acht *Globalen Hektar* pro Person liegt, wodurch die USA den zweiten Platz der höchsten Konsumenten belegt (Global Footprint Network, 2021). Beim damit verknüpften jährlichen Pro-Kopf-Fleischkonsum nimmt die USA sogar den ersten Platz auf der globalen Rangliste ein (Tostado, 2021). Auch das US-amerikanische Recyclingsystem ist symptomatisch für den hohen ökologischen Fußabdruck, der von politischer Seite inadäquat adressiert wird (Asendorpf, 2018; Wipperfürth, 2020). Gleichzeitig scheinen der Ist-Zustand mit den einhergehenden Umwelteinwirkungen in der Bevölkerung unzureichend be- und anerkannt zu sein, indem beispielsweise 30-50% der Amerikaner:innen den Klimawandel für nicht menschenverursacht halten (Busch et al., 2019). Hieraus ergibt sich eine Notwendigkeit von Umweltschutzmaßnahmen.

Die amerikanische Stichprobengröße wurde durch eine deutsche Kohorte ergänzt, denn auch in der EU existiert Potenzial zur Minderung negativer anthropogener Umwelteinflüsse. Schließlich beansprucht der private Haushaltssektor über ein Viertel des EU-Energiekonsums, dem lediglich der Transportsektor mit mehr als einem Drittel vorangeht und sowohl Güter wie auch den privaten Transport, allen voran PKW und Luftverkehr, umfasst (Eurostat, 2021). Außerdem besteht eine generelle Diskrepanz zwischen dem Plädoyer für Umweltschutz und dem tatsächlichen Handeln, das ein Dilemma zwischen Umweltschutz und Individual- bzw. Gesellschaftsinteresse kennzeichnet (Karp, 1996; Maloney & Ward, 1973). Zur Überbrückung dieser Diskrepanz rückt die Umweltbildung in den Fokus. Hierfür sind Schulen zentral, denn positive Einstellungen und damit Umweltschutzpräferenzen scheinen in jungen Jahren generiert und etabliert zu werden (z.B. Krettenauer et al., 2020; Olsson & Gericke, 2016; Otto et al., 2019; Savelsbergh et al., 2016), wodurch der Diskrepanz frühzeitig entgegengewirkt werden kann. Insgesamt wird der Nachdruck individueller Verhaltenssensibilisierung deutlich, die bereits im Schulalter beginnt (Otto et al., 2019). Die vorliegende Arbeit soll hierzu einen Beitrag liefern, indem Fördermaßnahmen für persistentes Umweltschutzverhalten über den Parameter *Umwelteinstellung* für den Schulkontext abgeleitet werden.

Grundsätzlich sind Umweltschutzmaßnahmen auf individueller (*bottom-up*) sowie kollektiver (*top-down*) Ebene situiert (Chawla & Cushing, 2007; Fraser et al., 2006; Oliveira, 2021; Stern, 2000). Letzteres beinhaltet politische Regulationen wie Verhaltenserleichterungen (z.B. Bereitstellen von Recyclingoptionen: Guagnano et al., 1995), informierende Maßnahmen und das Voranbringen umweltschonender Technologien, die dann wiederum auf individueller Ebene umgesetzt werden können (Tostado, 2021). Besteht invers betrachtet individuelle Nachfrage, ist die Wahrscheinlichkeit von *Top-Down*-Reaktionen höher (Oliveira, 2021). Folglich wird die Verstrickung von *Bottom-Up*- und *Top-Down*-Ansätzen ersichtlich (s. Abb. 1), die dem individuellen Umweltschutzverhalten eine maßgebliche Rolle zuspricht (Karp, 1996). In der vorliegenden biologiedidaktischen Arbeit wird Individualverhalten betrachtet, das von *Top-Down*-Maßnahmen beeinflusst wird. Zu letzteren zählen außerschulische Lernorte, die zur Erfüllung von Umweltbildungszielen beitragen können (z.B. Dresner & Gill, 1994; Fančovičová & Prokop, 2011).

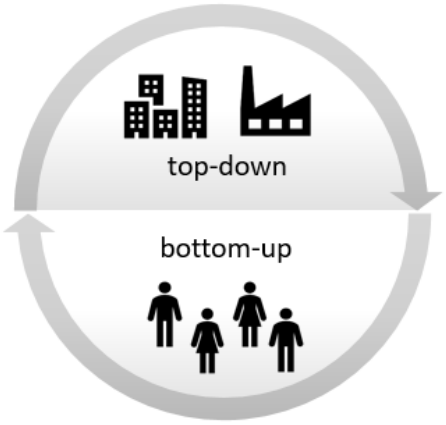

Abbildung 1: Zusammenhang von *Top-Down*- und *Bottom-Up*-Ansätzen für Umweltschutzmaßnahmen; Dabei sind Kollektivmaßnahmen (*top-down*) rahmengebend für individuum-basierende Ansätze (*bottom-up*), wobei summiertes Individualverhalten wegweisend für *Top-Down*-Maßnahmen ist.

In diesen Rahmen schulischer Umweltbildung mit *Bottom-Up*-Fokus fügt sich die vorliegende Arbeit. Im theoretischen Teil wird neben einer Definition von Umweltschutzverhalten und -wissen ein Einblick in die Vielzahl an potenziellen psychologischen und (psycho-) sozialen Einflussgrößen von Umweltschutzverhalten gegeben. Dabei wird die Einstellung als zur Programmevaluation und Verhaltensinitiation im schulischen Kontext sinnvolles Konstrukt herausgearbeitet. Anschließend werden außerschulische Lernorte als für die Umweltbildung vielversprechende Lernarrangements und für diese Arbeit zwei relevante Beispiele, nämlich die Biosphäre 2 und das Cooper Center in den USA, vorgestellt. Infolge der theoretischen Fundierung werden die Ziele und Fragestellungen der Arbeit dargelegt und die weitgehend quantitativen Methoden zur Beantwortung dieser vorgestellt. Diese beinhalten die Stichproben, Studiendesigns, Erhebungsinstrumente und statistischen Analysen. Daraufhin werden die wesentlichen Ergebnisse der fünf Teilarbeiten vorgestellt und von einer Zusammenfassung abgerundet. Letzteres summiert die Ergebnisse und überträgt diese auf Empfehlungen für didaktische und damit curricular verortete Maßnahmen, während weiterführende Forschungsfragen und -vorhaben als Ausblick angemerkt werden.

3.2 Theoretischer Hintergrund

Nachfolgend werden die zentralen Begriffe für eine theoretische Fundierung definiert. Hierfür wird Umweltschutzverhalten als das primäre Ziel der Umweltbildung eingeführt und im Anschluss auf die zwei zu betrachtenden Einflussgrößen Bezug genommen. Dazu zählen das Umweltwissen, das entkoppelt von psychologischen und (psycho-) sozialen Faktoren zwar als Basis, jedoch isoliert als unzureichend zur Verhaltensinitiation gilt (z.B. Heimlich & Ardoin, 2008), sowie die Umwelteinstellung. Anschließend werden außerschulische Lernorte als Kategorie des informellen Lernens beleuchtet. Diese gewinnen stetig an Bedeutung, da sie gegenüber der sich langsam ändernden Curricula aktuelle Umweltthemen integrieren und damit curriculare Lücken in der Umweltbildung füllen können (z.B. Dresner & Gill, 1994; Duerden & Witt, 2010; Jordan et al., 1986). Die Gliederungspunkte sollen nicht getrennt, sondern ineinandergreifend gesehen werden, wobei der erste Punkt als Zielvariable den hierauf aufbauenden mithin Aspekte vorwegnimmt.

3.2.1 Variablen zur Genese und Messung umweltschützenden Verhaltens

3.2.1.1 Umweltschutzverhalten

Die Umweltbildung zielt auf dauerhafte Verhaltensänderungen zu einem nachhaltigen Lebensstil ab (z.B. UNESCO, 2003). Umweltschutzverhalten umfasst dabei sämtliches Handeln, das der Natur zugutekommt und mit dem Naturschutz einhergeht (Lange & Dewitte, 2019). Hierzu zählt ebenso unterlassenes Handeln zugunsten der Natur wie der Verzicht auf Flugreisen. In dieser Arbeit wird nicht auf den Begriffspluralismus eingegangen, der etwa ambivalentes Handeln thematisiert, indem sich Umweltschutzverhalten durch neue Erkenntnisse als kontraproduktiv herausstellen könnten (Wals, 2010), sondern nach aktuellem Stand umweltschützend geltendes Verhalten impliziert. Die zentralen Fragen richten sich vielmehr danach, inwieweit Umweltschutzverhalten initiiert, beeinflusst und inklusive der Einflussgrößen gemessen werden kann.

Initiation durch Einflussgrößen

Das komplexe Forschungsfeld stellt zahlreiche Einflussgrößen für Umweltschutzverhalten zur Debatte, die in dieser Arbeit nicht in ihrer Gänze diskutiert werden können. Es wird vielmehr ein Einblick gegeben, um den Stellenwert der Einstellung hervorzuheben. Die Einflussfaktoren gliedern sich weitgehend in kognitive, psychologische, psychosoziale, soziale und kontextuelle Faktoren (Busch et al., 2019; Kollmuss & Agyeman, 2002). Während Umweltwissen in einem separaten Gliederungspunkt definiert wird, werden kontextuelle Faktoren abgesehen von Verhaltenskosten im Rahmen des Campbell-Paradigmas zumeist ausgeklammert (s. 3.2.1.2). Obgleich Einflüsse kontextueller Faktoren (z.B. sozioökonomischer Status oder Geschlecht) publiziert sind

(z.B. Gifford & Nilsson, 2014; Sirin, 2005), sind diese oft uneinheitlich (z.B. signifikante [Kollmuss & Agyeman, 2002] bis nicht-signifikante [Hines et al., 1987] Effekte des Geschlechts), häufig zu sehr auf kulturelle Gegebenheiten zurückzuführen und damit umfassenderen psychologischen und psychosozialen Faktoren im Rahmen dieser Arbeit unterzuordnen.

Zu den psychologischen und (psycho-) sozialen Variablen zählen Werte (z.B. Karp, 1996; Steg et al., 2014), Normen (z.B. Harland et al., 1999; Schwartz, 1977), Identitätsgefüge (z.B. Fielding & Hornsey, 2016; Jans, 2021), Risikowahrnehmungen (z.B. Yoon et al., 2021; Zhou et al., 2020), Kontrollwahrnehmungen (z.B. Allen & Ferrand, 1999), die Selbstwirksamkeit (z.B. Tabernero & Hernández, 2011), das Interesse (z.B. Palmer et al., 1998), die Motivation (z.B. Pelletier et al., 1998), die Faszination (z.B. Cheng & Monroe, 2012; Otto et al., 2020), Überzeugungen (z.B. Stern, 2000) und Einstellungen (z.B. Vining & Ebreo, 1992). Viele der zitierten Studien verfolgen dabei keinen exklusiven Ansatz, sondern verstricken mehrere Ebenen (z.B. Ajzen, 1991), indem z.B. Einstellungen auf Werten beruhen (Wiseman & Bogner, 2003) oder die Motivation als Kategorie der Einstellung gilt (Murphy et al., 2006). Diese unscharfe Differenzierung und die resultierenden Unterschiede zwischen Forscher:innen spiegeln sich in der Literatur wider (Beispiele in Potvin & Hasni, 2014). Die über Jahrzehnte genutzte Skala, nämlich das *New Environmental Paradigm* und die überarbeitete Version *New Ecological Paradigm* (NEP), wurde beispielsweise zur Messung von Werten (z.B. Albrecht et al., 1982), Überzeugungen (z.B. Edgell & Nowell, 1989) und Einstellungen (z.B. Luo & Deng, 2008; Ntanos et al., 2019; Schultz & Zelezny, 1999) genutzt oder schlicht keine Zuordnung deutlich (z.B. Chung & Poon, 2001; Steger et al., 1989). Seitens der Autoren des NEP wurde für die Erfassung der ökologischen Weltansicht plädiert (Dunlap, 2008) und dabei wurden Faktoren wie Überzeugungen und Einstellungen vermischt.

In der vorliegenden Arbeit wird primär das Konstrukt der Einstellung verwendet, da es **1)** zu den meistgenutzten Konstrukten der Umweltpsychologie gehört, **2)** viele der obengenannten Variablen zusammenführt und **3)** ein für Umweltschutz evozierendes Verhalten zielführenderes Konstrukt im Kontrast zu klarer abgrenzbaren, wie dem Interesse, zu sein scheint. Dabei wird, wie unter 3.2.1.2 ausgeführt, die Umwelteinstellung als die Bereitschaft sich für Naturschutz einzusetzen definiert. Nachfolgend werden dennoch die drei eben genannten Gründe ausgeführt:

1) Seit Langem existiert Literatur zur Umwelteinstellung (z.B. Arcury, 1990; Buttel, 1979; Fishbein & Ajzen, 1972; Likert, 1932). Generell ist die Einstellung eine der meistgenutzten Konzepte der Psychologie (z.B. Kaiser et al., 1999), galt als zentrale Entität der Sozialpsychologie (z.B. Schwarz & Bohner, 2007) und wurde seither als essentieller Parameter für Umweltschutzverhalten herausgearbeitet sowie eingesetzt (z.B. Bogner & Wiseman, 2006; Franzen & Vogl, 2013; Hines et al., 1987; Kollmuss & Agyeman, 2002; Leeming et al., 1993; Newhouse, 1990).

2) Die Bedeutsamkeit obengenannter Parameter für Umweltschutzverhalten soll keinesfalls negiert werden. Im Gegenteil: Zahlreiche Faktoren beeinflussen integrativ umweltschützendes Verhalten (Rokeach, 1968), z.B. zugrundeliegende Werte, darauf bauende Normen sowie Zugehörigkeitsgefüge im Sinn der Identitätsbildung (Kollmuss & Agyeman, 2002). Der Fokus dieser Arbeit liegt weniger auf der Unterscheidung dieser Faktoren, sondern auf der Erfassung einer Einheit zur Förderung von Umweltschutzverhalten, wofür das Konstrukt der Einstellung herangezogen wird. Dieses wird unter 3.2.1.2 elaboriert und integriert das Wert- und Normsystem. Daneben werden zunehmend Studien publiziert, die zeigen, dass trotz der Konstruktdiversifikation meist dieselbe latente Variable erfasst wird, die die Bereitschaft für Umweltschutz ausdrückt (Kaiser et al., 2013) und durch Hybridskalen wie das NEP angedeutet wird. Dennoch sollen die Parameter in Einklang gebracht werden:

Werte bilden das Fundament von Einstellungen und damit eine Eintrittsvariable für Umweltschutzverhalten (Chawla & Cushing, 2007; Stern et al., 1995; Stern, 2000). Dies wird z.B. durch das *Two Major Environmental Values Model* ausgedrückt, bei dem Einstellungen auf Werte schließen lassen (Bogner & Wiseman, 2002), sowie durch das Modell von Stern und Dietz (1994), in dem Einstellungen mittels Werte und Überzeugungen konstruiert werden (s. Abb. 2).

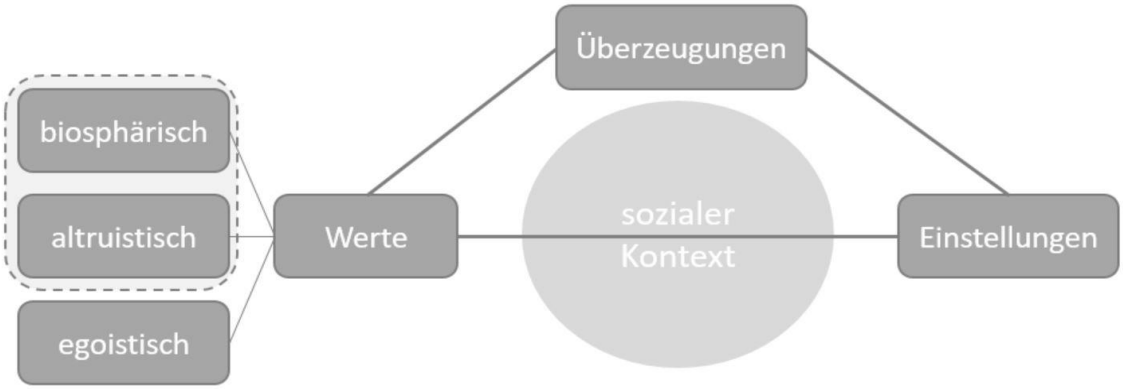

Abbildung 2: Konstruktion von Einstellungen nach Stern und Dietz (1994), die Werte als Maßstab von Handlungstendenzen sehen; Darauf basierend und beeinflusst von Überzeugungen (Erwartungshaltung bezüglich der Konsequenzen für ein wertgeschätztes Objekt) sowie dem sozialen Kontext (z.B. Medien oder Bekanntschaften) werden Einstellungen gebildet. Die Wertausrichtungen (biosphärisch, altruistisch und egoistisch) sind nicht exklusiv, sondern in Personen zu variierenden Graden vorhanden.

Werte wie Freiheit, Gleichheit und Umweltschutz sind Ursachen von Weltanschauungen und damit transsituationelle Leitprinzipien für Handlungsausrichtungen (Schwartz, 1994; Simmons et al., 1992). Abhängig von der Gerechtigkeitsfrage einem Objekt gegenüber kann beim Umweltschutz zwischen einer biosphärischen, egoistischen und altruistischen Ausprägung differenziert werden (Stern & Dietz, 1994). Diese Unterscheidung variiert: Einige Autoren gliedern die Wertausrichtung feiner (Schwartz, 1992; Steg et al., 2014), während Stern und Dietz (1994) auf eine Fusion der altruistischen und biosphärischen Facette verweisen. Da diese Ausführungen den

Umfang der vorliegenden Arbeit überschreiten, wird primär Stern und Dietz‘ (1994) Modell exemplarisch erläutert (s. Abb. 2), da die Autoren eine gängige Relation von Verhaltensparametern darstellen. Demnach steuern Werte die Formation von Einstellungen und damit Verhalten (s. auch Rokeach, 1968), während Überzeugungen als Mediator (Erwartungshaltung hinsichtlich handlungsbezogener Konsequenzen) wirken. Werte agieren demzufolge als Filter und Verstärker, sodass mit dem Wertsystem kongruente Informationen wahrscheinlicher wahrgenommen und integriert werden (Stern & Dietz, 1994). Dadurch wird die Einstellung als Faktor positioniert, der die Intensität, sich mit spezifischen Informationen zu beschäftigen, angibt.

In diese Zusammenhänge fügt sich das **Normsystem**, dem injunktive und deskriptive Normen angehören (Cialdini et al., 1990). Injunktive Normen umfassen moralische Regeln, wogegen deskriptive Normen eine Orientierung am tatsächlichen Verhalten der Gruppenmehrheit ausdrücken. Die Unterscheidung zeigt die in der Einleitung beschriebene Diskrepanz auf, wonach Menschen häufig moralkonformes Verhalten kennen, jedoch gruppenkonform normwidrig handeln. Hierbei werden **Identitätsgefüge** und Zugehörigkeitsbestrebungen deutlich, die sich der Normtheorie fügen. Durch diese Situationsgebundenheit gelten die eher extrinsischen Normen dynamischer als Einstellungen und müssen kontextbezogen aktiviert werden (Fielding & Hornsey, 2016), weshalb sie einen unbeständigeren Anhaltspunkt für Verhalten liefern. Schließlich entsteht mehr Druck über Normen durch die Anwesenheit der normvertretenden Gruppe. Eine klare Distinktion zwischen sozialen Faktoren wie Normen und persönlichen Faktoren wie Einstellungen gelingt ohnehin schwer, denn Erwartungen beeinflussen die Wertung und stehen ergo mit Einstellungen in Relation (Ajzen, 1991). Wenn beispielsweise die Mehrheit das Nutzen von Einwegplastiktüten verweigert, zeigt sich das tendenziell in einer entsprechenden Wertschätzungs- und Verhaltensänderung anderer. Damit sind Normen Bestandteil von Einstellungen (Kaiser & Scheuthle, 2003), weshalb in Teilarbeiten C bis E Variablen zur Einstellungsmessung integriert wurden, die Umweltschutznormen tangieren.

3) Die Abgrenzung zwischen **Interesse** und Einstellung beläuft sich weitgehend auf die Wertschätzungskomponente und Domänenspezifität (Potvin & Hasni, 2014). Eine Person kann sich für anthropogene Klimaeinträge interessieren, jedoch keine Wertschätzung demgegenüber besitzen und sich nicht klimafreundlich verhalten. Nach dem Modell der Interessensgenese muss Interesse nicht nur generiert, sondern erhalten werden, wodurch situationelles zu individuellem Interesse wird (Hidi & Renninger, 2006). Das individuelle Interesse baut auf Persistenz, drückt jedoch, wie im Beispiel angedeutet, die Wertschätzung unzureichend aus, die für Verhalten ausschlaggebender zu sein scheint (s. 3.2.1.2). Ferner ist Interesse eine domänenspezifische Präferenz, die konträr zur umfassenderen Einstellung selektive Einblicke gibt (Potvin & Hasni, 2014).

Auch **Überzeugungen** beeinflussen Umweltschutzverhalten, beziehen sich jedoch vielmehr auf die kognitive Domäne (Newhouse, 1990) und beeinflussen mithin Einstellungen (Rokeach, 1968; s. auch Abb. 2 nach Stern und Dietz [1994]). Die folgenden drei Aspekte zeigen Parallelen zu Überzeugungen und tragen folglich zur Einstellungskonstruktion bei: Die **perzipierte Kontrolle** (z.B. *Locus of control*) weicht in der Praxis jedoch von der etablierten Theorie Ajzen und Maddens (1986) ab, umfasst diverse Aspekte der Kontrolle und zeigt entsprechend inkonsistente Verhaltenseffekte von nicht existent bis sehr hoch (Kaiser et al., 1999). Die **Risikowahrnehmung** bildet eine Klasse von Überzeugungen hinsichtlich der Folgen von Umweltveränderungen auf wertgeschätzte Gegenstände (Stern & Dietz, 1994). Das wahrgenommene Risiko entspricht damit den wahrgenommenen Konsequenzen. Daher liegt der Fokus oft auf egoistischen Aspekten bezüglich negativer Folgen und verengt den Blick auf Umweltschutzverhalten, weshalb die Risikowahrnehmung beschränkte Aussagekraft hat (ebd.). Das Konzept der **Selbstwirksamkeit** besteht seit langem in der Verhaltensforschung (Bandura & Wessels, 1994), bezieht sich auf Überzeugungen seitens der Eigenwirksamkeit und ergo auf die kognitive Domäne. Darin wird die wahrgenommene Schwierigkeit der Aufgabenbewältigung deutlich, die der Beurteilung dient, ob eine Handlung initiiert wird. Der Schwierigkeitsaspekt wird unter 3.2.1.2 für eine Einstellungsdefinition im Rahmen des Campbell-Paradigmas berücksichtigt. Daneben wird die Selbstwirksamkeit von einigen Konstrukten wie der **Motivation** integriert (Glynn et al., 2011). Die Motivation umfasst weitere Facetten wie ex- und intrinsische Faktoren, wobei letzterer partiell der **Faszination** entspricht und in Teilarbeit A unter 5.3 genauer in Einklang mit Einstellungen gebracht wird.

Zusammenfassend bilden Werte, die im Zuge der Sozialisation entstehen und als entsprechend stabil gelten, Grundausrichtungen, auf denen Einstellungen unter Einfluss von Normen und Überzeugungen beruhen (Ajzen, 1991; Stern & Dietz, 1994). Diese sind wiederum im kognitiven und situationellen Kontext verortet. Wenngleich sämtliche erwähnte Parameter einen Beitrag zur Verhaltensimplementation leisten, wird in der vorliegenden Arbeit primär die Einstellung zur Förderung von Umweltschutzverhalten herangezogen. Die Einstellung scheint nämlich hinsichtlich der Lehrprogrammevaluation empfindlicher gegenüber Veränderungen als zugrundeliegende Werte und gleichzeitig stabiler als Normen zu sein, die kontextbezogen aktiviert werden müssen. Ferner verdeutlicht die Differenz zwischen injunktiven und deskriptiven Normen die vermeintliche Einstellungs-Verhaltens-Diskrepanz, die die Einstellungsdefinition im Rahmen des Campbell-Paradigmas überwinden kann. Die Messung von Werten ist sinnvoll, um im Zuge der Dateninterpretation Grundausrichtungen zu erfassen. Normen können hingegen Anhaltspunkte für Programme liefern, die auf soziale Identitäten wie Nachbarschaftsinitiativen bauen. Einstellungen vereinen indes viele der erwähnten Parameter, sind sensitiv gegenüber relativ persistenten Änderungen und daher für Umweltschutzverhalten hilfreich (s. auch 3.2.1.2).

Empirische Messung

Die Vielfalt an Messmöglichkeiten für Umweltschutzverhalten spiegelt sich in der Anzahl methodischer Herangehensweisen wider (Milfont & Duckitt, 2004). Da die Darlegung sämtlicher Methoden den Rahmen dieser Arbeit überschreiten würde, werden die generell gängigen und die für diese Arbeit relevanten Herangehensweisen zur Verhaltensmessung mit Bezug auf die Einflussgrößen auf Grundlage quantitativer Analysen herangezogen (für einen Überblick, s. Abb. 3).

Grundsätzlich wird zwischen spezifischen Verhaltensweisen wie Recycling und allgemeinem Umweltschutzverhalten sowie zwischen beobachtetem Verhalten (Feldbeobachtungen, z.B. Farage et al., 2021; Geller et al., 1973; vs. Laborbeobachtungen, z.B. Huffman et al., 2014; oder beide Ansätze integriert, z.B. Murtagh et al., 2015) und Selbstberichten von bis dato implementiertem Verhalten (z.B. Kaiser, 1998; Karp, 1996; Palmer & Suggate, 1996) differenziert (Lange & Dewitte, 2019). Übergangsformen leiten beispielsweise an, das Verhalten binnen weniger Wochen selbst zu dokumentieren (z.B. Kaiser et al., 2020; Manoli et al., 2014). Da die Verhaltensbeobachtung nicht nur zeit- und kostenintensiv ist, sondern einer möglichst homogenen Messumgebung bedarf und tendenziell nur selektive Einblicke gewährt, rückte der Fokus zunehmend auf Fragebogenselbstberichte (Lange & Dewitte, 2019). Ferner existieren Selbstberichte in Form des ökologischen Fußabdrucks (z.B. Bleys et al., 2018; Huddart Kennedy et al., 2015) oder Tagebüchern (z.B. Chu & Chiu, 2003; Maleetipwan-Mattsson et al., 2013). Allerdings sind Fragebögen als Momentaufnahmen für Lehrprogrammevaluationen geeigneter (Lange & Dewitte, 2019). Daneben können Feld- oder Laborbeobachtungen besser spezifisches als allgemeines Verhalten und vielmehr kleine Stichproben als empirische Programmevaluationen abdecken (ebd.).

Zur Messung von allgemeinem Umweltschutzverhalten zur empirischen Programmevaluation eignen sich demnach auf Basis quantitativer Analysen Selbstberichtskalen mit mehrstufigen Antwortmöglichkeiten der Zustimmung. Diese bergen die Gefahr der Beeinflussung durch soziale Erwünschtheit, d.h. das Antwortmuster von Teilnehmer:innen wird in eine Richtung geschoben, die mit einer potenziellen Erwartungshaltung des sozialen Umfelds einhergeht (Chao & Lam, 2011). Schüler:innen neigen ergo zu Antworten, die Zuspruch seitens Lehrer:innen finden. Insofern eine Entkopplung von der schulischen Prüfungsform stattfindet, scheint die soziale Erwünschtheit jedoch eine marginale Rolle bei den für diese Arbeit relevanten Messinstrumenten zu spielen (z.B. Kaiser, 1998; Oerke & Bogner, 2013). Generell sind Mehr-Item-Skalen weniger gegenüber Messfehlern anfällig, weshalb solche eingesetzt wurden. Zwar können einzelne Items missverstanden oder Antwortformate wie ‚häufig' verschieden interpretiert werden, allerdings wird dies i.d.R. durch eine Mindestanzahl an Items relativiert (Schwarz, 1999; Schwarz & Bohner, 2007), weshalb die Skalen dieser Arbeit in ihrer gekürzten Form zehn Items nicht unterschreiten.

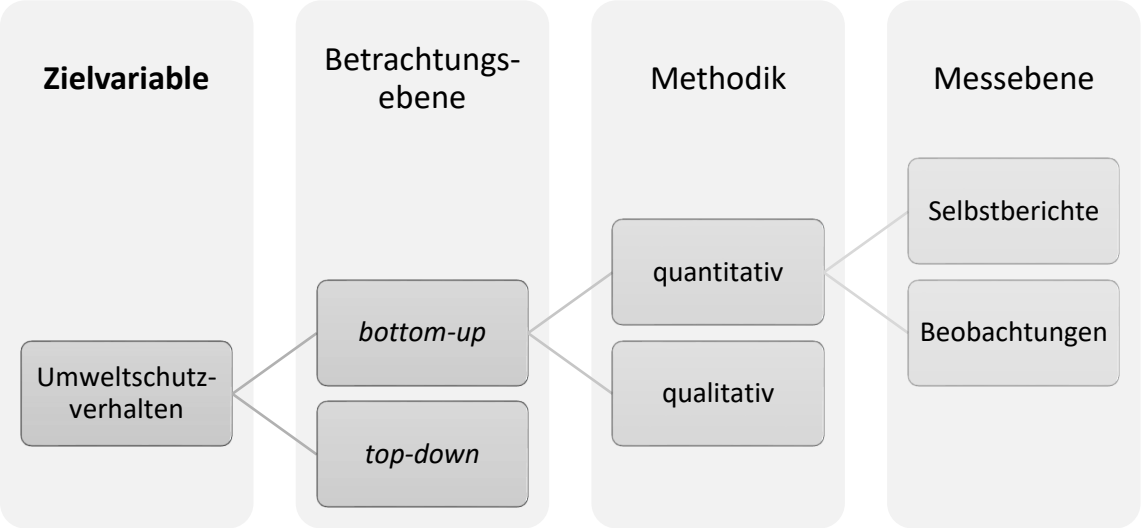

Abbildung 3: Übersichtsdarstellung zur Erfassung von Umweltschutzverhalten; dargestellt sind mögliche und für diese Arbeit ausgewählte Erfassungsschritte (weiterführende Linie). Die Differenzierung zwischen spezifischem Verhalten (z.B. Recycling) und allgemeinem Umweltschutzverhalten ist aus Platzgründen nicht integriert, wobei sich auf allgemeines Umweltschutzverhalten bezogen wird.

Im Rahmen des Campbell-Paradigmas kann von Verhaltensselbstberichten auf Einstellungen geschlossen werden (Campbell, 1963; Kaiser et al., 2010), womit es einen theoretischen Zugang zur vermeintlichen Einstellungs-Verhaltens-Diskrepanz (z.B. Hines et al., 1987) liefert. Dafür werden Barrieren betrachtet, die Verhalten erschweren und beispielsweise als kontextuelle Faktoren bereits in zahlreichen Theorien Anerkennung finden (z.B. Diekmann & Preisendörfer, 1992; Gardener & Stern, 1996; Stern & Dietz, 1994).

Barrieren werden als Kosten bezeichnet und umfassen sämtliche Hindernisse, die Verhaltensumsetzungen mit sich bringen. Hierzu gehören zeitliche, finanzielle und anderweitig ressourcenschöpfende Investitionen. Einkaufstaschen in Deutschland mehrfach zu nutzen ist beispielsweise ein Umweltschutzverhalten, das mit geringen Kosten einhergeht, da es normkonform ist und kein oder kaum finanzieller oder zeitlicher Mehraufwand entsteht. Die aktive Partizipation an Umweltschutzorganisationen fordert dagegen Zeit, Geld und gegebenenfalls die Rechtfertigung gegenüber anderen, wodurch es zu einem kostenintensiveren Verhalten wird. Der Logik folgend wird Verhalten impliziert, wenn die Einstellung den Kostenumfang überschreitet, wodurch Verhalten in einem Maß umgesetzt wird, das mit der zugrundeliegenden Einstellung kongruent ist. Dadurch wird vom Verhalten und den jeweiligen Kosten auf die Einstellung geschlossen. Hieraus wird die kulturelle Gebundenheit und die Verstrickung von *Top-Down*- und *Bottom-Up*-Ansätzen ersichtlich, indem beispielsweise Gebühren auf bis dato kostenfreie Plastiktüten in Supermärkten deren Konsum reduzieren (He, 2012; Ritch et al., 2009). Einen tieferen Einblick in die Einstellungsmessung liefert der nachfolgende Gliederungspunkt, woraufhin unter 3.2.1.3 Umweltwissen als weitere Säule von Umweltschutzverhalten angeführt wird.

3.2.1.2 Umwelteinstellung im theoretischen Rahmen des Campbell-Paradigmas

Eine Einstellung beschreibt die Wertung einer Entität und ihrer Assoziationen (Ajzen & Fishbein, 1977; Eagly & Chaiken, 1993). Dieser evaluative Kontext umfasst bei der Umwelteinstellung primär drei Wertschätzungsentitäten, nämlich die Umwelt (z.B. Arbuthnot, 1977), Aspekte der Umwelt wie die Luftqualität (Hines et al., 1987) und Umweltschutzverhalten (Taylor & Todd, 1995). Innerhalb der Umweltbildung gilt im Sinne nachhaltigen Handelns Umweltschutzverhalten als die zielführende Wertschätzungsentität (Ajzen & Fishbein, 1977; Eagly & Chaiken, 1993; Hines et al., 1987). Durch den Bezug zum Verhalten ergibt sich die Häufigkeit des Auftretens zielgerichteter Handlungsmuster: Umso ausgeprägter die Einstellung, umso häufiger werden spezifische Handlungen, die der Zielorientierung der Einstellung unterliegen, implementiert (Campbell, 1950). Resultierend leitet sich auf der theoretischen Grundlage des Campbell-Paradigmas der konzeptionelle Rahmen der Umwelteinstellung in Anlehnung an Kaiser et al. (2010) ab:

Die Umwelteinstellung – ausgedrückt durch die Bereitschaft sich für den Naturschutz einzusetzen, ergo Umweltschutzverhalten – zeigt sich in der Häufigkeit und Persistenz spezifischer Handlungsmuster inklusive Meinungsäußerungen. Das Campbell-Paradigma liefert den theoretischen Rahmen und besagt, dass eine Einstellung von manifesten Handlungen ableitbar ist. Es unterliegt der Annahme, dass sich eine Einstellung zielorientiert und in einstellungskonsistenter Persistenz zeigt. Eine isoliert betrachtete Handlung kann auf diversen Zielorientierungen beruhen. Eine Person könnte auf Einwegkaffeebecher verzichten, 1) um Geld durch das Mitbringen eines Bechers zu sparen, 2) da die Plastikbecher gesundheitlich bedenkliche Risiken bergen (Halden, 2010) oder 3) um naturschutzkonform zu agieren. Deshalb wird eine Vielzahl an Handlungen betrachtet, die i.d.R. als Skala von Selbstberichten abgefragt wird, um eine Einstellung herauszufiltern. Die Einstellungsausprägung kann dann durch Kosten geschätzt werden.

Jede Handlung und damit Meinungsäußerung birgt Verhaltenskosten, die durch die Umsetzung in Kauf genommen werden. Diese können finanzielle, zeitliche und anderweitige Ressourcen beanspruchen, beispielsweise das Geld, das für umweltbezogene Literatur ausgegeben, und die Zeit, die für das Lesen dieser beansprucht wird. Kosten umfassen sämtliche Mühen und Beeinträchtigungen, die eine Person zugunsten einer Handlung akzeptiert, also auch soziale Unannehmlichkeiten wie normwidrige Äußerungen. Daraus lässt sich eine Hierarchie an Verhaltenskosten durch deren Schwierigkeit ableiten: Es ist i.d.R. weniger kostenintensiv, das Licht beim Verlassen eines Raumes auszuschalten als bei Umweltschutzdemonstrationen teilzunehmen. Das Campbell-Paradigma baut auf dieser Hierarchie, die wiederum auf die Einstellung einer Person schließen lässt: Umso kostenintensiver die Handlungen, der eine Person zustimmt, umso

positiver wird die Einstellung resümiert. Wenn eine Person bereits ressourcenarme Verhaltensweisen ablehnt (z.B. Mülltrennung und Lichtausschalten beim Raumverlassen), wird auf eine geringe Umwelteinstellung geschlossen. Das steht konträr zu einer Person, die angibt, Mitglied einer Umweltschutzorganisation zu sein, Produkte in Nachfüllpackungen sowie Bücher, Zeitschriften und weitere Medien zu Umweltthemen zu konsumieren.

Aus diesen Beispielen ergibt sich die Kulturabhängigkeit und der Umgebungsbezug von Verhaltenskosten: In Deutschland ist es schließlich einfacher, Müll zu trennen als in einigen Entwicklungsländern, da eine ausgebaute Infrastruktur für die Mülltrennung, -sammlung und -abholung besteht (Troschinetz & Mihelcic, 2009). In Entwicklungsländern würde die Mülltrennung auf eine wesentlich höhere Umwelteinstellung deuten, denn es müssen mehr Hürden (Verhaltenskosten) zur Verhaltensausführung überwunden werden (z.B. weite Strecken zu Recyclingtonnen).

Es existieren auch nationale, umgebungsbezogene Unterschiede: In München lebende Personen haben i.d.R. einen einfacheren Zugang zu öffentlichen Verkehrsmitteln als in ländlichen Regionen lebende Personen mit eingeschränkter Infrastruktur. Letztere ziehen generell häufiger das eigene Auto vor, da die Nutzung des öffentlichen Nahverkehrs mehr Aufwand (z.B. Zeit) erfordert. Daraus lassen sich (inter-) nationale und regionale Unterschiede ableiten, die für den Umweltschutz genutzt werden können: Werden durch Maßnahmen Verhaltenskosten reduziert, werden spezifische Handlungsmuster tendenziell öfter umgesetzt. Obwohl Kosten entsprechendes Verhalten erschweren oder erleichtern und damit Anhaltspunkte für Umweltschutzinitiativen liefern, ist die Einstellungsausprägung entscheidender. Auf Kostenreduktion basierende Änderungen werden häufig nur solange aufrechterhalten, solange die Kosten niedrig bleiben (Kaiser et al., 2020). Für darüber hinausgehende langfristige Verhaltensänderungen ist die zugrundeliegende Einstellung verantwortlich, die als Disposition hohe Kosten überwiegen kann.

Schließlich erweist sich die Einstellungsschärfung im Rahmen des Campbell-Paradigmas sinnvoll zur Förderung von Umweltschutzverhalten (s. auch 3.2.1.1). Mithilfe des Campbell-Paradigmas wird die Einstellungs-Verhaltens-Diskrepanz erklärt, indem eine Einstellung vom Verhalten abgeleitet wird und – invers gesehen – die Einstellungsschärfung Umweltschutzverhalten evoziert. Laut vorab skizzierter Modelle (z.B. Stern & Dietz, 1994) müssten ähnliche intrapersonelle Faktoren (psychologisch, psychosozial) identisches Verhalten hervorrufen, wodurch Kostenunterschiede wie die Infrastruktur vernachlässigt werden. Das Campbell-Paradigma erlaubt indes eine Perspektive, durch die Kosten extern niedrig gehalten und Einstellungen zur Kostenüberwindung geschärft werden können, wobei Letzteres ein bedeutsamerer Aspekt von Umweltbildung ist.

3.2.1.3 Umweltwissen

Umweltwissen nimmt eine zentrale Rolle für Umweltschutzverhalten ein (z.B. Hines et al., 1987; Leeming et al., 1993; Osbaldiston & Schott, 2012; Oskamp et al., 1991; Yoon et al., 2021). Schließlich wird Wissen zu Ökosystemzusammenhängen etc. sowie daraus resultierenden Handlungsoptionen benötigt, um aus ökologischer, ökonomischer und sozialer Perspektive verantwortungsbewusst entscheiden zu können (Hungerford & Volk, 1990; Stutzman & Green, 1982). Daraus gehen bereits verschiedene Wissensdomänen für Umweltschutzverhalten hervor, die in der Metaanalyse von Hines et al. (1987) eingebracht und von Frick et al. (2004) ausgeführt wurden.

Frick et al. (2004) unterscheiden Systemwissen, Handlungswissen und Effektivitätswissen. Systemwissen (identisch zu prozeduralem Wissen [Schultz, 2002]) beschreibt die Kenntnis und ein Verständnis von Ökosystemzusammenhängen. Ferner kann zwischen Fakten (z.B. Nahrungsketten und deren Hauptakteure) und anthropogenen Ökosysteminteraktionen (z.B. globale Umweltproblematiken wie Klimagas- oder Mikroplastikeinträge) differenziert werden (Díaz-Siefer et al., 2015). Handlungswissen beschreibt Wissen über Handlungsoptionen (Frick et al., 2004). Eine Person kann z.B. die Folgen steigender CO_2- und CH_4-Niveaus oder von Plastikeinträgen nennen (Systemwissen), jedoch kein Wissen zu schadensumgehenden oder -mindernden Handlungen besitzen (Handlungswissen). Solche Handlungen wären bei Kurzstrecken der Vorzug des Fahrrads vor dem Auto oder der Verzicht auf Einwegplastikprodukte, Mikroperlen in Kosmetika oder synthetische Kleidung. Effektivitätswissen überschreitet diese individuelle Perspektive durch das Erfassen der Wirksamkeit von Maßnahmen (z.B. erneuerbare Energien vs. Energien aus Atomkraft). Dadurch können Handlungsmuster und -optionen (z.B. politische Regulationen) hinsichtlich ihrer Effektivität kontrastiert und hierarchisiert werden (Díaz-Siefer et al., 2015).

Die drei Wissensdomänen wirken synergetisch (Roczen et al., 2014), weshalb Lehrprogramme diese idealerweise gleichermaßen aufgreifen. Wird an ein Umweltthema herangeführt, bietet sich eine sukzessive Herangehensweise an, bei der zunächst ein systemwissensbasierter Grundstock gelegt (Hungerford & Volk, 1990) und daraufhin über Handlungsoptionen und deren Effektivität reflektiert wird (ein Beispiel zum Thema *Wasser*: Liefländer et al., 2015). Der Zusammenhang zwischen Wissen und Umweltschutzverhalten ist bekannt (z.B. Boerschig & Young, 1993; Zelezny, 1999). Die kritischen Fragen richten sich vielmehr nach den Einflussfaktoren des Wissenserwerbs, wobei die Literatur Hinweise liefert, dass der Umwelteinstellung eine zentrale Rolle zukommt (z.B. Henn et al., 2019). Gleichzeitig bedarf die evaluative Komponente der Einstellung Wissen, um z.B. Handlungskonsequenzen abzuschätzen und generell Wertungen ausbilden zu können (Kaiser et al., 1999; Qian et al., 2021; Stutzman & Green, 1982).

3.2.2 Außerschulische Lernorte mit studienrelevanten Beispielen

Nachfolgend werden außerschulische Lernorte als für die Umweltbildung relevante Kategorie des informellen Lernens eingeführt. Darauf aufbauend werden zwei für diese Arbeit relevante Beispiele, nämlich die Biosphäre 2 sowie das Cooper Center, vorgestellt und dem informellen Lernen zugeordnet.

3.2.2.1 Außerschulische Lernorte als Kategorie informellen Lernens

Außerschulische Lernorte stellen einen Bereich des informellen Lernens dar, weshalb zunächst informelles Lernen und daran anknüpfend das Lernen an außerschulischen Lernorten definiert wird. Generell beschreibt informelles Lernen sämtliches Lernen außerhalb des Klassenzimmers und umfasst damit nicht nur didaktisch aufbereitete Orte wie Museen, sondern auch freundschaftliche und familiäre Gespräche (Bell et al., 2009; Fenichel et al., 2010; die potenzielle Distinktion von *nicht-formalem Lernen* [z.B. Eshach, 2007] wird hierin aufgrund der unklaren Abgrenzung zum informellen Lernen nicht aufgenommen, sondern dem informellen Lernen zugeordnet). Lernen wird dabei als Resultat diverser Erfahrungen in authentischen, alltagsnahen Kontexten und damit als holistisch, kumulativ und dynamisch gesehen (Gerber et al., 2001). *Outreach Learning* korrespondiert mit dem Begriff *außerschulischer Lernort* als spezifischer Bereich informellen Lernens, insofern schulexterne Institutionen sich Schulen mit einem Bildungsangebot öffnen (Vennix et al., 2017), wie die Forschungsinstitution *Biosphäre 2* sowie das Lernzentrum *Cooper Center*. Beide Lernorte befinden sich in Arizona, verfolgen umweltbildungsrelevante Lernziele, bieten Lehrangebote für nahezu alle Jahrgangsstufen an und ermöglichen dabei direktes affektives Naturerleben in einem praktisch- und forschungsorientierten Lernansatz.

Außerschulische Lernorte umfassen sämtliche Lernorte außerhalb des Schulgebäudes und inkludieren damit auf dem Schulgelände liegende, wie den Schulgarten, bis hin zu externen Institutionen, wie die Biosphäre 2, die eine Verknüpfung von Forschung und Bildung bieten (Gerber et al., 2001). Dabei ist die Begegnung mit Originalobjekten ausschlaggebend (ebd.). Obgleich durch den Besuch außerschulischer Lernorte ein organisatorischer, zeitlicher und finanzieller Mehraufwand entsteht, werden dortige Lehrprogramme als lohnenswert gesehen (Hofstein & Rosenfeld, 1996). Schließlich können sie für die Wissensverknüpfung, Motivationssteigerung und Erfüllung curricular verankerter kognitiver sowie affektiver Lernziele förderlich sein (Gerber et al., 2001; Kyndt et al., 2013; Potvin & Hasni, 2014). Qualitätskriterien außerschulischer Lernorte sind dabei die Exemplarität, Repräsentativität und Authentizität der Lerngegenstände sowie die auf Eigenaktivität abzielenden Aufgabenstellungen, die die Beobachtungs- und Problemlösekompetenz schulen und Anlass zum Forschen geben. Dadurch können curriculare Anforderungen wie Hand-

lungsorientierung, Anwendungsbezogenheit und der Anspruch, Schüler:innen an den Forschungscharakter heranzuführen, erfüllt werden (ISB, 2021; KMK, 2005; NGSS Lead States, 2013). Demgemäß werden offenere Lernformen z.B. über Lehr- und Sozialformen ermöglicht, die einen Wechsel zur Schüler:innenzentrierung zulassen und Verantwortungsbewusstsein schulen können. Die hohe Selbstregulation und Praxisnähe sollen schließlich tieferes Lernen ermöglichen und zum Umweltbewusstsein beitragen, das durch fächerübergreifende Arrangements intensiviert werden und die intrinsische Motivation steigern kann: Ein kreativer, authentischer Umgang mit dem Lerngegenstand soll durch multisensorische Erfahrungen und Erkundungen positives Erleben fördern. Dies wirkt trägem – ergo nicht anwendbarem, alltagsisoliertem – Wissen entgegen, zumal Schüler:innen oft Schwierigkeiten haben, im Unterricht Erlerntes auf die Realität zu übertragen (Kim & Dopico, 2016). Außerschulische Lernorte können helfen, entsprechende Brücken zu schlagen (Dillon et al., 2017).

Außerschulische Lernorte können aus zeitlicher und didaktischer Perspektive differenziert werden. Die investierte Zeit hat einen Einfluss auf die thematische Tiefe, nach derer drei Kategorien unterschieden werden können, nämlich *Erkundungen* im Rahmen einer (Doppel-) Stunde, *Halb*- bzw. *Ganztagsausflüge* und über einen Tag hinausgehende *Schulfahrten* (Beiersdorfer & Davis, 1994). Aus Hofstein und Rosenfeld (1996) kann eine Unterscheidung aus didaktischer Perspektive abgeleitet werden, wonach aufbereitete Lernorte (z.B. Museen) und didaktisch nicht aufbereitete Lernorte (z.B. Wald) kontrastiert werden. Letztlich ist jeder außerschulische Lernort auf einem Kontinuum der temporalen und didaktischen Achse anzusetzen. Beide Kategorisierungsansätze dienen Lehrkräften als Grobstrukturierung der Unterrichtsvorbereitung und schaffen einen Überblick über das vorhandene Lehrangebot.

Für diese Arbeit wurde ein didaktisch stark und ein moderat aufbereiteter Lernort betrachtet, weshalb letzterer besonders klare Anweisungen für Lernende bereitstellt. Beide Settings kommen Lehrkräften entgegen, insofern sie den Vorbereitungsaufwand (Fachwissensaneignung, Disziplinarmaßnahmen, didaktische Aufbereitung, etc.) durch vorgefertigte, von geschultem Personal durchgeführte Lehrprogramme mindern. Die Biosphäre 2 entspricht dabei einem Ganztagesausflug und der dreitägige Aufenthalt am Cooper Center einer Schulfahrt. Hilfreich für den Lerneffekt ist, die Lernerfahrung mit Vor- und Nachbereitungsaktivitäten zu rahmen, denn letztlich beeinflusst die Planung, Strukturierung und Einbettung außerschulischen Lernens in den Klassenunterricht den Lernerfolg (Beiersdorfer & Davis, 1994; Dillon et al., 2017). Die Einbettung hat bei Tagesausflügen wie der Biosphäre 2 noch höhere Wichtigkeit als bei extensiveren Programmen wie am Cooper Center, bei dem eine Themenhinführung und ein reflektiver Themenabschluss sowie die Integration des Erlernten in den Schul- und Alltag Programmbestandteil ist.

3.2.2.2 Die Forschungs- und Bildungsinstitution Biosphäre 2

(zusammengefasst nach University of Arizona, 2020)

Die Biosphäre 2 ist eine Forschungs- und Bildungsinstitution in der Wüste Arizonas, die von Schüler:innen als Tagesausflug besucht und zur Erfüllung umweltbildungsrelevanter Lernziele genutzt wird (ISB, 2021; NGSS Lead States, 2013). Die Einmaligkeit des Lernens an der Biosphäre 2 ergibt sich durch deren Forschungscharakter und Infrastruktur, weshalb nachfolgend zunächst die geschichtlichen Hintergründe bis hin zur aktuellen Nutzung und darauf aufbauend das Lehren und Lernen an der Institution vorgestellt wird.

Die Biosphäre 2 wurde zwischen 1986 und 1991 in Arizona, USA, nahe Tucson auf einer Fläche von 12,750 m^2 erbaut. Sie folgte dem Ziel, ein materiell geschlossenes jedoch energetisch offenes (via Sonnenlicht und Elektrizität), sich selbst erhaltendes Ökosystem als Miniaturversion der Erde – die Biosphäre 1 – zu schaffen, um Forschung für Weltraummissionen anzukurbeln (Nelson et al., 1993; Walter & Lambrecht, 2004; Weyer et al., 2000). Daher wurde unmittelbar nach der Fertigstellung ein zweijähriges Autarkieexperiment mit acht Teilnehmer:innen initiiert (Weyer et al., 2000). Aufgrund der hohen Bodenrespiration und Sauerstoffabsorption der Betonkonstruktion musste nach 16 Monaten flüssiger Sauerstoff zugegeben werden. Kurze Zeit später wurde das Experiment beendet, jedoch bald ein zweites Autarkieexperiment mit sieben Teilnehmer:innen begonnen, das wegen der hohen Distickstoffmonoxidkonzentration und der abnehmenden Wasserqualität nach sechs Monaten abgebrochen wurde (Walter & Lambrecht, 2004). Damalige Studien analysierten vor allem das Konstruktionsdesign, Ökosystemdynamiken sowie den Gesundheitszustand der Teilnehmer:innen infolge des Sauerstoffmangels und der Kalorienrestriktion (Nelson et al., 1993; Walter & Lambrecht, 2004; Weyer et al., 2000).

Nach Abschluss der Autarkieexperimente wurde und bis heute wird die Institution als Riesenlaboratorium für manipulative Klimaforschungsexperimente genutzt, da durch die materielle Abgeschlossenheit Parameter selektiv geändert und sich daraus ergebende Folgen eruiert werden können. Die Größe der fünf Biome (s. Abb. 4) lässt über typische Labore hinausgehende Forschungsdesigns zu. Damit bildet die Biosphäre 2 eine Brücke zwischen klassischen Laborexperimenten und der Feldforschung, um z.B. die Klimaerwärmung und Ökosysteminteraktionen zu untersuchen (Walter & Lambrecht, 2004). In einer Initiative wurde z.B. der Regenwald Trockenstress ausgesetzt, Stoffe wurden mittels Isotopenmarkierung verfolgt und Konsequenzen für Fauna und das Bodensystem erforscht (Shorter et al., 2020). Ferner finden Forschungsprojekte zur Nachhaltigkeit und Weltraumforschung statt, die das Ziel der Ressourceneinsparung teilen, wie bioregenerative Nahrungsversorgungsmöglichkeiten (Furfaro et al., 2017). Die Biosphäre 2 hebt sich also von gängigen Laboratorien durch die räumlichen Ausmaße der fünf Biome sowie

durch den Grad der Abdichtung von Umweltfaktoren ab, während evolvierende Ökosysteme darin erhalten und manipulative Forschungsansätze implementiert werden können. Dieses Potenzial wird für die Umweltbildung genutzt, indem Schüler:innen einen authentischen Einblick in naturwissenschaftliche Berufs-, Forschungs- und Erkenntnisfelder erhalten.

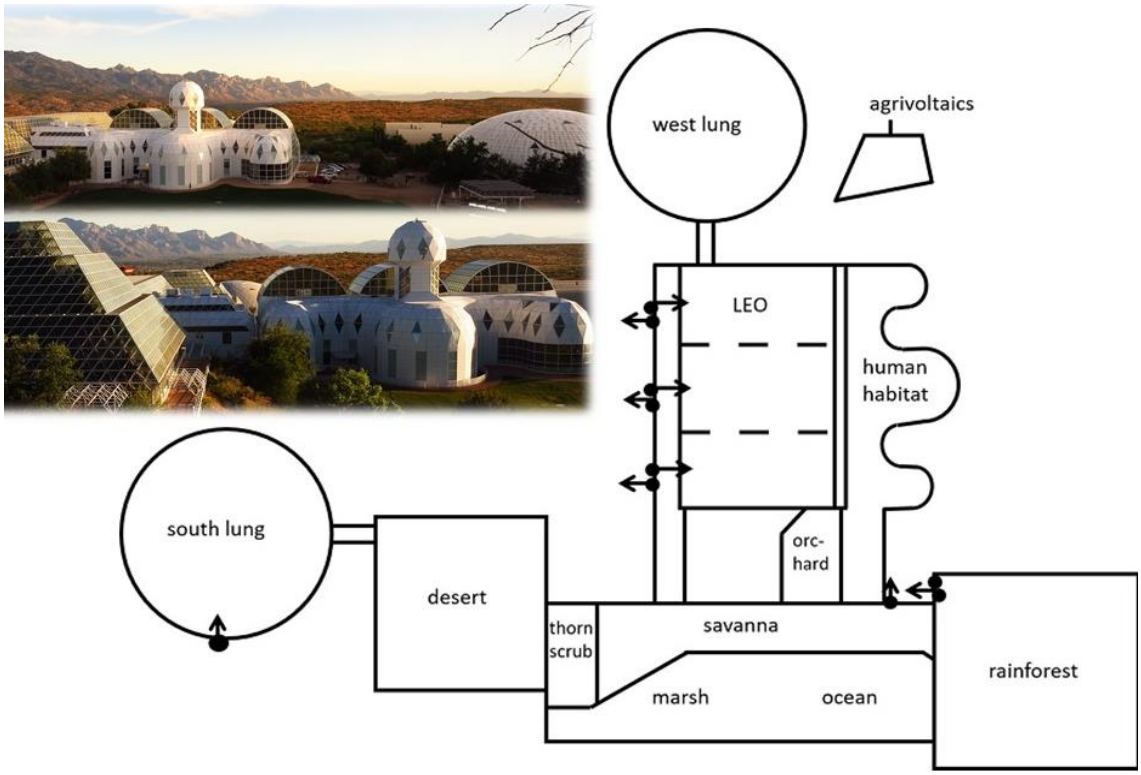

Abbildung 4: Grundriss (Kraus, 2021) und Frontfotografien der Forschungs- und Bildungsinstitution Biosphäre 2 in der Wüste Arizonas, USA; Der Gebäudekomplex umfasst fünf Biome (Nebelwüste [s. Abb. 5], Savanne, Mangrovensumpf, Ozean und Regenwald), den ehemaligen Wohnraum der Autarkieversuchsteilnehmer:innen, der als Ausstellung erhalten blieb oder in Büros und Lernräume umfunktioniert wurde, zwei *Lungen* zum Druckausgleich des geschlossenen Systems, das Vorzeigeprojekt LEO (*Landscape Evolution Observatory*) und eine Agrivoltaikanlage, die Photovoltaik und Landwirtschaft verknüpft (Stand der Fotografien: April 2019)

Zentral für das Lernen vor Ort sind globale Umweltfragen, die auf grundlegenden Dynamiken natürlicher sowie anthropogen beeinflusster Systeme beruhen und sich besonders auf den Wasser- und Energiehaushalt hinsichtlich der Geo-, Klima- und Ökosystemforschung beziehen. Daraus wird ersichtlich, dass die Lehrprogramme vielmehr auf Zusammenhangs- anstatt Faktenwissen abzielen. Die Programme sind curricular orientiert und an der praxisbezogenen, interaktiven, auf Experimenten basierenden Eigentätigkeit ausgerichtet. Jedes der fünf Programme (*Sustainability*, *Marine Science*, *Systems in Space*, *Plants & Our Planet* und *Ecosystem Services*) kann den Jahrgangsstufen angepasst und adressatengerecht eingesetzt werden.

Sustainability erklärt Nachhaltigkeit an den Themen *Plastikverschmutzung* und *Wassernutzung*. Dabei wird individuelles sowie gesellschaftliches Verhalten reflektiert und es werden gemeinsam Alternativen erarbeitet. *Marine Science* beinhaltet marine Ökosystemzusammenhänge und

die Ozeanversauerung, wofür Schüler:innen das Konzept inklusive pH-Wert verstehen, den Prozess im globalen Klimawandel verorten und entsprechend umweltschützendes Verhalten lernen sollen. *Systems in Space* spiegelt den ursprünglichen Weltraummissionscharakter der Institution wider und stellt in einem Ausstellungsraum nachhaltige, weltraumtaugliche Agrareinheiten wie das *Lunar Greenhouse* vor, in dem Pflanzen in erdfreien, bewässerten Plastiktaschen in einem ausfahrbaren Schlauchmodul angebaut werden (s. Abb. 5). *Plants & Our Planet* umfasst curricular verankertes Grundwissen zur Photosynthese und der Pflanzenmorphologie. Darauf fußend werden Kormusteile aus den Biomen gesammelt und hinsichtlich ihrer Adaptionen untersucht (Stomatadistribution und -öffnungsgrad, morphologische Vergleiche, etc.). *Ecosystem Services* soll die Schüler:innen an die Ökosystemdienstleistungen (kulturell, regulierend, unterstützend und bereitstellend: Daily, 2012) der fünf Biome heranführen, sodass sich Natur und Alltagsrelevanz annähern und eine Naturwertschätzung evoziert wird. Die fünf Programme vereint der Nachhaltigkeits- und Umweltschutzbezug, der sich der angestrebten Balance und intendierten Reflexion anthropogen-fokussierter und umweltschützender Verhalten fügt.

Abbildung 5: Fotografien der Lernumgebung der Biosphäre 2 in Arizona, USA; Querschnitt (links) und komplettes Modul (Mitte) des *Lunar Greenhouse* sowie die Nebelwüste (rechts) in einem pyramidenförmigen Abschnitt der Glas- und Stahlkonstruktion (Stand der Fotografien: April 2019)

Die Interdisziplinarität der Forschung soll sich in den Lehrprogrammen widerspiegeln und im curricularen Abgleich authentisches, multiperspektivisches Lernen ermöglichen. Durch das handlungs- und problemorientierte, praxisbezogene, experimentell basierte und interdisziplinäre Konzept, das durch die Nähe zur Forschung authentisches Lernen erzeugen und die affektive Ebene zunehmend ansprechen soll, stehen die Programme im Einklang mit curricularen Anforderungen und Qualitätskriterien (s. 3.2.2.1) für außerschulische Lernorte (ISB, 2021; NGSS Lead States, 2013; Zeidler et al., 2005). Weitere Informationen zu den Lehrprogrammen finden sich in Teilarbeit A (s. 5.3).

3.2.2.3 Das Umweltbildungszentrum Cooper Center

(zusammengefasst nach Van Matre & Johnson, 1988)

Das Cooper Center ist ein außerschulischer Lernort in der Wüste Arizonas. Dort sollen Schüler:innen innerhalb von drei Tagen die Umwelt in ihrem möglichst natürlichen Zustand im Rahmen des Umweltbildungsprogramms *Earthkeepers* erfahren. Die didaktische Aufbereitung bezieht sich vorrangig auf angeleitete Forschungsaufträge mittels naturwissenschaftlicher Arbeitsweisen als betreute und selbstständige Schüler:innenaktivitäten, um an biologisches Arbeiten heranzuführen und tieferes Lernen durch die Wissensgenerierung im reziproken Überprüfungsprozess zu ermöglichen. Teilnehmende erarbeiten sich nämlich in Einzel-, Partner:innen- oder Gruppenarbeit System-, Handlungs- und Effektivitätswissen (s. 3.2.1.3) über deren natürliche Umwelt, während weitere Aufgaben auf positive Naturerfahrungen beispielsweise durch Sinneswahrnehmungen (visuell, auditiv, olfaktorisch oder kinästhetisch) abzielen. Generell fließen anthropogene Aspekte via Ökosystemdienstleistungen ein und bilden die Verstrickung sowie Abhängigkeit von Natur und Mensch ab. Die Schüler:innen sollen aufgabengeleitet die Fragen durchlaufen, wie 1) Leben auf der Erde möglich ist, 2) die Menschheit mit der Erde zu beidseitigem Gunsten interagieren und 3) Individuen – ergo die Schüler:innen selbst – nachhaltig mit der Erde in Beziehung stehen können.

Demnach greift das *Earth Education*-Programm wesentliche Aspekte curricular verankerter Umweltbildung auf und tangiert das Konzept *Bildung für nachhaltige Entwicklung* (Hopkins & McKeown, 2002), wobei sich bei *Earthkeepers* soziale wie ökonomische Aspekte dem Umweltschutzaspekt fügen. Dabei ist Wissen zu Ökosystemzusammenhängen wie die Zirkulation von Nährstoffen und Energie fundamental. Durch das holistische Programm im Freien soll ein Wissenszuwachs, eine positive Umwelteinstellung und Umweltschutzverhalten generiert werden (s. Abb. 6). Diese werden durch Nachbereitungsaufgaben verstärkt, wofür die Schüler:innen das neu erlernte Wissen anwenden, indem sie mit dem geschulten Personal Umweltschutzverhalten auswählen und in ihren Alltag integrieren. Hierzu zählen Ressourceneinsparungen hinsichtlich Energie und Materialien wie der Verzicht auf Plastikverpackungen beim Einkauf. Außerdem sollen Schüler:innen im Zuge der Nachbereitung ihre Verhaltensänderungen dokumentieren, sich der Natur exponieren und anderen Personen davon berichten. Letzteres folgt der Intention, durch Identitätsbildung dauerhaft Einstellungen und damit Verhalten zu ändern. Für das Absolvieren dieser Aufgaben gewinnen die Schüler:innen *Schlüssel*, jeweils einen für den Wissenserwerb, einen für ein Mindestmaß an Naturerfahrungen, einen für die Integration von Umweltschutzverhalten in den Alltag über mindestens einen Monat und einen für das (Mit-) Teilen ihres neuerworbenen Wissens, ihrer Naturerfahrungen sowie ihrer Verhaltensänderungen. Durch

den Erwerb der vier Schlüssel werden die Schüler:innen vier bis sechs Wochen infolge der Schulfahrt zu *Earthkeepers* ernannt.

Durch die Exemplarität, Authentizität und Repräsentativität der Lerninhalte, die zum forschenden Denken im direkten Naturkontakt anregen, werden wesentliche Qualitätskriterien für außerschulische Lernorte erfüllt (s. 3.2.2.1). Außerdem wird durch das offene Lernsetting der dreitägigen Schulfahrt die Sozial- und Lehrform regelmäßig gewechselt, während der Fokus auf der Handlungsorientierung und damit der Schüler:innenzentrierung liegt und die Lehrkraft in eine Moderatorenrolle rückt. Dadurch können die Selbstwirksamkeit und damit ein verantwortungsvollerer Umgang mit der Umwelt gestärkt werden. Die Selbstregulation und Praxisnähe mit der affektiven Komponente der Naturerfahrung sollen über die vier- bis sechswöchige Erfahrung hinausgehend intensives, nachhaltiges Lernen ermöglichen und letztlich zur Schärfung von Umwelteinstellungen und umweltschützenden Verhaltensänderungen beitragen.

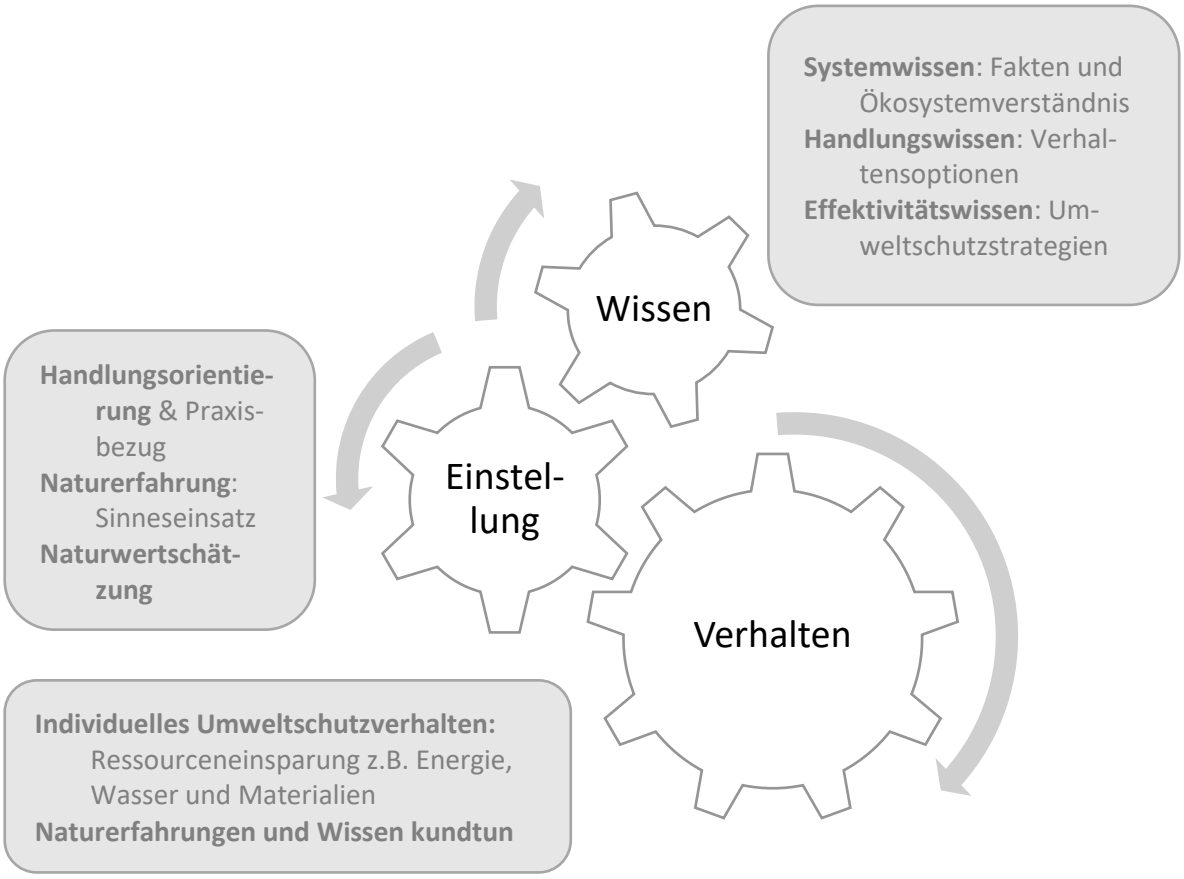

Abbildung 6: Schematische Darstellung des aus der *Earth Education* stammenden Umweltbildungsprogramms *Earthkeepers*, das am Cooper Center, einem außerschulischen Lernort in der Wüste Arizonas, USA, für Schüler:innen umgesetzt wird; Das Programm soll die Komponenten *Umweltwissen* (s. 3.2.1.3), *Umwelteinstellung* und *Umweltschutzverhalten* mit den angeführten Beispielen stärken. Die Räder sollen dabei die Verzahnung und die Synergieeffekte der drei Komponenten darstellen (nach Van Matre & Johnson, 1988).

3.3 Ziele und Fragestellungen der Teilarbeiten

Im Folgenden wird die Logik der Teilarbeiten im Sinne einer Progression skizziert, die sich dem Erkenntniszuwachs widmet, d.h. die Erkenntnisse einer Teilarbeit stellten die Ausgangslage für darauffolgende Teilarbeiten dar. Diese Sukzession dient dem übergeordneten Ziel der Schärfung von Umwelteinstellungen, wodurch eine stärkere Neigung zu Umweltschutzverhalten ausgelöst werden soll. Diverse Fachdisziplinen tangieren das Thema, wobei in dieser Arbeit eine fachdidaktische Perspektive eingenommen wird: Durch die Vermittlung biologischer, curricular verorteter Themen an außerschulischen Lernorten soll das Potenzial der Umweltbildung besser ausgeschöpft werden, wodurch zu Beginn die folgenden Fragen formuliert wurden:

- Wie kann Schüler:innen Umweltschutzverhalten möglichst effizient vermittelt werden?
- Welche Parameter beeinflussen und erleichtern Umweltschutzverhalten?
- Inwieweit helfen Lernortwechsel/ außerschulische Lernorte, die sich durch Authentizität und Alltagsnähe (ergo Schüler:innen- und Gesellschaftsrelevanz) auszeichnen?
- Welche Umwelteinstellungsskalen dienen der nachhaltigen Programmevaluation, liefern solide Güte und lassen eine (inter-) nationale Vergleichbarkeit zu?

Diese umfassenden Fragen dienten als Leitfragen, die infolge der unter 3.2 dargelegten Literaturrecherche konkretisiert wurden und zu den folgenden Fragestellungen führten:

- Welchen Einfluss zeigen Umweltbildungsprogramme an außerschulischen Lernorten auf den Umweltwissensstand sowie die Umwelteinstellung? **(Teilarbeit A, C, D und E)**
- Inwieweit eignen sich dabei die Biosphäre 2 (Tagesausflug) und das Cooper Center (Schulfahrt) zur Wissensgenese und Einstellungsschärfung? **(Teilarbeit A, C und E)**
- Welches Potenzial zeigen Lehrprogrammmodifikationen beispielsweise durch vor- und nachbereitenden Unterricht für die Wissens- und Einstellungssteigerung? **(Teilarbeit B)**
- Welchen Effekt zeigt die Umwelteinstellung auf den Wissenserwerb als eine Säule von Umweltschutzverhalten **(Teilarbeit A, C, D und E)** und auf ressourceneinsparende, über einen Monat dokumentierte Umweltschutzverhalten? **(Teilarbeit C und E)**
- In welchem Zusammenhang stehen Umweltwissen, Umwelteinstellung und Umweltschutzverhalten? **(Teilarbeit A, C, D und E)**
- Welche Empfehlungen lassen sich durch die Kontrastierung etablierter Einstellungsskalen formulieren, sodass Lehrprogramme hinsichtlich ihrer Effizienz besser vergleichbar und Fördermaßnahmen besser ableitbar werden? **(Teilarbeit A, C und D)**
- Welches Messinstrument eignet sich dabei am besten zur Programmevaluation und zur Schärfung der Umwelteinstellung, ergo als Messstandard? **(Teilarbeit A, C, D und E)**

Hieraus wird die sukzessive Vorgehensweise deutlich: Die primären Fragestellungen waren an den Effekten außerschulischer Lernorte auf die Wissens- und Einstellungsstärkung sowie auf die Beziehung der beiden Variablen hin zu Umweltschutzverhalten ausgerichtet. Dabei kristallisierte sich eine Undurchsichtigkeit auf verschiedenen Ebenen heraus: Die Vielzahl an Einstellungsmessinstrumenten erschwert die Vergleichbarkeit von Programmevaluationen und damit das Potenzial, nachhaltige Lehrempfehlungen zur Einstellungsschärfung auszusprechen. Die Einstellungsinstrumente der ersten Teilarbeit schienen zwar reliabel, konnten jedoch keine Einstellungsprogression verzeichnen und ließen keine konkreten Lehrempfehlungen infolge von Tagesinterventionen an der Biosphäre 2 ableiten. Die Skalen waren demnach für kontextuell isolierte Kurzzeitinterventionen sowie für den jahrgangübergreifenden Einsatz unzureichend. Daneben schien das Potenzial der Exkursionen nicht ausgeschöpft zu werden, weshalb eine Unterrichtseinheit konzipiert wurde, das Lehrkräften vor- und nachbereitenden Unterricht zur Verfügung stellt, sodass Schüler:innen vorbereitet zum außerschulischen Lernort kommen und das Erlernte nachbereiten können. Das ist besonders für ein curricular wenig, hingegen global zunehmend bedeutsam werdendes Thema wie der Plastikverschmutzung relevant. Aufgrund der anhaltenden Pandemie konnte dieses Lernmodul jedoch nicht quantitativ evaluiert bzw. konnten weitere Datenerhebungen an der Biosphäre 2 nicht durchgeführt werden.

Daraufhin bestand in weiteren Teilarbeiten der Bezug zu außerschulischen Lernorten über intensivere Lehrprogramme, die eine Themenhinführung und -nachbereitung bereits beinhalteten. Da sich diese zur Etablierung von Umweltwissen und -einstellungen mit diversen Messinstrumenten als hilfreich herausgestellt hatten, wurde der Blick mithilfe erfolgreich gezeigter Programme auf einen Messstandard gerichtet. Teilarbeit D summiert die gewonnenen Erkenntnisse und überträgt sie auf Empfehlungen für eine neuartige Einstellungsskala, die das Ziel verfolgt, 1) flexibel einsetzbar zu sein, 2) Interstudienvergleiche zuzulassen und 3) Fördermaßnahmen abzuleiten. Diese Teilarbeit ist ein erster Schritt und bedarf Folgestudien zur Feinjustierung. Teilarbeit E stellt dabei eine erste Anwendung einer praktikablen, gekürzten Version im Rahmen des erfolgsversprechenden Lehrprogramms *Earthkeepers* dar.

Die vorliegende Arbeit beansprucht nicht die vollständige Beantwortung der vorab gestellten Fragen, sondern folgt der Bemühung, einen Beitrag zur Beantwortung zu liefern, um letztlich Schüler:innen effektiver an Umweltschutz und eine nachhaltige Lebensweise heranzuführen. Die Teilarbeiten sollen daher nicht als geschlossene Einheit gesehen werden, sondern Erkenntnisschritte aufzeigen, die im Nachgang der Dissertation weiterverfolgt werden sollen. Dabei soll durch Programmmodifikationen der Lernort *Biosphäre 2* erneut herangezogen sowie die in Teilarbeit D vorgestellte Einstellungsskala transkontextuell eingesetzt werden.

3.4 Methoden

Nachfolgend werden die Stichproben, das Studiendesign, die Messinstrumente sowie die statistischen Analysen der Teilarbeiten beschrieben. Da die Teilarbeiten auf unterschiedlichen Datenerhebungen beruhen, werden nur wesentliche Punkte überblickshaft angeführt. Weitere Informationen finden sich in den entsprechenden Manuskripten.

3.4.1 Stichproben und Studiendesigns

Die vier quantitativen Teilarbeiten basieren auf verschiedenen Stichproben, weshalb deren Eckpunkte in Tabelle 1 zusammengefasst sind. Teilarbeit B ist hiervon ausgenommen, denn diese stellt eine Unterrichtseinheit dar und bedarf folglich keiner Stichprobengrundlage.

Tabelle 1: Informationen zum Alter, der Geschlechterverteilung, der Stichprobengröße und dem Erhebungszeitraum der vier quantitativen Teilarbeiten; einige Teilnehmer:innen gaben das Geschlecht nicht an, weshalb diese bei den Geschlechterverteilungen im Hinblick auf die Stichprobengröße fehlen.

Teilarbeit	M_{Alter} **(*SD*)**	**Geschlecht**	***N***	**Erhebungsjahr**
Teilarbeit A	13.06 (1.01)	♀: 35.7% (*n* = 81) ♂: 30.4% (*n* = 69)	227	2019
Teilarbeit C	9.96 (0.81)	♀: 40.9% (*n* = 2694) ♂: 39.2% (*n* = 2579)	6585	2005-2013
Teilarbeit D	14.47 (1.78)	♀: 49.6% (*n* = 790) ♂: 49.9% (*n* = 795)	1592	2011-2013
Teilarbeit E	9.38 (0.51)	♀: 54.7% (*n* = 135) ♂: 41.3% (*n* = 102)	247	2018-2019

Anmerkungen: *M* = Mittelwert, *SD* = Standardabweichung, *N/ n* = Stichprobengröße, ♀ = weiblich, ♂ = männlich

Die vier Teilarbeiten fügen sich als umweltbildungsbasierte Interventionsstudien einem *Pre-Post*-Design. Jeweils vor und nach einem Lehrprogramm wurde ein Fragebogen zur Messung des Umweltwissens und der Umwelteinstellung eingesetzt. Lediglich in Teilarbeit D wurde die Einstellung einmalig vor dem Programm herangezogen. Teilarbeit A bezieht sich auf den unter 3.2.2.2 beschriebenen außerschulischen Lernort, den Schüler:innen für einen Ganztagesausflug besuchten. Die Intervention von Teilarbeiten C und E wird unter 3.2.2.3 als Schulfahrt mit mindestens einmonatigen Folgeaktivitäten beschrieben. Teilarbeit D setzt sich aus vier Studien zusammen, die für eine Sekundäranalyse zusammengefasst wurden (Tabelle 2). Als Einschlusskriterien letzterer 1) fanden die Originalstudien in dem gleichen Zeitraum und in derselben fränkischen Region statt, 2) zentralisierten Umweltbildung, 3) folgten einem identischen Studiendesign, wobei die gleichen Messinstrumente herangezogen wurden, und 4) eigneten sich in eben dieser Konstellation zur Beantwortung der Forschungsfragen. Sämtliche Teilarbeiten nutzten anonymisierte Papierfragebögen und alle Studien wurden den rechtlichen Rahmenbedingungen entsprechend durchgeführt (s. jeweiligen Studien für Kennzeichen und Erläuterungen).

Tabelle 2: Vier Interventionsstudien zur Umweltbildung, die für Teilarbeit D im Rahmen einer Zweitanalyse herangezogen wurden

Originalstudie	**Thema der Intervention**	M_{Alter} **(*SD*)**	***N***
Schneiderhan-Opel & Bogner, 2021	Ökosystem Wald	12.72 (0.74)	688
Sattler & Bogner, 2017	(A-) Biotische Interaktionen im Zoo	15.71 (0.76)	337
Bissinger & Bogner, 2018	Klimawandel, tropischer Regenwald	15.77 (1.39)	319
Schumm & Bogner, 2016	Erneuerbare Energien	16.02 (0.57)	248

Anmerkungen: *M* = Mittelwert, *SD* = Standardabweichung, *N* = Stichprobengröße,

3.4.2 Erhebungsinstrumente

Zur Erfassung der Umwelteinstellung wurden die in Tabelle 3 gelisteten Skalen herangezogen. Für die Umweltwissensmessung wurden programmspezifische Skalen erstellt, die den jeweiligen Teilarbeiten bzw. Studien entnommen werden können.

Tabelle 3: Zusammenfassung der verwendeten Messinstrumente, deren Abkürzung, Autor:innen, Itemzahl und ein Verweis auf den Einsatz in den Teilarbeiten

Messinstrument	**Abkürzung**	**Autoren**	**Itemzahl**	**Einsatz in**
Science Motivation	SMOT	Glynn et al., 2011	25	Teilarbeit A
Fascination with Science	FIT	Otto et al., 2020	12	Teilarbeit A
New Environmental Paradigm	NEP	Dunlap & Van Liere, 1978	10	Teilarbeit C
Two Major Environmental Values Model	2-MEV	Wiseman & Bogner, 2003	15	Teilarbeit C Teilarbeit D Teilarbeit E
General Ecological Behavior	GEB	Kaiser, 1998	11 40	Teilarbeit D Teilarbeit E

Die fünf Messinstrumente folgen demselben Prinzip, nämlich anhand manifester Items (Aussagen, die auf einer Likert-ähnlichen, fünfstufigen Skala beantwortet werden) latente Variablen zu erfassen. Damit wird das nicht unmittelbar messbare Konstrukt der Einstellung über verschiedene Facetten greifbar. Die Skalen unterscheiden sich hinsichtlich ihrer Fragestellungen insofern, als dass sie entweder meinungsbasierte Items, die eine Angabe zum Grad der Zustimmung fordern, darstellen (SMOT, NEP, 2-MEV sowie mehrheitlich FIT) oder retrospektiv die Häufigkeit umweltschützenden Verhaltens abfragen (vier FIT-Items und GEB). Letztere liegen näher am tatsächlichen Verhalten (Stern & Dietz, 1994), jedoch tragen beide Ansätze komplementär zur Erfassung der Umwelteinstellung bei (Brügger et al., 2011; Kaiser et al., 2013).

3.4.3 Datenauswertung: Statistische Analysen

Für die quantitative Auswertung wurden das Statistische Paket für Sozialwissenschaften (SPSS, 24. Version: IBM Corp., 2016), die zugehörige Software *Amos* für Strukturgleichungsmodellierung (24. Version: Arbuckle, 2016) sowie die Software *ConQuest* für die Rasch-Kalibrierung (Adams & Khoo, 2015) genutzt. Ferner diente Microsoft Excel 2016 der Datenvisualisierung.

In **Teilarbeit A** wurde das etablierte Konstrukt der Motivation faktoranalytisch über Amos einer Qualitätsanalyse unterzogen. Das neu publizierte Konstrukt der Faszination wurde ferner mit SPSS faktoranalysiert, um exploratorisch die Skalenstruktur zu untersuchen und daraufhin eine konfirmatorische Faktoranalyse über Amos durchzuführen. Weiterhin wurde die Faszination mit ConQuest Rasch-kalibriert. Infolge solider Reliabilität wurden beide Skalen in einem Pfadmodell kontrastiert und mit weiteren Variablen, insbesondere dem Wissensstand der Schüler:innen, in Relation gesetzt. Diese Zusammenhänge wurden mit Spearman-Korrelationen via SPSS bestätigt. Daneben wurden Programmeffekte mithilfe von Wilcoxon-Tests über SPSS eruiert.

In **Teilarbeit C** wurden erneut Amos und SPSS zur Gütebestimmung zwei etablierter Skalen (2-MEV und NEP) durch Faktoranalysen und deren Gegenüberstellung herangezogen. Daraufhin wurden in Strukturgleichungsmodellen die zwei Latenten des 2-MEV, nämlich *Preservation* (Naturschutztendenz) und *Utilization* (Naturnutzungstendenz), mit dem Wissensstand der Schüler:innen und einem Verhaltensindikator, der Umweltschutzverhaltensänderungen repräsentiert, in Zusammenhang gebracht. Mithilfe von T-Tests über SPSS wurden Interventionseffekte auf den Einstellungs- und Wissensstand und in Relation zum Verhaltensindikator untersucht.

In **Teilarbeit D** wurde von Faktoranalysen abgesehen und das Rasch-Modell eingesetzt. Zwei bekannte Skalen (2-MEV und GEB) wurden für ein neuartiges Einstellungsmessinstrument vereint und einer gemeinsamen Rasch-Kalibrierung unterzogen. Infolge diverser Güteuntersuchungen der Skala (spezifische Objektivität, geschlechterspezifische differentielle Item-Funktionsweise mittels ConQuest, Abgleich der altersbezogenen Einstellungskurve durch Mittelwerts- und Korrelationsanalysen über SPSS) wurde diese durch Regressionsrechnungen über SPSS mit den Wissensständen der Schüler:innen in Relation gesetzt, um den Einfluss der Einstellung auf den Wissensstand und –zuwachs (ergo dem Lernen) infolge der Programmpartizipation zu beleuchten. Für die Ergebnisvisualisierung wurde Excel genutzt.

In **Teilarbeit E** wurden die Erkenntnisse aus Teilarbeit D auf einen neuen Kontext (junge Altersgruppe in den USA) übertragen und überprüfend ähnliche Rechnungen der Rasch-Kalibrierung sowie der Einstellungspositionierung zum Wissenserwerb mittels Korrelations- und Regressionsanalysen herangezogen. Ferner dienten T-Tests über SPSS der Programmevaluation.

3.5 Ergebnisse und Diskussion

Im Anschluss werden die wesentlichen Ergebnisse und Diskussionen der Teilarbeiten zusammengefasst. Vier Teilarbeiten folgen einem quantitativen, nomothetischen Ansatz, wogegen Teilarbeit B eine Unterrichtseinheit darstellt.

3.5.1 Teilarbeit A: Lernen am außerschulischen Lernort *Biosphäre 2*

Die Reliabilität zweier Einstellungsfacetten (Motivation: Glynn et al. [2011], Faszination: Otto et al. [2020]) konnte bestätigt werden. Die Faszination ließ sich dabei über ein Rasch-Modell der originalen Publikation gleich kalibrieren und mit optimalen Reliabilitätswerten faktoranalysieren. Während Faktoranalysen eine Strukturdarstellung von Skalen und Folgeanalysen von Subskalen erlauben, liefert ein Rasch-Modell durch die spezifische Objektivität eine hohe Ergebnisvergleichbarkeit (Linacre, 1998). Es eignet sich daher für (inter-) nationale Vergleiche, um Maßnahmen auf politischer wie curricularer Ebene zu entwickeln. Beide Konstrukte zeigten einen signifikanten Effekt auf den Wissensstand: Umso stärker die Motivation bzw. Faszination, umso mehr Wissen war vorhanden. In einem Pfadmodell, durch Korrelationsrechnungen und Literaturunterstützung wurde die Ähnlichkeit beider Konstrukte deutlich, die sich zudem in einer identischen Korrelation mit einer Variable zeigte, die die Häufigkeit des Sprechens über Schulthemen zuhause ausdrückt. Letztere ist ein Indikator für informelles Lernen (Bell et al., 2009). Obwohl dieses Item keine ultimativen Aussagen zulässt, scheint die Häufigkeit, über Schulthemen zu sprechen, mit einer stärkeren Ausprägung der Motivation und Faszination einherzugehen.

Obgleich der Wissensstand infolge der Programmpartizipation signifikant zunahm, konnten bei der Motivation und Faszination nur nicht-signifikante Verbesserungen festgestellt werden. Bereits der Vortest ergab sehr hohe Mittelwerte, die Steigerungen kaum zuließen. Dem könnten die soziale Erwünschtheit, ein Deckeneffekt oder die Konstrukttheorien zugrunde liegen. Eine perzipierte, leistungsdruckbezogene Erwartungshaltung kann z.B. bei Schüler:innen ein Antwortmuster hervorrufen, das mit der Lehrkrafterwartung konform scheint. Dem wurde entgegengewirkt, indem vor der Datenerhebung betont wurde, dass die Fragebögen nicht beurteilt, sondern anonym ausgefüllt und für eine Studie verwendet würden. Ein Deckeneffekt ist unwahrscheinlich, da die Stichprobe eine Altersgruppe von neun bis 19 Jahren und diverse Schulen umfasste, während die Exkursionen nicht freiwillig, sondern schulisch initiiert waren. Folglich kann eine überdurchschnittlich positiv eingestellte Stichprobe ausgeschlossen werden.

Daher rückt die dritte Begründung in den Fokus: Die Skalen scheinen vielmehr Motive als die Motivation – mit der Faszination als Facette der Motivation – zu erfassen und lassen eine Diskrepanz zwischen Items erkennen, die meinungsbasierte Äußerungen und selbstberichtetes

Verhalten abfragen. Eine Motivation gilt temporär und zeigt sich in der Intensität, Ausdauer und Qualität an Aufmerksamkeit, die in Aufgaben investiert wird (Bandura, 1988; Brophy, 2004), also im Ressourcenaufwand zur Aufgabenerfüllung (Glynn et al., 2011). Ein Motiv ist beständiger und beschreibt Verhaltensausrichtungen wie eine Leistungsorientierung (Revelle & Michaels, 1976). Die Abgrenzung beider ist unscharf, allerdings scheinen einige Fragen beider Skalen vielmehr Motive anstelle der Motivation abzufragen, z.B. zu Karriereausblicken, zur Selbstbestimmtheit und zur Selbstwirksamkeit. Motive gelten persistent, weshalb sich diese infolge einer Tagesintervention kaum ändern und die nicht-signifikate Zunahme der Mittelwerte begründen können.

Dies klärt jedoch nicht die Frage nach den sehr hohen Mittelwerten. Hierfür liefert das Campbell-Paradigma eine mit dem vorigen Argument einhergehende Erklärung. Dabei sind Änderungen im Verhalten inklusive der Zustimmung von Aussagen von der Einstellung und den Verhaltenskosten (z.B. Zeit, Geld) bedingt (Kaiser et al., 2010). Items, die eine Meinung widerspiegeln, werden wahrscheinlicher positiv beantwortet als Items, die tatsächliches Verhalten abfragen. Schüler:innen stimmen folglich leichter Aussagen wie „Umweltschutz ist wichtig“ als verhaltensbezogenen Aussagen wie „Ich setze mich für den Umweltschutz ein“ zu. Dieses Muster zeigte die Faszinationsskala, indem lediglich die vier verhaltensbezogenen Items einen durchschnittlichen Mittelwert ergaben. Folglich würde die Dominanz an meinungsbasierten Items, die zudem eine leichtfertige und hohe Zustimmung erlauben (z.B. die hohe Wahrscheinlichkeit auf die Aussage „Umweltschutz ist wichtig“ mit „stimme voll zu“ zu antworten), die Mittelwerte erklären. Das schließt meinungsbasierte Items generell nicht aus, sondern plädiert für eine Balance mit Verhaltensselbstberichten und für eine nuancierte Schwierigkeit an Meinungsäußerungen, sodass nicht leichtfertig sämtlichen Items vollends zugestimmt, sondern eine Differenzierung möglich wird. Bei obigem Beispiel würde dies implizieren, statt nach der Wichtigkeit des normkonformen Umweltschutzes differenzierter zu fragen (z.B. „Ich halte Einwegplastiktüten für unnötig“). Ergo wäre eine Skalenrestrukturierung zur Evaluation von Kurzzeitinterventionen empfehlenswert.

Diese Teilarbeit legt damit die Basis für die weiteren Teilarbeiten, nämlich neben der Programmevaluation einer adäquaten Einstellungsmessung nachzugehen sowie die Rolle der Einstellung zu beleuchten und letztere zu schärfen, indem z.B. vom Klassenunterricht isolierte außerschulische Lernorte eingebunden werden. Während der Datenerhebung zeigte sich, dass die Schüler:innen höchstens marginal auf die Lerngegenstände vorbereitet waren und meist keine Nachbereitung stattfand, wodurch Einstellungsänderungen auch nicht durch Facetten wie der Motivation greifbar wurden. Daher sollten Lehrkräften Lehrmaterialien kostenfrei und digital zur Verfügung stehen, um tieferes Lernen zu ermöglichen und ferner das Potenzial der Biosphäre 2 überregional zugänglich zu machen. Die Unterrichtseinheit wird nachfolgend vorgestellt.

3.5.2 Teilarbeit B: Unterrichtseinheit zur Plastikverschmutzung

Um das Potenzial des beliebtesten Lehrprogramms der Biosphäre 2, nämlich *Sustainability* (S. Fallon, persönliche Kommunikation, 10. April 2019), auszuschöpfen, wurde eine Unterrichtseinheit entwickelt, die den Tagesausflug vor- und nachbereitend in den Klassenunterricht integriert und das zusätzlich ohne Tagesausflug überregional nutzbar ist. Für das Thema *Plastikverschmutzung* existieren nämlich trotz der globalen Bedeutsamkeit keine konkreten curricularen Vorgaben (NGSS Lead States, 2013), weshalb entsprechende Lehrmaterialien in Medien wie Schulbüchern fehlen und es tendenziell wenig Kapazität zur Aufbereitung eines lehrplanlosgelösten Themas gibt. Um die Unterrichtseinheit weitreichend einsetzen zu können, wurden zwei Varianten erstellt, nämlich eine zur Einbettung des außerschulischen Lernortes und eine weitere im *The American Biology Teacher* publizierte, lernortunabhängige Version zur überregionalen Nutzung.

Das Modul ist in drei Einheiten gegliedert. Die erste Einheit führt die grundlegende Terminologie (z.B. Makro- vs. Mikroplastik) sowie gängige Herstellungsprozesse und Anwendungsbereiche von Plastik ein. Dieses Wissen wird an der Biosphäre 2 vertieft (Fragmentierung, Akkumulation und Distribution von Plastik mit Schwerpunkt auf das marine Ökosystem). Alternativ zur Exkursion können Schulversuche zur Mikroplastikextraktion aus synthetischer Kleidung und Kosmetika durchgeführt werden. Das leitet zur weitreichenden Plastiknutzung über, indem Schüler:innen mithilfe eines Kartenspiels der Verwendung in Alltagsgegenständen nachgehen. Die zweite Einheit wird von der Frage geleitet, inwieweit die Plastiknutzung problematisch ist, und stellt entweder die Nachbereitung der Exkursion oder die Fortführung des Klassenunterrichts dar. Durch Modellarbeit, einem Informationstext, zwei Kurzzeitversuchen sowie einem Kartenspiel erhalten Schüler:innen Input und lernen über Verbreitungswege, z.B. vom Hausabfluss zum Meer, und die erhöhte Toxinakkumulation und -abgabe durch die Oberflächenvergrößerung infolge der Fragmentierung. In der dritten Einheit soll mithilfe eines Versuchs, eines Videos und durch Spiele an die sechs ‚Rs' (*Refuse*, *Reduce*, *Reuse*, *Recycle*, *Rethink* und *Redesign*) und damit an einen verantwortungsvollen Umgang herangeführt werden. Das Modul leitet also von der Produktion über die Nutzung hin zu nachhaltigem Handeln und soll Schüler:innen gegenüber dem Plastikkonsum sensibilisieren, wobei Vor- und Nachteile des Konsums reflektiert werden.

Die Schulversuche wurden von 17 Studierenden der Universität Bayreuth durchgeführt und als sinnvoll bewertet, zumal sie sich durch geringe Modifizierungen adressatengerecht für die Unter-, Mittel- sowie Oberstufe aufbereiten lassen, um möglichst viele Schüler:innen erreichen zu können. Ferner führt das Modul an curricular gefordertes wissenschaftliches Arbeiten heran (ISB, 2021; NGSS Lead States, 2013), indem es den Forschungscharakter der Biosphäre 2 durch simplifizierte Forschungstätigkeiten mithilfe von Fragen, Modellen und Versuchen aufgreift.

3.5.3 Teilarbeit C: *Earth Education*-Programm *Earthkeepers*

In Teilarbeit C wurden zwei etablierte Einstellungsmessinstrumente (2-MEV und NEP) faktoranalytisch kontrastiert sowie das Lehrprogramm *Earthkeepers* hinsichtlich Wissens-, Einstellungs- und Verhaltensänderungen inklusive deren Relationen untersucht. Dafür wurden Daten von Umweltbildungszentren aus drei Staaten über eine Spanne von neun Jahren herangezogen.

Im ersten Schritt wurden die beiden Subskalen des zweidimensionalen 2-MEV (*Preservation* und *Utilization*) mit dem eindimensionalen NEP mittels einer konfirmatorischen Faktoranalyse in Beziehung gesetzt. Während Preservation und das NEP hochsignifikant korrelierten, zeigte das NEP mit Utilization eine identische, negative Korrelation wie Preservation mit Utilization. Das lässt nicht nur eine konforme Basis beider Skalen erkennen, sondern deutet eine Unidimensionalität der vermeintlich orthogonalen 2-MEV Subskalen an, der mit weiteren Berechnungen nachgegangen wurde. Hierzu zählten 1) die Konstruktvalidität (Diskriminanten- und Konvergenzvalidität) der konfirmatorischen Faktoranalyse, 2) die signifikanten, negativen Korrelation der beiden Latenten Utilization und Preservation, 3) die exploratorische Faktoranalyse (diffuse Ladungen für Utilization und ein sehr hoher Eigenwert für Preservation), 4) der Vergleich von Cronbach Alpha- und McDonalds Omega-Reliabilitätswerten, 5) Strukturgleichungsmodelle, in denen die Subskalen mit Wissen und Verhalten in Verbindung gebracht wurden, und 6) der Literaturabgleich, in dem sich Utilization oftmals als die schwächere (z.B. uneinheitliche Faktorladungen und beschränkte Aussagekraft auf den Wissensstand) und zugleich invers zu Preservation korrelierte Latente herausstellte (z.B. Milfont & Duckitt, 2004). Eine konfirmatorische Faktoranalyse, in der sämtliche 2-MEV-Items auf eine Latente ausstrahlten, ergab solide Reliabilität, allerdings luden drei Utilization-Items nicht signifikant auf den gemeinsamen Faktor. Dieser Diskrepanz und dem Verweis auf Unidimensionalität des 2-MEV wurde in Teilarbeit D nachgegangen, indem diejenigen Items des 2-MEV zusammengenommen wurden, die (invers) Naturschutz ausdrücken, um auf einen Messstandard für die Umwelteinstellung hinzuarbeiten.

Hinsichtlich der Programmevaluation zeigten Schüler:innen der drei Staaten signifikante Langzeitänderungen beim Umweltwissen und der Einstellung. Die Signifikanz war stärker, wenn nach der Schulfahrt Umweltschutzverhalten in den Alltag integriert wurde. Das Programm scheint ergo jahres- und staatenübergreifend ein erfolgreicher Umweltbildungsansatz zu sein, wobei die Resultate auf den positiven Effekt der Vor- und Nachbereitung eines Lehrprogramms verweisen.

Strukturgleichungsmodelle deuteten den Effekt der Umwelteinstellung auf Umweltwissen und des Wissensstands auf Umweltschutzverhalten an. In Folgestudien wurde daraufhin der (synergistischen) Relation dieser Säulen nachgegangen, zumal in dieser Teilarbeit nur Systemwissen eingesetzt worden war, weshalb nachfolgend eine komplexere Wissensskala genutzt wurde.

3.5.4 Teilarbeit D: Lernförderliche Rolle der Umwelteinstellung

Teilarbeit D folgte der Hypothese, dass die Umwelteinstellung das Maß an Umweltwissen und damit Umwelthandeln beeinflusst. Ferner wurde ein altersbezogener Einstellungstrend skizziert und eine Einstellungsskala vorgestellt, die die etablierten Instrumente 2-MEV und GEB und damit meinungsbasierte Items sowie Verhaltensselbstberichte im Rahmen des Campbell-Paradigmas vereint, um einen Item-Pool einzuführen, der trotz Anpassungen an Alter und Umgebungen losgelöst von einer festen Item-Zahl (über-) regionale Vergleichbarkeit zulässt. Ferner lässt der GEB durch Verhaltensselbstberichte nicht nur auf eine Einstellung, sondern auf tatsächliches Verhalten schließen, wodurch die Skala Einstellungs- sowie Verhaltensänderungen abbildet.

Tatsächlich zeigte die kombinierte Skala eine bessere Reliabilität als beide Skalen separat. Die Konvergenzvalidität bestätigte dabei die Erfassung desselben Konstruktes, indem eine Person bei den jeweiligen Kalibrierungen einen identischen Einstellungswert erhielt. Ferner wurde die Skala zur Qualitätsprüfung auf ihre differentielle Item-Funktionsweise hinsichtlich des Geschlechts getestet, die – bestätigt durch eine Korrelationsrechnung – geschlechtsspezifisch fair war. Auch die Item-Verteilung war auf einem Kontinuum der Verhaltenskosten im Abgleich mit bisherigen Publikationen und der Logik des Campbell-Paradigmas folgend stimmig (z.B. Kaiser et al., 2010), wobei meinungsbasierte Items erwartungsgemäß tendenziell geringere Verhaltenskosten abbildeten. Außerdem konnte als weiteres Qualitätsmaß ein in der Literatur bekannter Alterstrend der Umwelteinstellung abgebildet werden. Dieser Trend beschreibt hohe Einstellungswerte für Zehn- bis Zwölfjährige, eine rapide Abnahme mit einem Tiefpunkt zwischen 15 und 17 Jahren und einer nachfolgenden sukzessiven Zunahme der Umwelteinstellung.

Nach der Skalenvalidierung wurde der Effekt der Einstellung auf den Wissensstand (System-, Handlungs- und Effektivitätswissen) infolge der Programmpartizipation, die zugleich als Evaluation des kontextuell eingebundenen Programms herhielt, eruiert. Eine multiple Regressionsanalyse zeigte, dass das Vorwissen und die Einstellung nahezu gleichermaßen zum Wissensstand nach Programmabschluss beitrugen. Während positive Effekte des Vorwissens bekannt sind (z.B. Integration in bestehende Wissensnetze [Chandler & Sweller, 1991], Einfluss der Intelligenz [Nisbett et al., 2012]), scheint die Einstellung den motivationalen Antrieb zu erklären. Obgleich Faktoren wie der sozioökonomische Status einwirken können (Sirin, 2005), bestimmt wohl die Einstellung 1) das Wahrnehmen von Lernmöglichkeiten sowie 2) die Intensität des Lernens mit und ist damit förderlich für den Lernerfolg. Folglich sollte eine Inputorientierung in der Umweltbildung aufgeweicht werden, indem der Systemwissenstransfer zugunsten der Einstellungsschärfung reduziert sowie durch Handlungs- und Effektivitätswissen ergänzt wird. Offen bleiben indes konkrete Determinanten der Umwelteinstellung sowie der altersbezogenen Einstellungskurve.

3.5.5 Teilarbeit E: Lernen am außerschulischen Lernort *Cooper Center*

Diese Teilarbeit ist eine Fortführung von Teilarbeit C und D, indem die in Teilarbeit D vorgestellte Skala zur Einstellungsmessung sowie der theoretische Rahmen des Einflusses von Einstellungen auf den Wissenszuwachs herangezogen wurden, um beide Ansätze in einem neuen Kontext zu prüfen. Eine deutlich jüngere, amerikanische Kohorte (M_{Alter} = 9,38) nahm hierfür an einer Schulfahrt zum außerschulischen Lernort *Cooper Center* teil. Sollte die in Teilarbeit D vorgestellte Skala, die die Bereitschaft für Umweltschutz mithilfe von Meinungsäußerungen und Verhaltensselbstberichten misst, tatsächlich flexibel hinsichtlich der Item-Kompilation (Altersgruppe, Umwelt, Kultur sowie Fragebogenlänge) sein, dann sollte sie neben einer soliden Güte auch einen Einstellungs- und Wissenszuwachs verzeichnen können. Vorherige Studien zum Cooper Center nutzten zwar verschiedene Skalen (vor allem 2-MEV und NEP), die nach Teilarbeit C ohnehin ein ähnliches Konstrukt zu messen scheinen, jedoch konnten stets Einstellungs- und Wissenszunahmen verzeichnet werden. Das Cooper Center ist daher ein umweltbildungsrelevanter außerschulischer Lernort, durch den Änderungen der Einstellung antizipiert werden können. Das sollte die Skala aus Teilarbeit D ebenso abbilden können. Ferner wurde wie in Teilarbeit C erwähnt ein repräsentativerer Wissenskatalog eingesetzt, der nicht nur System-, sondern auch Handlungs- und Effektivitätswissen beinhaltet und sich einer Evaluation unterzieht.

Die Rasch-kalibrierte Einstellungsskala zeigte trotz der in Anbetracht zu Studie D gekürzten Item-Zahl eine geeignete Güte mit einer zu erwartenden Item-Verteilung hinsichtlich der Verhaltenskosten. Die Skala konnte Einstellungsänderungen infolge der Programmpartizipation verzeichnen sowie den Einfluss der Einstellung auf den Wissensstand und -zuwachs vor allem durch die Integration von Handlungs- und Effektivitätswissen bestätigen: Umso höher die Umweltschutzpräferenz – ergo die Umwelteinstellung – umso mehr Umweltwissen zeigten die Schüler:innen vor und nach dem Lehrprogramm und umso mehr Umweltwissen wurde im Laufe der Intervention hinsichtlich System-, Handlungs- und Effektivitätswissen erworben.

Das Potenzial des Lehrprogramms wurde erneut und diesmal mithilfe eines umweltbildungsrelevanteren Wissenskomplexes abgebildet. Außerdem scheint die in Teilarbeit D konstituierte Skala tatsächlich Einstellungsänderungen abbilden und losgelöst von einer fixen Item-Zahl konträr zu den Empfehlungen gängiger Einstellungsinstrumente flexibel eingesetzt werden zu können. Hierbei können der Umgebung, der Altersgruppe und dem Forschungsziel folgend meinungsbasierte Items und Verhaltensselbstberichte aus einem Pool zusammengestellt werden, um Restriktionen der Zielgruppe zu honorieren. Fragen nach Autofahrten und Haushaltseinkäufen sind z.B. erst mit entsprechendem Alter sinnvoll. Dennoch sind (Interstudien-) Vergleiche möglich, wobei für eine solide Reliabilität eine Mindestzahl von 14 Items empfohlen wird.

3.6 Schlussfolgerung und Ausblick

Zuerst wurde die Umwelteinstellung als sinnvolle Einflussgröße zur Ableitung von Fördermaßnahmen für Umweltschutzverhalten im Schulkontext herausgestellt. Infolge der Teilarbeiten wurde dann ein Messstandard vorgestellt und anschließend in einer praktikablen, gekürzten Version erfolgsversprechend eingesetzt. Obgleich diese Skala weiterer Validierung bedarf, stellte sie deutlich das Potenzial außerschulischer Lernorte für die Umweltbildung dar.

Das Potenzial außerschulischer Lernorte zeigte sich durch Wissens- und Einstellungszunahmen. Der Wissenszuwachs wurde mit der Ergänzung des Systemwissens durch Handlungs- und Effektivitätswissen durch höhere Korrelations- und Regressionswerte in Relation mit der Einstellung umso prägnanter. Dabei wurde die Synergie beider Variablen deutlich: Der Umweltwissenserwerb wurde durch die Einstellung statistisch signifikant beeinflusst, wodurch sich die lernförderliche Rolle der Einstellung abzeichnete. Umso höher die Einstellung, umso mehr Wissen besaßen die Schüler:innen vor und nach dem Besuch außerschulischer Lernorte und umso stärker war der Wissenszuwachs vor Ort. Wird wiederum die Einstellung durch den Besuch dieser Lernorte geschärft, kann von entsprechenden Wissens- und Verhaltenssteigerungen ausgegangen werden. In Folgestudien sollen die exakten Parameter der Einstellungsschärfung untersucht werden, wobei die Literatur auf die Alltagsnähe, Relevanz und Exemplarität der Lerngegenstände sowie auf die Handlungsorientierung und Schüler:innenzentrierung hinweist (z.B. Gerber et al., 2001). Weiterhin zeigten außerschulische Lernorte, die in den Schul- und Alltag integriert wurden oder als Schulfahrt eine Hinführung und Abrundung vor Ort umfassten, größere Lernerfolge.

Damit ergeben sich Lehrempfehlungen 1) für den Besuch und die kontextuelle Einbettung außerschulischer Lernorte, 2) für die bewusste Einbindung der Einstellungsschärfung sowie 3) für die Integration der drei Umweltwissensdomänen (System-, Handlungs- und Effektivitätswissen) in Lernzielen. Beim Wissen empfiehlt sich eine sukzessive Progression mit einer Einführung von Systemwissen und folgender Elaboration von Handlungsmöglichkeiten (z.B. durch Diskussionen, Ideennetze, Rollenspiele, Gruppenpuzzle: Tilbury, 1995) und deren Effektivität.

Ferner wurde eine altersbezogene Kurve abgebildet, wonach die Einstellung bis zwölf Jahre steigt und über das Jugendalter absinkt. Hierin sind Folgestudien nötig, um am Alter ausgerichtete curriculare Empfehlungen zu formulieren. Dafür soll die Skala aus Teilarbeit D an der Biosphäre 2 durch den nuancierten Einsatz von Meinungsäußerungen und Verhaltensselbstberichten mit Nachtests einige Wochen infolge der Intervention genutzt werden, sodass Wissens-, Einstellungs- und Verhaltensänderungen besser gefasst und die Lehre modifiziert werden kann – um letztlich das Potenzial außerschulischer Lernorte für Umweltbildung besser auszuschöpfen.

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5 Teilarbeiten

Im Folgenden werden zunächst die fünf Teilarbeiten gelistet. Daraufhin wird der Eigenanteil der jeweiligen Arbeiten dargestellt und von den Manuskripten in ihrer Originalfassung gefolgt.

5.1 Publikationsliste

A. Baierl, T.-M., Bonine, K., Johnson, B., & Bogner, F. X. (2021). Biosphere 2 as an informal learning platform to assess motivation, fascination, and cognitive achievement for sustainability. *Studies in Educational Evaluation*, *70*(5), 101061. https://doi.org/10.1016/j.stueduc.2021.101061

B. Baierl, T.-M., & Bogner, F. X. (2021). Plastic pollution: Learning activities from production to disposal – From where do plastics come & where do they go? *The American Biology Teacher*, *83*(5), 308-312. https://doi.org/10.1525/abt.2021.83.5.320

C. Baierl, T.-M., Johnson, B., & Bogner, F. X. (2021). Assessing environmental attitudes and cognitive achievement within 9 Years of informal earth education. *Sustainability*, *13*(7), 3622. https://doi.org/10.3390/su13073622

D. Baierl, T.-M., Kaiser, F. G., & Bogner, F. X. (2022). The supportive role of environmental attitude for learning about environmental issues. *Journal of Environmental Psychology, 81*(2022), 101799. https://doi.org/10.1016/j.jenvp.2022.101799

E. Baierl, T.-M., Johnson, B., & Bogner, F. X. (2022). Informal earth education: Significant shifts for environmental attitude and knowledge. *Frontiers in Psychology, 13*(819899). https://doi.org/10.3389/fpsyg.2022.819899

5.2 Darstellung des Eigenanteils

Die Ausführungen sind in die fünf Teilarbeiten gegliedert. Ferner können Details zu aus der Literatur entnommenen Skalen den Teilarbeiten und Gliederungspunkt 3.4.2 entnommen werden.

Für **Teilarbeit A** wurde zusammen mit meinem Doktorvater ein Fragebogen konzipiert. Dieser umfasste zwei publizierte Skalen (*Science Motivation*: Glynn et al., 2011; und *Fascination with Science*: Otto et al., 2020) sowie eine Wissensskala, deren Fragen zudem mit Prof. Bonine abgestimmt worden waren, insbesondere im Hinblick auf den curricularen Abgleich mit den *Next Generation Science Standards* (2013). Die Datenerhebung an der Biosphäre 2 wurde unter Mithilfe des lokalen *Education*-Teams von mir durchgeführt. Die statistischen Analysen, deren Interpretation und Verschriftlichung erfolgten in Zusammenarbeit mit meinem Doktorvater.

Die in **Teilarbeit B** vorgestellte Unterrichtseinheit wurde von mir konzipiert. Die darin enthaltenen Experimente wurden mit Studierenden der Universität Bayreuth zur Optimierung durchgeführt. Übernommene Elemente von online verfügbaren Materialien wurden entsprechend gekennzeichnet. Das Manuskript wurde von mir als Erstautorin verfasst und von meinem Doktorvater angeglichen.

Der Datensatz für **Teilarbeit C** wurde von Prof. Johnson bereitgestellt, da aufgrund der Covid-Pandemie entgegen ursprünglicher Pläne keine neuen Daten erhoben werden konnten. Die statistischen Analysen, deren Interpretation, Visualisierung und Verschriftlichung inklusive der Diskussion wurden von mir als Erstautorin unter Supervision meines Doktorvaters durchgeführt. Prof. Johnson sorgte für die korrekte Integration situationeller Gegebenheiten der Datenerhebung und stellte die sprachliche Korrektheit des Manuskriptes sicher.

Die Grundlage von **Teilarbeit D** bildeten vier in anderen Kontexten bereits publizierte Datensätze, die im Rahmen einer Sekundäranalyse für darüber hinausgehende Forschungsfragen herangezogen wurden. Die Datenanalyse erfolgte in enger Zusammenarbeit mit Prof. Kaiser, um dessen Campbell Paradigma ohne Brüche zu folgen. Sämtliche statistische Analysen und deren Visualisierung sowie die Verschriftlichung des Erstentwurf wurden von mir übernommen.

Der Datensatz von **Teilarbeit E** wurde wie bei Teilarbeit C von Prof. Johnson bereitgestellt. Das Manuskript (statistische Analysen, deren Visualisierung, Interpretation und Verschriftlichung) wurde von mir als Erstautorin unter Supervision meines Doktorvaters eigenständig verfasst. Prof. Johnson übernahm erneut die sprachliche Anpassung.

5.3 Teilarbeit A

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Biosphere 2 as an informal learning platform to assess motivation, fascination, and cognitive achievement for sustainability

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ABSTRACT

Educational outreach facilities provide unique opportunities to learn sciences at the forefront of research. An example is Biosphere 2, a site of environmental and ecological research, which is coupled to Education for Sustainable Development (ESD). Research facilities can evoke the relevance of sciences in everyday life. This is important in secondary schooling to increase students' engagement in sciences, while environmental challenges continue to expand. We therefore examined the role of fascination and motivation on learning with 5th to 12th grade students who participated in a half- to full-day on-site education program. Our data confirmed the construct of fascination through Rasch and factor analysis, revealed substantial knowledge gains, showed effects of motivation and fascination on knowledge scores, and suggested that authentic learning enhanced science engagement. Results further indicated that both instruments measure an analogous construct, while motivation appeared to have more predictive power on cognitive achievement.

1. Introduction

Current economic and social challenges such as global warming render Education for Sustainable Development (ESD) indispensable (Bascopé, Perasso, & Reiss, 2019). Key aspects target biology education and pertain to environmental protection, health promotion, or sustainable urbanization (UNESCO, 2005). In general, ESD aims to unify preservation of nature and human development so an anthropocentric perspective does not dominate an ecological one (Kopina & Meijers, 2014), and it builds on knowledge, attitude, and skills (Amran, Perkasa, Satriawan, Jasin, & Irwansyah, 2019). Attitude reflects a person's evaluation of and affection towards an object or matter (Ajzen & Fishbein, 1977; Eagly & Chaiken, 1993) and points at the "probability of recurrence of behavior forms of a given type or direction" (DeFleur & Westie, 1963, p. 21). Attitude is thus crucial to engage in science and to integrate conceptual ideas into everyday experiences, so learning becomes more meaningful and knowledge beneficial in everyday life, including decisions for a more sustainable lifestyle. Attitude thus reflects the intensity and quality of student involvement through behavioral (intrinsic motivated action), affective (utility aspects of a task), and cognitive (expansion of perception, which is understanding concepts in new ways) aspects (Pugh, Linnenbrink-Garcia, Koskey, Stewart, & Manzey, 2010). The recently developed Fascination with Science scale (Otto et al., 2020) covers those areas to analyze and promote student engagement for deeper science learning. ESD programs should consequently incorporate student engagement through experiential and inquiry-based learning and allow knowledge acquisition and application in meaningful learning environments related to real-world problems (OECD, 2013; UNESCO, 2005). ESD integrates aspects of the Responsible Research and Innovation (RRI) EU policy agenda (Tassone, O'Mahony, McKenna, Eppink, & Wals, 2018). RRI aims at responsible science education through merging innovative research and traditional education to address sustainability challenges; key aspects of RRI are authenticity and novelty (Tassone et al., 2018).

ESD and RRI are embedded in Biosphere 2 (B2), which interlinks earth systems, human progress, and sustainability driven research. B2 is thus an ideal platform to investigate science learning (environmental knowledge gains) and student engagement (assessed through the Science Motivation scale [SMOT] and Fascination with Science scale [FS]) to promote a more sustainable lifestyle in an authentic context, which is

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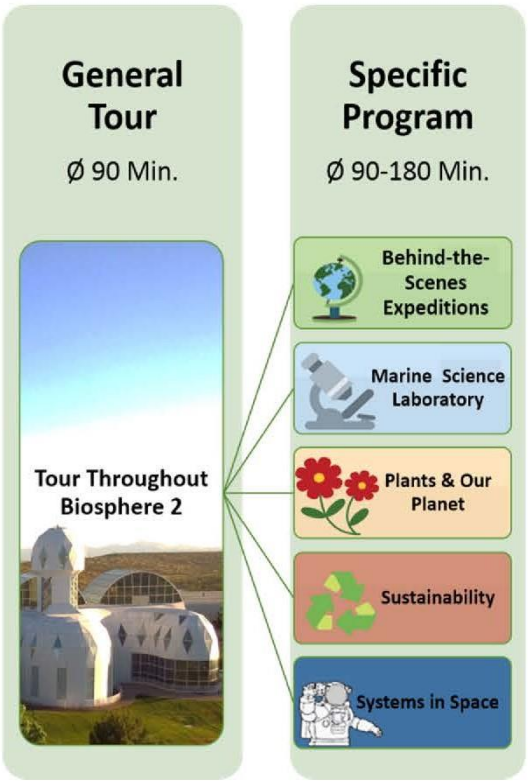

Fig. 1. B2 K-12 education program overview; after an interpretive tour throughout the facility, which allows an insight into the mechanical technosphere, the human habitat, and the five biomes (tropical rainforest, ocean, mangrove wetland, savanna, and fog desert), the students focus on one or two preselected topic(s) and work through educational lab or field stations.

too often neglected in the traditional classroom. Informal learning environments show promising potential to foster science motivation (e.g., Nugent et al., 2015); although the SMOT has been validated cross-culturally and applied for informal settings (e.g., Salta & Koulougliotis, 2015; Schumm & Bogner, 2016), we encountered no study on motivation changes as the result of a short-term informal educational program. In this research, we were interested in how motivation affected knowledge gains and how motivation changed after a B2 program. We first introduce B2 and place it in the science education context. Then, we define the constructs of measurement (motivation and fascination), introduce scales for assessment, and relate them to the B2 educational programs. To our knowledge, this is the first study to validate the Fascination with Science scale, and to relate it to the Science Motivation scale. For drawing conclusions on the scales and knowledge gains, we chose a nomothetic approach to include representative numbers of secondary schooling grades (Rickinson, 2001).

1.1. Research and education at Biosphere 2 (B2)

B2 in the Arizona desert was designed in the 1980s to emulate the Earth's ecosystem - called Biosphere 1 - within a sealed glass and steel structure. The goal was to implement research on reconstructing ecosystems and potentially sustaining human colonization elsewhere in the solar system (Walter & Lambrecht, 2004; Weyer et al., 2000). Since the mid-1990s, the B2 mission shifted increasingly towards ecosystem and environmental research, science education, and public outreach (Biosphere 2 [B2], 2019). Scientists from various disciplines cooperate to investigate topics such as the effects of climate change by introducing resilient corals or algae-consuming herbivores in its 2.5 million liter research ocean. As a large-scale laboratory, B2 allows scientists to change parameters selectively, simulate current or future global conditions, estimate ecosystem-scale responses, and contribute to development of feasible solutions.

Based on B2's unique infrastructure, the K-12 half- or full-day educational programs integrate the ongoing research and thus focus on earth systems and solutions for a sustainable future (B2, 2019). At the beginning of each field trip, students experience a 90-minute tour throughout the facility; they learn about the five study biomes, the research conducted in each, and the original closed-system design. Then, the students engage in one or two of five education programs (Fig. 1), which are in alignment with the Next Generation Science Standards (NGSS Lead States, 2013), based on lab or field stations, and involve inquiry-based and hands-on activities to create meaningful science learning. B2 educators designed and modified the programs to meet the students' requirements and to enhance learning. (1) Behind the Scenes Expeditions allows students to collect and compare data across the biomes, including temperature and salinity, and introduces them to ecosystem services such as regulating services of a forest. (2) Marine Science Laboratory dives into the ocean-biome by elaborating on marine food webs, effects of climate change like ocean acidification (e.g., experiment to acidify water through CO_2 and its effects on calcifying organisms), and viable solutions on an individual or global level. (3) Plants & Our Planet reviews basic curricular requirements like photosynthesis by comparing plant samples collected in different biomes with distinct environmental pressures (e.g., tropical rainforest vs. desert biome). Students first draw conclusions on a macroscopic level (e.g., surface-ratio) and then compare their samples on a microscopic level (e.g., stomata distribution). (4) Sustainability introduces the main concepts of plastic pollution and hydrology, allows students to reflect upon their own behavior, and prompts environmentally friendly solutions (e.g., strategies to save water or avoid single-use plastic items). The newest program, (5) Systems in Space, revives elements of B2's original vision and allows students to immerse in space research by discussing self-sustaining units and linking technology with ecology. All programs share the goals of encountering the unique B2 research approach, of empowering students by making them feel part of a larger science enterprise, and of imparting sustainability concepts where the natural environment goes hand in hand with human development. Some photographs of learning stations are in the appendix (Figs. A1–A5).

1.2. B2 as an informal learning environment

Informal learning is all learning that occurs outside the traditional classroom setting, including everyday experiences such as discussions at home and designed settings like museums (Bell, Lewenstein, Shouse, & Feder, 2009). The term acknowledges that learning develops from multiple experiences and is cumulative, holistic, and dynamic (Gerber, Marek, & Cavallo, 2001). Outreach learning forms a subset of informal learning; it comprises all activities for which external institutions reach out to schools to prompt motivation towards the STEM domain by providing authentic learning opportunities (Vennix, den Brok, & Taconis, 2017). It includes field trips to research facilities like B2 and aims at embedding the curriculum in real-world sciences (Sacco, Falk, & Bell, 2014). Informal approaches are recognized to foster deeper learning because awareness of STEM in daily life encourages motivation, cross-links system knowledge (Kyndt et al., 2013; Potvin & Hasni, 2014), and enables cognitive and affective learning alike (Gerber et al., 2001). Structured informal learning programs show growing evidence of their potential in promoting interest in science (careers) (Nugent et al., 2015). As such, research facilities like B2 provide a contextualized, practical approach to sciences in alignment with ESD. We therefore chose to investigate the effects of the B2 on-site education programs on motivation, fascination, and environmental knowledge.

1.3. Construct of science motivation

Motivation is an indicator for the quality of learning and ESD (Nieswandt & Shanahan, 2008; Savelsbergh et al., 2016). While motives form a rather stable part of our belief system (Zimbardo & Gerrig, 2003), motivation is temporary and can be evoked and sustained by single activities (Potvin & Hasni, 2014). Motivation is a construct to identify the intention, persistence, and quality of attention regarding situational learning and single tasks (Brophy, 2004). It contributes to the amount of energy (e.g., implementing strategies, focusing attention) students expend in activities and overall learning (Glynn, Taasoobshirazi, & Brickman, 2007). Developing motives and motivation for immersion in science is individual and based on experience. Therefore, a growing number of outreach facilities aim to engage students in science in an authentic learning environment (Laursen, Liston, Thiry, & Graf, 2007).

To understand the decline in science motivation among American students, Glynn, Brickman, Armstrong, and Taasoobshirazi (2011) designed the Science Motivation scale (SMOT) based on five domains: Intrinsic Motivation, Self-determination, Grade Motivation, Career Motivation, and Self-efficacy. According to them, grade and career motivation focus on extrinsic motivation through the short-term goals of grades and the long-term goals of career choices. The scale's underlying social cognitive theory (Bandura, 1986) refers to grade and career motivation not only as extrinsic motivators (e.g., approval or money) but also as intrinsic ones such as self-efficacy, thus linking the SMOT categories. There is no clear line between intrinsic and extrinsic motivation (Pelletier, Tuson, Green-Demers, Noels, & Beaton, 1998); both are dynamic and merge at a certain point. This is the case when extrinsic motivation is internalized so it becomes congruent with one's values (Ryan & Deci, 2020). In the scope of this paper, we rely on the definitions from Glynn et al. (2011) and use their tool. Note that they express tendencies and overall assumptions for each category. According to them, intrinsic motivation focuses on personal interest, curiosity, enjoyment, and an internal drive to succeed. Derived from Deci and Ryan (1985), self-determination refers to the students' perception of being able to control learning, is crucial to feeling autonomous, and, therefore, essential to overall motivation. High self-efficacy indicates the competence to carry out and to accomplish tasks through a student`s perceived ability to organize and implement behavior as students are more likely to learn and succeed if they believe they can achieve the desired outcome (Bandura, 1991; Stajkovic & Luthans, 2003; Velayutham, Aldridge, & Fraser, 2011). A person is more likely to pursue a career if there is confidence in one's abilities. In a meta-analysis, self-efficacy was among the strongest influencers of academic achievement across grade levels and disciplines (Nugent et al., 2015; Richardson, Abraham, & Bond, 2012). Although there are five SMOT domains, all of them interact to capture motivation.

1.4. Construct of fascination with science

Fascination provides a new perspective on student engagement in science to promote deeper learning and axiomatically relates attitudinal and behavioral self-reported statements within the Campbell paradigm. Fascination is a construct of three main competencies, namely Identification with Scientific Enterprise, Interest and Excitement, and Participation (Otto et al., 2020). These competencies originate from Rosenberg and Hovland's (1960) attitude model, which builds on cognitive, affective, and behavioral indicators. Those indicators, though, have limited relevance for overt behavior, as the distinction between indicators and their responses is merely linguistic, rendering the relationship circular (Kaiser & Wilson, 2019). Such a circularity was also ascribed to the Campbell paradigm and probably restricted its application in attitude research. Circularity means that attitude derived from behavioral indicators would mainly explain the same behavior the attitude was derived from, so they were identical to the empirically assessed indicators. As a solution, there can be a clear line between indicators (verbal expressions) and consequences (actual behavior). Attitude is then defined through a set of manifest indicators (e.g., evaluative statements, behavioral self-reports) and distinct from its consequences through a temporal or logical separation. Following this approach, Otto et al. (2020) introduced the Fascination with Science scale (FS) and labelled its latent variables Cognition, Affection, and Behavior. Engagement in science is thereby reflected by showing (1) a willingness to develop skills, knowledge, or competencies, and expressing the importance of science (Cognition), (2) positive emotional reactions towards science (Emotion), and (3) a willingness to engage in extracurricular science activities (Behavior). All three variables share the aspect of volitional engagement with an absence of extrinsic rewards, which resonates with intrinsic motivation. The scale thus builds the construct of fascination trough the three components of Cognition, Emotion, and Behavior, while relying on the conceptual framework of the Campbell paradigm.

The Campbell paradigm frames the interplay between attitude and the difficulties (behavioral costs) involved to manifest an intention (Kaiser, Byrka, & Hartig, 2010). Inconsistencies between attitude and behavior (attitude-behavior gap) are thus mostly methodological and lie in the behavioral costs a person faces when performing an act such as time, money, situational difficulties, inconvenience, or social proscription, and this function of attitude and cost allows prediction of behavior. In other words, behavior is the arithmetic difference of a person's attitude level and the performative cost involved. In an educational setting, it implies the more a student is willing to engage (e.g., in experiments) the more fascination is prevalent. By assessing attitude this way, costs can be adapted to facilitate student performance.

The total Fascination scale consists of 84 items and seven subscales to measure STEM areas (science in general, technology, biology, astronomy, physics, chemistry, and geoscience). Each subscale comprises 12 items and the latent variables of Cognition, Emotion, and Behavior. For the scope of this paper, we focus on science in general as it goes well with the SMOT and covers main ideas of the B2 outreach programs such as feeling part of a scientific enterprise, and ESD, which targets cognitive, affective, and behavioral aspects. The items rely on evaluative statements and self-reported behavior.

1.5. Objectives of the study

Our study used the established SMOT and the recently developed FS to analyze program effects of the B2 informal education programs. We also validated the FS. In addition to knowledge, we investigated the effects of a sustainability oriented informal learning setting on fascination and motivation; existing literature lacks effects of short-term informal programs on both. Evidence of these effects would be crucial to derive recommendations for the growing number of education outreach facilities to engage students in sciences and educate them towards a more sustainable life. Our research questions were:

1) Can we confirm the FS through factor and Rasch analysis, and how does the FS relate to the SMOT?
2) What impact does a sustainability oriented informal learning program have on fascination, motivation, and knowledge?
3) How do the FS and SMOT affect knowledge scores in a multivariate context (age, and the frequency to talk about school at home)?

2. Methods and procedures

2.1. Participants

We administered the questionnaire to 227 5th to 12th grades before and after they participated in an educational B2 program (age: MS ± SD: 13.06 ± 1.01). Gender showed an almost even distribution with 35.7 % females and 30.4 % males; 1.8 % chose not to answer, and the remaining 32.2 % left the response field blank. 135 students provided information

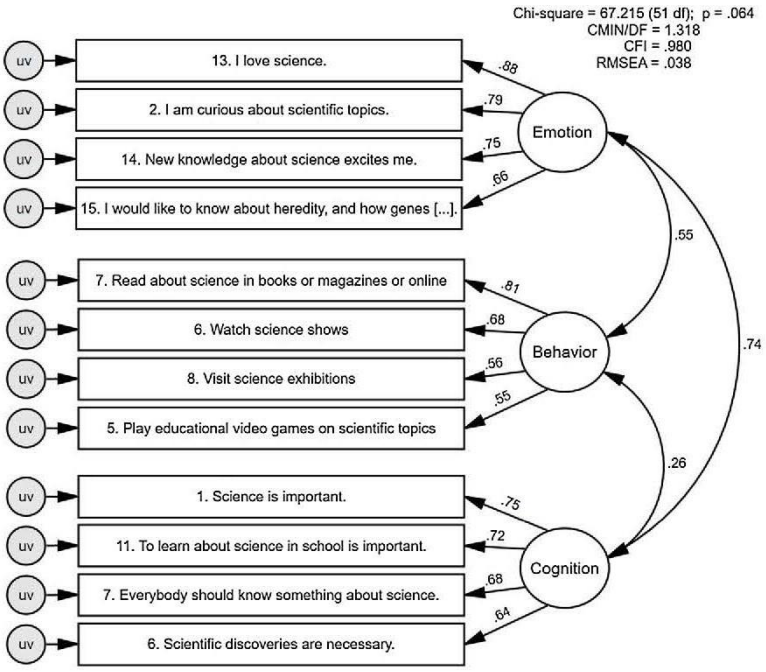

Fig. 2. CFA to estimate the construct Fascination with Science. The observed items in rectangles measure the latent higher order values in ellipses (Emotion, Behavior, and Cognition). Since each manifest variable is prone to unobserved parameters, the error terms (uv) outweigh disturbing effects and allow a more reliable measure of the true score. Item numbers indicate their order in the questionnaire.

about race/ ethnicity: 44.9 % White, 7.9 % Hispanic or Latinx, 1.8 % Asian, 1.3 % Native Hawaiian or other Pacific Islander, 0.9 % Black or African American, and 0.4 % American Indian or Alaska Native. The students completed the questionnaire a few days before or on the day of the field trip. Although school classes chose different programs (most participated in Sustainability and Ecosystem Services), they all experienced the main tour throughout the facility, and all programs share a similar outline and the underlying concepts of earth systems, environmental education, and sustainability.

2.2. Instruments

We used the modified Science Motivation scale (SMOT) of Schumm and Bogner (2016) with a five-point response pattern: strongly disagree, disagree, partially agree, agree, and strongly agree. Five items represent each latent higher order factor (Intrinsic Motivation [IM], Self-determination [SD], Career Motivation [CM], Grade Motivation [GM], and Self-efficacy [SE]), resulting in a 25-item scale (Fig. 3). We further used the Fascination with Science scale (FS), which comprises the three higher order factors Behavior (B), Emotion (E), and Cognition (C) with four items each (Fig. 2). All cognitive and affective items were grouped in one table with the same five-point scale for the SMOT. The behavioral section followed a different response pattern (never, seldom, sometimes, often, very often), introduced by the question "How often have you done this outside school?". We modified one behavioral item to meet the environment in Arizona: The local fauna (e.g., lizard) replaced the examples given in the original instrument (e.g., tusk).

We designed an ad-hoc knowledge scale. It assessed system knowledge, which comprises facts and fundamental concepts (Roczen, Kaiser, Bogner, & Wilson, 2014) (Six items cover cohesive knowledge and a general understanding of biological concepts such as nutrient cycling in ecosystems and aim at topic based misconceptions. This involves carbon uptake, which is often incorrectly considered to be absorbed through roots (Coley & Tanner, 2012). The remaining items test facts introduced during the general tour or included in all five programs. Every item allowed one correct answer resulting in an either correct (1) or incorrect (0) response, so each student could score up to 10 points.

2.3. Demographic questions

We included items to contextualize the student responses. In addition to age, grade, gender, and ethnicity, two items asked about the math and science grades on a five-point response scale (not so good, average, good, very good, or excellent). One item asked, "How often do you talk about things you learn at school with someone in your family?" and allowed the students to respond in a five-point pattern (never, once every few weeks, once a week, two or three times a week, or every day). Two items inquired about the parental education and provided six response options (He/ she did not finish high school, he/ she finished high school, he/ she got a vocational diploma, he/ she graduated from a community college, he/ she graduated from university, or I do not know).

Given that learning also occurs subconsciously in out-of-school contexts, we asked students how often they talked about things they learn at school with someone in their family. This social-contextual variable addresses whether school is integrated at home and, thus, whether this type of informal learning is provided. Informal science learning at home is associated with science fascination and values (Lin & Schunn, 2016). Family support can generally affect attitude towards science and career choices (Nugent et al., 2015) and induce internalized motivation (Grønhøj & Thøgersen, 2017). Parents play a key role in enhancing their children's motivation and self-efficacy concepts if sciences are acknowledged (Nugent et al., 2015; Ryan & Deci, 2020), as parent interest in formal and informal science settings and scientific topics induces personal relevance, which in turn fosters engagement in (complex) scientific topics (DiEnno & Hilton, 2005). Self-efficacy then affects learning and career choices, and parent-involvement enhances academic performance (Byrnes & Miller, 2007; Rickinson, 2001). Although we are aware that we cannot draw overall conclusions from one item estimating the frequency of talking about school at home, it

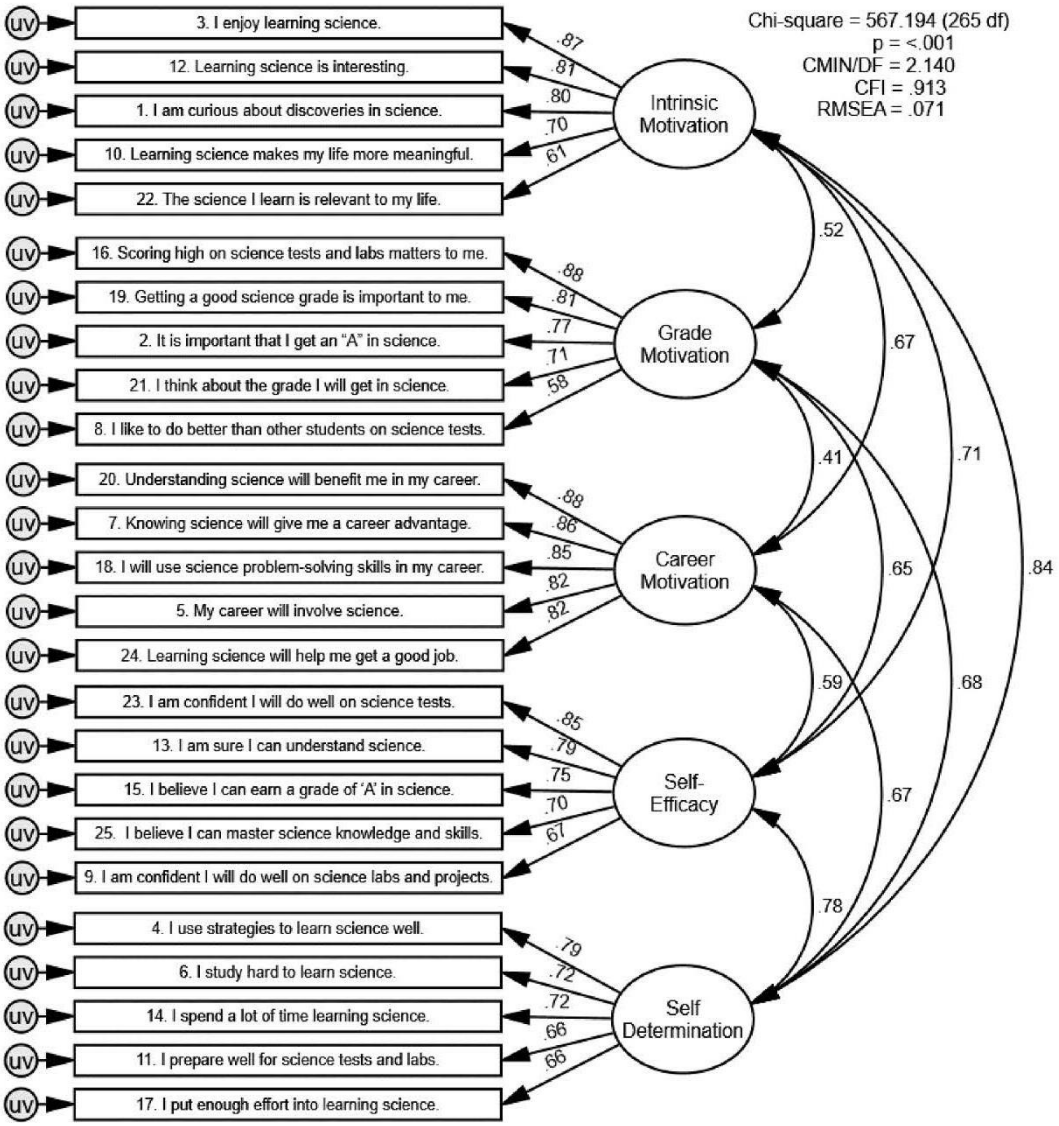

Fig. 3. CFA to estimate the construct Science Motivation. The observed items measure the latent factors Intrinsic Motivation, Grade Motivation, Career Motivation, Self-efficacy, and Self-determination. The error terms (uv) indicate all unobserved variables that are not represented in the model but affect the measurement; they isolate the true score of the measured variable from the error term. Item numbers indicate their order in the questionnaire.

covers an aspect of informal learning that might relate to fascination, motivation, and cognitive achievement, while it would be relatively undemanding for parents to realize at home.

2.4. Statistical analyses

Factor analysis is the recommended technique to investigate a scale's dimensionality by correlating the observed variables to form categories or latent factors. It partitions raw scores and classifies the items to form dimensions, whereas the one-dimensional Rasch analysis can construct interval measures (Linacre, 1998) and help rate the data (Maydeu-Olivares, Cai, & Hernández, 2011). A Rasch analysis positions individuals and items on a continuum (items perceived least to most difficult in a hierarchical order) and computes a person parameter for each individual (probability of engagement, labelled as logit). For attitude, logits thus indicate the degree of endorsement, how likely a person is to engage in or agree with a statement. The factor and Rasch analysis can be applied for the same measurement tool and even complement each other (Linacre, 1998). In a first step, we assessed the quality of our instruments to investigate program effects and relate the variables in a multivariate context. The SMOT is traditionally factor analyzed, so we ran a factor analysis to test whether we can confirm the construct with our cohort. The factor analysis allowed us to investigate program effects on each subscale, as they form distinct categories of motivational forces (e.g., external grade motivation vs. intrinsic motivation), which delineates profile pictures (e.g., strengths in some and weaknesses in other areas) to develop learning activities accordingly. In contrast, Otto et al. (2020) designed the FS for a Rasch model. Yet the FS is split into cognitive, emotional, and behavioral items, indicating multidimensionality, which would become apparent with factor analysis. To assess the quality of the FS, we thus ran both a factor and a Rasch analysis to further investigate (1) the better statistical analysis technique for the recently developed tool and (2) possible contributions of each analysis to ESD program development. For scale validation, we ran the attitude analyses with the

pre and post data. Since both yielded identical results, and since we ultimately investigate the post program attitude effects on knowledge scores, we only report the post score analyses.

For basic analyses, we used nomothetic, non-parametric tests of the Statistical Program for Social Sciences (SPSS, 24 version) as our data were not normally distributed. These included McDonald's Omega reliability scores, Spearmann correlations, and Wilcoxon tests to determine program effects in a pre-post comparison. A power analysis showed that our sample size was sufficient to conduct such analyses (power of .96, which is above Cohen's (1992) threshold of .8). We factor-analyzed the SMOT and FS using oblimin rotation, since we expected interrelations among the manifest and latent variables (Costello & Osborne, 2005; Field, 2013). We further used IBM SPSS AMOS 24 (Analysis of Moment Structures; Arbuckle, 1997) to calculate confirmatory factor analyses (CFA), to relate the SMOT and FS, and to assess the effects of those on knowledge scores through path modeling in a multivariate context. All AMOS figures display standardized values and rely on the Maximum Likelihood Solution. We lacked some information due to misprints of the questionnaire for one school group, so we used Little's Missing Completely at Random Test, which was not significant ($\chi^2 = 881.872$, df = 864, $p = .329$), and therefore used data imputation for estimating the missing scores. In Figs. 2, 3, 6 and A7, single-headed arrows represent regression weights, while double-headed arrows estimate correlations (Arbuckle, 1997). We reported absolute and incremental fit indices to estimate the adequacy of our postulated model. Hooper, Coughlan, and Mullen (2008) recommend reporting the Chi-Square, the degrees of freedom, the *p*-value, the Root Mean Square Error of Approximation (RMSEA) as an absolute index, and the Comparative Fit Index (CFI) as an incremental index. Good models show a low Chi-Square (χ^2) in relation to the degrees of freedom with a non-significant *p*-value. Since the χ^2 is sensitive to sample size and assumes multivariate normality (Hooper et al., 2008), we focused on the relative χ^2 (CMIN/DF), which adjusts for sample size and should be less than 5.0 (Wheaton, Muthén, Alwin, & Summers, 1977). The CFI threshold is .9, and the RMSEA should be lower than .07 while values below .03 indicate excellent fit.

To analyze fascination and knowledge, we used the dichotomous Rasch model (for a full account, see Wilson, 2005). The probabilistic Rasch model, used for the FS by Otto et al. (2020), describes the probability of engagement and thereby creates a hierarchical order of items regarding their difficulty. This model combines the person parameter (number of items answered correctly) and item difficulty (number of people who answered the item correctly) to one score (logit) (Bond & Fox, 2010). Item difficulties reflect the cost (e.g., time, money, or inconvenience) a person faces when performing an act (Kaiser et al., 2010). For the FS and depending on infrastructure, it is, for example, less costly to watch a science show on television than to visit a science exhibition (less money and time spent to drive to the exhibition and pay for entrance), so we would expect more people to engage in watching science shows on television. This methodological approach resonates with DeFleur and Westie's (1963) attitude definition, who point at the frequency of performance. The Rasch model has the capacity to evaluate the functioning of items, identifying biased and redundant items (Bond & Fox, 2007). A logit indicates the probability to answer to increasingly demanding performances positively and thus represent a person's disposition. The higher the score, the higher the performance level (here: fascination or knowledge level). The model thus positions participants on a continuum regarding their fascination or knowledge level and computes a logit (person parameter) for each participant. We used ConQuest Joint Maximum Solution to conduct the analysis (Adams & Khoo, 1996). This way, missing data is of less concern as the Rasch model summarizes missing observations and relates them to their expectations (Wright & Masters, 1982). We dichotomized the five-point responses to 0 (strongly disagree, disagree, partially agree, or never, seldom, sometimes), and 1 (agree, strongly agree, or often, very often), which is a justified approach in attitude research to prevent excessive measurement error (DeCoster, Iselin, & Gallucci, 2009).

3. Results

3.1. Quality of the instruments

An exploratory factor analysis (EFA) of the FS in SPSS yielded three subcategories. Pairwise exclusion resulted in $n = 155–198$ because the tables of one group ($n = 41$) were cut due to some misprinting, so some students could not answer all items. The Kaiser-Meyer-Olkin measure of sampling adequacy (.846) was high and the Bartlett-test of Sphericity significant ($p < .001$) (Cleff, 2015; Field, 2013). Variances were above Urdan's (2010) criteria of 10 % with Emotion explaining 39.46 %, Behavior 15.51 %, and Cognition 11.15 % of the variance, which resulted in 66.11 % total variance. McDonalds Omega (ω) estimates the reliability and was good for both scales (FS: ω = .862, and SMOT: ω = .952; Hayes & Coutts, 2020).

The CFA in AMOS revealed similar results with good model fit indices for the FS and acceptable ones for the SMOT (Figs. 2 and 3). The internal structure of both instruments reflected the original constructs and high internal consistencies. If we substitute the last item in the FS Emotion subset ("Science is fascinating") by an Emotion item from the Fascination with Biology scale ("I would like to know about heredity, and how genes influence how humans develop"), fit indices and reliabilities considerably increase. The original indices were $p = <.001$, CMIN/DF = 2.531, CFI = .978, and RMSEA = .078, and indices based on our item substitution are illustrated in Fig. 2. Since the factor analyzed structure of the SMOT has been confirmed several times cross-culturally (e.g., Glynn et al., 2011; Salta & Koulougliotis, 2015; Schumm & Bogner, 2016), and based on the relations among the observed items and latent factors, which represented the predicted structure with our cohort, we only report construct validity and invariance tests of the FS. Construct validity builds on convergent and discriminant validity (Hair, Black, Babin, Anderson, & Tatham, 2006). For convergent validity, factor loadings should be above .5 for sample sizes exceeding 100 (Stevens, 2002). Alternatively, the Average Variance Extracted (AVE), which is calculated by dividing the sum of squared factor loadings by the number of items, should surpass .5 (Hair et al., 2006). Emotion provided good convergent validity (.60), whereas Behavior and Cognition were just below the threshold (B = .44, and C = .49), implying that they related moderately to measure the same construct. Discriminant validity tests if the latent factors deviate sufficiently to form separate categories and is calculated by the square root of the AVE (E: .77, B: .66, and C: .70), which should exceed the correlation among the latent variables. Behavior clearly discriminated from Emotion and Cognition, while the latter were less distinct. For measurement invariance, we tested the CFA for males and females. Simultaneous fit indices indicated good configural invariance ($\chi^2 = 107.040$, df = 102, $p = .347$, CMIN/DF = 1.049, CFI = .990, RMSEA = .018), meaning both groups are equivalent in their factor structure. Imposing factor loading constraints for metric invariance ($\chi^2 = 115.481$, $p = .366$, CFI = .991, RMSEA = .017) suggested that all loadings were invariant across the groups (χ^2-difference test: $\Delta\chi^2 = 8.441$, Δdf = 19, $p = .982$). In summary, the EFA and CFA identified the three dimensions predicted by Otto et al. (2020), which showed an identical pattern of correlations with Emotion and Cognition relating strongest, and the FS produced promising fit indices; yet its construct validity is only moderate.

In line with the design of the FS (Otto et al., 2020), we also conducted a Rasch analysis. The person separation reliability (*rel*) estimates the ratio between actual performance (observed behavior) minus the mean square errors of those and the variance of behavior scores (Wright & Masters, 1982); its value was good (*rel* = .80; Mean Score [*MS*] = .27; Standard Deviation [*SD*] = 2.10). Item fit statistics were adequate with mean square infit values (MNSQ) from MNSQ = .63 to MNSQ = 1.21 ($MS \pm SD = .96 \pm .18$), so they are within the cut-off levels of Bond and Fox (2010), who suggest .6 at the lower and 1.30 at the upper end.

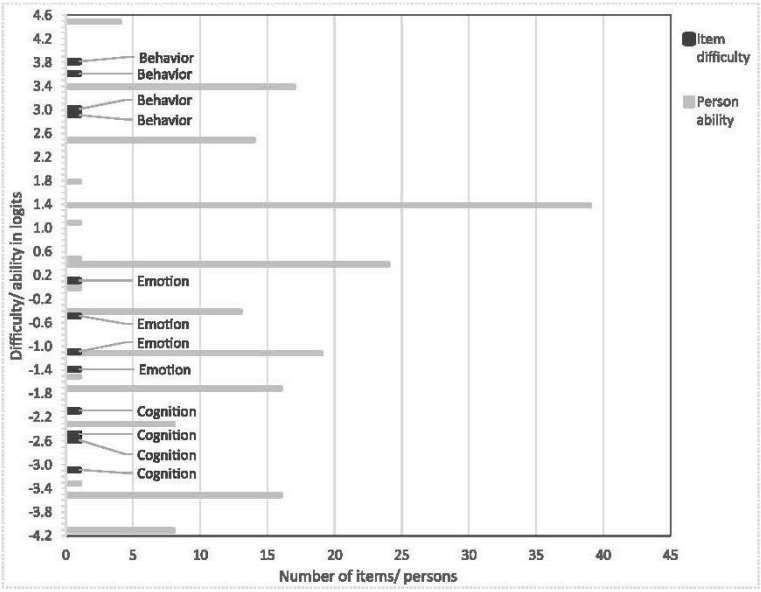

Fig. 4. Person item map of the Rasch analyzed FS. Lower item numbers indicate easier, higher numbers more challenging items, which means the higher the difficulty, the less likely the item is to be endorsed. Lower person parameters indicate less probability to engage in increasingly demanding items and vice versa; a person parameter of zero is equivalent to 50 % probability to engage in the behavior. The items of each latent factor are clustered together (Behavior, Emotion, and Cognition).

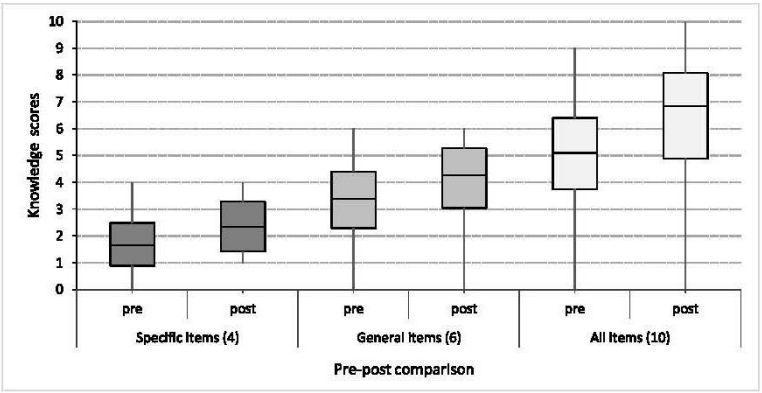

Fig. 5. The box plots illustrate knowledge gains for the specific, general, and all knowledge items in a pre-post comparison. The students could gain one point per question, so they could score four in the specific, six in the general, and ten points in the merged section. Horizontal lines indicate grouped median scores. Vertical lines depict minimum and maximum scores.

MNSQ indicate the discrepancy between the observed data and the model prediction. Ideally, they are close to 1.0 and have a narrow *SD* (e.g., $\leq .1$). MNSQ values above indicate more variation in item responses than the model predicted (underfit), whereas values below indicate less variation than the model predicted (overfit). Two items ("I love science", and "Science is fascinating") showed very little variation in their response pattern, whereas one item ("Scientific discoveries are necessary") revealed excessive variation in relation to the model prediction. This means that people with a high person ability for fascination (likely to engage in increasingly demanding fascination-related activities) disagreed with the item, while people with low ability scores agreed. Item difficulties (δ) ranged from $\delta = -3.13$ to $\delta = 3.84$ with the *MS* arbitrarily set at zero ($MS \pm SD = .00 \pm 2.63$) and aligned with a good distribution (Bortz & Döring, 2006; Linacre, 2004). The measurement thus hierarchically orders items according to their perceived difficulty. Ideally, person and item parameters are congruent, which means they cover an identical area on the y-axis of the person item map, which relates person ability (probability of engagement) and item difficulty scores (cost related to each item); this allows differentiating among participants and items. The 12 items cover a wide range of difficulties and person parameters but cannot differentiate well among the upper medium scoring students (Fig. 4). The latent factors of Behavior, Emotion, and Cognition cluster, while Behavior forms the costliest items, so they required most resources to be agreed with.

If the data align with the Rasch model, all variation can be explained by one dimension. This, in turn, means that all deviations indicate multidimensionality (Linacre, 1998). The lower validity in deviating infit scores (MNSQ, regarded as a local quality-control for local independence) did not absolutely conform with unidimensionality; however, different response types (via MNSQ) may reflect multidimensionality but are only of concern if the pattern strongly points at more dimensions (Wright & Stone, 1979). Except for the three items with slightly deviating MNSQ, the Rasch model revealed good fit indices and aligned with Otto et al. (2020). Consequently, both methodological approaches (factor and Rasch analysis) yielded good results, rendering both justified for the FS.

We analyzed knowledge with a Rasch model and merged the pre and post data for uniform calibration to investigate program effects. The

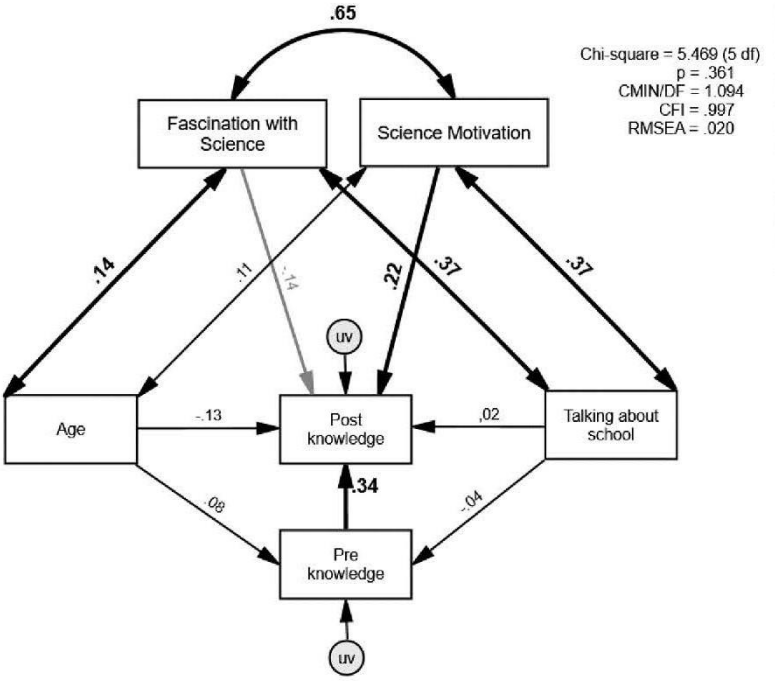

Fig. 6. Path model illustrating the relationships between the FS and SMOT, the pre and post knowledge scores, age, and the variable of how often students talk about school with someone in their family. Bold lines indicate significant regression weights (single-headed arrows) or correlations (two-headed arrows). The error terms or unobserved variables (uv) compensate for unobserved distractors and allow a more accurate measurement. Fascination and motivation highly correlate, and the stronger construct suppresses the regression weight of the other when pointing at the same variable. Therefore, the grey line indicates an artificially repressed score.

Table 1
Correlation matrix between the Fascination with Sience scale (FS), the Science Motivation scale (SMOT), and individual factors (how often the student talks about school at home, and science grades) in line with the path analysis model.

			Talk about school	Science grade	FS
Science Motivation	**SE**	*r*	**.323**	**.498**	**.485**
		p	.004	<.001	<.001
	CM	*r*	**.265**	**.244**	**.557**
		p	.001	.002	<.001
	GM	*r*	**.230**	**.390**	**.390**
		p	.004	<.001	<.001
	IM	*r*	**.355**	**.389**	**.621**
		p	<.001	<.001	<.001
	SD	*r*	**.305**	**.393**	**.613**
		p	<.001	<.001	<.001
Fascination with Science		*r*	**.367**	**.338**	/
		p	<.001	<.001	

Notes: SE Self-efficacy, CM Career Motivation, GM Grade Motivation, IM Intrinsic Motivation, SD Self-determination.
Bold value denotes significant values.

analysis ($n = 454$) revealed a fit range from MNSQ = .90–1.20 ($MS \pm SD = 1.00 \pm .09$), and neither infit nor outfit values suggested excessive under- or overfit. The person separation reliability was acceptable given the low number of items ($rel = .54$, $MS \pm SD = .27 \pm 1.13$); having few items generally impacts the reliability score. Item difficulties ranged from $\delta = -.99$ to $\delta = 1.22$ ($MS \pm SD = .00 \pm .65$) and corresponded with a good distribution (Bortz & Döring, 2006). The ten knowledge items cover a wide range of difficulties and allow drawing distinctions among the medium scoring students (Fig. A6, appendix); however, the scale differentiated less among the top or lowest scoring students. For our heterogeneous cohort, a few more difficult and very simple items would have been required to draw such distinctions, which would have further increased the reliability score.

3.2. B2 program effects

For the most part, we found increases from pre- to posttest for the FS, the SMOT, and their subscales, though none of them was statistically significant. We used the factor scores for motivation (IM: Z = −.439, GM: Z = −.311, CM: Z = −.175, SD: Z = −.145, SE: Z = −.167) and, additionally, Rasch logits for fascination (Z = −1.789), as *MS* would be biased because the real distances of Likert-type responses typically differ between items and latent factors. Looking at the *MS*, except of Behavior ($MS \pm SD = 2.45 \pm .05$), an improvement was unlikely due to a potential ceiling effect because the students had already scored high in the pretest with GM ($MS \pm SD = 4.31 \pm .05$) and Cognition ($MS \pm SD = 4.31 \pm .04$) scoring highest. Only Grade Motivation significantly decreased (Z = −2.825, $p = .005$).

There were significant knowledge gains with the 197 students who completed the full pre- and posttest, presuming that listwise exclusion displays the clearest results (Field, 2013). The students increased their scores in the four specific items to test facts (Z = −6.238, $p < .001$, d [effect size assessed with Cohen's d] = .414), the six general items to test understanding (Z = −5.540, $p < .001$, $d = .368$), and both categories merged (Z = −7.075, $p < .001$, $d = .469$). Table A2 (appendix) shows all items, their multiple-choice answers, *MS* with *SD*, and difficulty scores. For the box plot illustration (Fig. 5), we chose sum scores because Rasch analyses of only four or six items would not provide reliable outputs.

3.3. Relationships among fascination, motivation, and knowledge in a multivariate context

A simultaneous approach via path modelling allows adjusting all path coefficients without having to run and relate single analysis (Byrnes & Miller, 2007). This allowed us to position all relevant variables in one analysis. In line with literature, the first model (Fig. 6) relates the Rasch-analyzed FS and the factor analyzed SMOT while drawing relationships towards age, the variable talking about school at home, and knowledge scores. The strongest regression weight (b) is between the pre and post knowledge scores ($b = .34$, $p < .001$), and the highest correlation (r) between the FS and SMOT ($r = .65$, $p < .001$). Further relevant

correlations are with talking about school at home ($r = .37$, $p < .001$), and fascination with age ($r = .14$, $p = .045$). Only motivation showed a statistically significant effect on the knowledge score ($b = .22$, $p = .020$). In path modeling, with two identical constructs pointing towards the same variable, the stronger construct can suppress the weaker one and artificially repress its regression weight (Cheung & Lau, 2007). Therefore, the regression weight of fascination ($b = -.14$) is not significant and colored in grey. This became more apparent when we ran the analysis without the regression weight from motivation to knowledge. We ran another model with the FS factor scores (see Fig. A7, appendix). Correlations (e.g., between FS and SMOT: $r = .70$, $p < .001$) and regression weights were similar and fit indices slightly increased (CMIN/DF = 2.961, $p = .706$, CFI = 1.0, RMSEA = <.001). Improved fit indices might point at a factor analytical approach.

To further examine the AMOS relationships, we ran Spearman correlations with subsequent Bonferroni corrections. Those verified correlations between fascination, motivation, and contextual variables (Table 1). There were no considerable relationships with socio-economic elements like parental education.

4. Discussion

We split our research objectives into methodology and effects of the informal sustainability oriented B2 programs. We will first discuss the methodological results with the Fascination with Science scale (FS) having been successfully factor and Rasch analyzed to be then related to the Science Motivation scale (SMOT) in a multivariate context, with both tools strongly correlating. We will secondly discuss effects of the B2 educational programs, with knowledge gains being most prominent.

4.1. Construct of fascination with science and its relationship with the SMOT

We were able to conduct a factor and Rasch analysis for the FS. Exploratory and confirmatory factor analysis yielded the three latent factors proposed by Otto et al. (2020), which are Cognition, Emotion, and Behavior; those three factors were grouped on the person item map of the FS Rasch analysis. The correlations among the three latent factors were in line with the publication of the scale, which is Cognition and Emotion correlating stronger than with Behavior. For each of those, the general items (e.g., "I love science", and "Science is important") contributed more to the latent factor than specific ones (e.g., "Scientific discoveries are necessary") indicating evocation of personal relevance of sciences in daily life. For the behavioral items, reading about science and watching shows appeared more important than visiting exhibitions or playing educational games, which resonated with the item difficulties of the Rasch analysis; visiting exhibitions or playing educational games requires more resources or costs and is therefore less likely to be carried out. Reliabilities and fit indices were good for the factor analysis and increased to excellent when substituting one item from the Fascination with Biology subscale. The original item ("Science is fascinating") is similar to another item within the same subset ("I love science"), and the substitute ("I like to learn about the heredity […]") blends contextually in the science section. If the goal is to analyze fascination with science, it might be worth keeping the substitute for a more robust scale. The only weakness revealed the moderate construct validity with Cognition and Emotion correlating slightly too strongly and Cognition and Behavior deviating slightly too little.

To follow recommendations in the literature, we conducted a Rasch analysis for the FS. With respect to the low number of items, fit indices were good, and the item distribution covered a wide range of difficulties, which is a continuum of less to more demanding performances. Ideally, there would be some easier and moderately difficult items to differentiate between the lower and medium scoring students, which Otto et al. (2020) already observed, and which would increase the person separation reliability. The range of person parameters showed a large variance in fascination scores. Within our cohort, we thus had the full range of little to perfectly fascinated students. This is reasonable given our age-heterogeneous group and the trend of decreasing science engagement in adolescence (Rosenberg & Hovland, 1960). As stated within the publication of the scale, the three latent factors clustered with Cognition displaying the easiest and Behavior the most challenging items (Otto et al., 2020). Schneiderhan and Bogner (2020) confirmed such a distribution for the Fascination with Biology scale. This indicates that the students are aware of the importance of sciences and deem it necessary to learn about it; the discrepancy between emotions and behavior, however, may point at targeting affective and activity-based learning outcomes and engaging students in activities like experimenting by decreasing task difficulty (performance cost). Perceiving personal relevance is essential to learning sciences and – according to the Campbell paradigm – helps in overcoming performance difficulties (Kaiser et al., 2010). A lack of emotional attachment and performance opportunities, on the other hand, builds an impediment to science engagement (Otto et al., 2020).

Combining those findings, the factor and Rasch analysis seem appropriate for the FS. Choosing one methodological approach is less a question of dimensionality but more of the research purpose (Linacre, 2004), and the FS demonstrated that both approaches yielded promising results. Path modelling supported both approaches with very good fit indices and identical results (correlations and regression weights), regardless of whether we used the factor or Rasch scores. Both methods resonated in that they revealed the behavioral items to be those students engaged in least (high item difficulty), while the cognitive items were perceived least demanding. Such a cost-effectiveness-relationship is often a trade-off that can be facilitated by infrastructure or through education, in this case, ESD approaches. A factor analysis figures out latent variables by looking at item correlations. This may help analyzing profile pictures (e.g., research on multilevel regression analysis) to develop learning activities accordingly, while the Rasch analysis helps to further rate the data and specify on individual items.

In path analysis, we related the two attitudinal instruments in a multivariate context. The distinction between fascination and motivation is not sharp in the literature (see introduction), and the high correlation of both constructs displayed this overlap. Both instruments seem to measure a similar construct, or build on similar dispositions, although, for example, the FS asks for spare-time behaviors and the SMOT for school performance behaviors, while the latter more strongly emphasizes external motivators. Both, however, cover congruent ideas of emotion, cognition, and behavior with the SMOT providing more subscales. The correlation matrix with demographic variables confirmed this common ground; the items talking about school at home, science grades, and age correlate with the FS and SMOT alike. Both instruments have a positive effect on the knowledge score. When pointing identical constructs at the same variable, the stronger construct can overpower the other and artificially repress its regression weight (Cheung & Lau, 2007). Looking at the factor and the Rasch analysis, the FS appears to be a valid instrument, while the SMOT seems to be the stronger construct with more predictive power for system knowledge scores.

4.2. Program effects on fascination, motivation, and knowledge scores

We found no statistically significant changes for the FS or SMOT, probably owing to the ceiling effect (Pedhazur & Schmelkin, 1991), which has been revealed with the SMOT in previous studies (e.g., Dong, Li, Minstrell, & Cui, 2020), though many did not report mean scores of its subcategories. There seems to be a similar trend for the recently developed Fascination subscales (Otto et al., 2020; Schneiderhan & Bogner, 2020). With the exception of Behavior, the students scored high in the pretest, which makes considerable increases unlikely. According to the Campbell paradigm, behavioral activities require high costs, as they are time and energy consuming (e.g., visiting exhibitions) (Kaiser et al., 2010). We therefore anticipated the behavioral items to score

lowest, which corresponded with their difficulty level, Otto et al. (2020), and Schneiderhan and Bogner (2020). Another explanation for the weak program effects may lie in the constructs themselves. In some regards, both constructs measure stable motives instead of temporary motivation; motives are unlikely to change based on a half-day intervention, whereas motivation can be evoked by single activities (Zimbardo & Gerrig, 2003). A motive such as the need for achievement gives the direction of behavior (e.g., performing well at school), while motivation is a spontaneous stimulus to perform a task (e.g., solving a specific problem). The line between motives and motivation is blurry, but aspects of both instruments (e.g., career motivation, self-efficacy, and self-determination) point at stable motives. Self-efficacy reflects the perceived probability to succeed or fail, which is grounded in the motive to achieve success (Ajzen, 1991). The Campbell paradigm provides a similar explanation in other words: It deems attitude to be fairly consistent, while performative costs vary and more strongly influence behavior (Kaiser et al., 2010). Situational costs like task difficulty mediate between intention and performance, while attitudes change slowly (e.g., Cheng & Monroe, 2012). Further studies would be required to better identify the cause of our fascination and motivation scores. Consequently, to investigate effects of short-term informal education programs, there could be a methodological change (instruments clearly assessing motivation, or item difficulties adapted to the age group) or program modification (more intensive program that may include in class preparation and follow-up activities). We suggest that incorporating the B2 programs into classroom work would show stronger effects on fascination and motivation. Lessons are currently developed to embed the B2 programs in the traditional setting, and we aim at investigating their effects on knowledge and attitude.

One effect regarding grade motivation raised curiosity. Grade motivation provided the highest scores, which has been revealed with a slightly older school sample (Schumm & Bogner, 2016) and seems to be higher in lower grades (Salta & Koulougliotis, 2015), and which reflects the perceived importance of grades. In particular, 4th to 9th grade students learn for grades as they may feel a duty towards their parents or social pressure. Such extrinsic motivators prompt short-term learning and can interfere with deeper understanding (Stan, 2012). Thus, grades often reflect disciplinary power instead of profound insight and can result in indifference towards subjects or alienation of personal preferences (Stan, 2012), which would support the overall moderate effect of motivation on knowledge. In this study, grade motivation decreased, which suggested a shift in what is perceived to be important and an understanding that science is less about grades in an artificial classroom setting but more about being embedded in real-life contexts. The situational change at B2 might have provoked personal or societal relevance, which induced a shift from external to internal motivation. It is important for students not to regard curricular topics as isolated units and anchor them on terminology to receive good grades but gain long-term interest (Hallyburton & Lunsford, 2013).

Cognitive knowledge increased for specific as well as general items, which is in line with other informal education programs (Liefländer, Bogner, Kibbe, & Kaiser, 2015; Baierl, Johnson, & Bogner, 2021; Clark et al., 2016). Deeper learning and ESD build on system knowledge (Arbuthnott, 2009). Many students show, however, insufficient conceptual knowledge (Rickinson, 2001) and focus on terminology to concentrate on short-term, external goals like grades (Stan, 2012). Our designed items include basic concepts about photosynthesis (CO_2-uptake) or nutrient cycling which are of research interest at B2 and crucial to establish a scientific understanding of our natural world. Knowledge gains are prevalent for general and specific items, indicating that B2 is successful in engaging students to learn facts and fundamental concepts. Contextualizing information in our informal learning environment thus enables students to gain basic knowledge even without additional in-classroom preparation or follow-up activities. Nevertheless, further studies should investigate the effects of pre and post classroom work because those often enhance learning (Felix & Johnson, 2013; Randler & Hulde, 2007). Follow-up tests are required to determine long-term performances, which was difficult to assess in this study since summer-holidays followed the data collection period and students were redistributed in new classes in the subsequent school year.

Our findings refer to the B2 educational programs but can be generalized to other science centers and may help program development. The B2 programs cover essential curricular topics such as photosynthesis but place them in the current global issues of climate change and ESD. This way, basic curricular topics are related to real-world problems, while advocating a more sustainable lifestyle. This is not only the goal of B2, but of many science centers (e.g., Cooper Center in AZ, US; Baierl et al., 2021) or traditional in-class programs, as we are facing growing environmental crisis, while movements such as Fridays for Future are ever-present. Relating current research and real-world problems to the curriculum is a fruitful approach to provoke personal relevance and to create long-lasting learning, and learning is facilitated via individual experiences (Schunk, 1984). Middle school is a critical stage for STEM education and career choice, and research indicates that informal education is helpful to induce interest at that age, which is a critical stage to negotiate career trajectory (Nugent et al., 2015). We do recognize that participating in such experiences consumes resources, so with the evaluation of B2 programs, we aim at transferring them in an openly accessible online format. This way, educators can use prepared learning materials to teach curriculum-relevant topics (e.g., photosynthesis, plant anatomy, climate change, carbon cycle, food webs, ocean acidification, or sustainable agriculture) in the real-world science--framework of B2 to create an authentic learning experience. The benefit of B2 is that it allows students to adopt a science perspective on curricular topics: Students work with hypotheses and are encouraged to think in the large-scale laboratory framework of B2. In future research with more intense B2 programs, it would be interesting if having students think like scientists affects career motivation and other factors.

4.3. *Fascination and motivation affect knowledge acquisition in a multivariate context*

There is a considerable effect of either fascination or motivation on knowledge scores, which means the higher the fascination or motivation level, the more students knew and learnt about environmental knowledge. System knowledge, in turn, appears to be fundamental to additional forms of knowledge, which are action-related and effectiveness knowledge (Frick, Kaiser, & Wilson, 2004). These types of knowledge help with translating conceptual knowledge into pro-environmental engagement (e.g., not only knowing the effects of rising CO_2 and CH_4 levels in the atmosphere but also strategies to mitigate those effects such as using public transportation). Fascination and motivation thus seem to be constructs contributing to knowledge acquisition, which is indicated by previous research (e.g., Otto et al., 2020; Knox, Moynihan, & Markowith, 2003), and various studies showed the higher the attitude level, the more the students knew, (e.g., Schneiderhan & Bogner, 2020; Felix & Johnson, 2013; Clark et al., 2016). Since there is little evidence in literature about how sustainability-oriented programs enforce fascination and motivation (e.g., through pre-post comparisons), we aim to investigate such effects, as there is growing recognition that motivational outcomes can be promoted and supported by informal education (e.g., Nugent et al., 2015).

The variable *talking about school at home* strengthens the argument of isolated factual knowledge disconnected with personal relevance. This variable related to the FS and SMOT alike, confirming the more fascinated or motivated, the more often the students talked about sciences and vice versa; however, the variable was unassociated with system knowledge, indicating the need to contextualize the latter, which was also observed by Schumm and Bogner (2016) and Uzzell (1999). The years of primary and secondary education are essential for shaping science attitude (Pelletier et al., 1998). This implies the need to evoke fascination or motivation in earlier school years, particularly because

they tend to decline during secondary schooling and are harder to influence or generate in older students (Bennett & Hogarth, 2009; DeWitt et al., 2011; Gibson & Chase, 2002; Savelsbergh et al., 2016; Pelletier et al., 1998). Attitude can be strengthened by educators and parents, by simply introducing scientific topics in daily discussions at home (see also Nugent et al., 2015).

Learning is socio-culturally mediated (Rickinson, 2001), but we found stronger relationships of fascination, motivation, and knowledge with science grades (Schumm & Bogner, 2016) and how often students talk about school at home than with gender or parental education. Age marginally related to factual knowledge (see also Rickinson, 2001). Regarding motivation, self-efficacy showed the strongest relation with the frequency of talking about school at home. There is a link between self-efficacy and expressed interest (Potvin & Hasni, 2014), suggesting that students feel acknowledged when talking about curricular topics at home and, thus, show more self-efficacy and better grades. Research indicates that self-efficacy is a stronger predictor of achievement than socio-economic elements like gender, ethnicity, or the parents' profession (Schumm & Bogner, 2016; Kupermintz, 2002; Lau & Roeser, 2002). Potvin and Hasni (2014) observed that self-efficacy is identical to high self-esteem, which entails better self-regulatory skills, a wider range of learning strategies, and, thus, deeper learning (Kuyper, van der Werf, & Lubbers, 2000), signaling the need to support self-efficacy in classroom settings and at home. Talking at home helps embed curricular topics in everyday life, which induces motivation and deeper learning as the content meets personal or societal relevance (see also Savelsbergh et al., 2016). When the home cannot provide these, outreach facilities can serve as alternatives and guide towards sustainability.

4.4. Study limitations

We already discussed two study limitations, which are the unclear line between motives and motivation within the FS and SMOT and the lack of a follow-up test to investigate long-term learning effects due to logistic difficulties. Long-term effects could then refer to knowledge gains and pro-environmental shifts in fascination and motivation, which ideally results in more sustainable behavior and a critical mind as to global environmental challenges. We also mentioned the ceiling effect for both scales, which might be the result of extraordinarily fascinated or motivated students. We could have been able to reduce such an effect by including some negatively formulated items in the scales. Moreover, self-reported data runs the risk of social desirability. Oerke and Bogner (2013) claimed little association of social desirability on similar scales, and we tried attenuating for it by letting the students know that the questionnaires were anonymized and none of their teachers would see or grade them. Another point refers to the knowledge scale: We covered system knowledge with only ten items. Due to time restrictions to fill in the questionnaire, we mainly chose selective facts and did not assess complex understanding via open-ended questions. There is a tendency to isolate system knowledge as part of the curriculum, which appears important as an extrinsic motivator like grades but rather unassociated with everyday life or attitude (Stan, 2012). From this perspective, the effect of fascination and motivation on knowledge can be regarded stronger as the regression weight indicates; if we already have a significant effect on system knowledge, we propose the influence on a more comprehensive knowledge scale would be more powerful (e.g., the environmental knowledge scale; Roczen et al., 2014; Frick et al., 2004). We further used an ad hoc knowledge scale, but we asked general environmental knowledge questions, covered by the B2 programs and NGSS alike; this implies it is not a standardized scale comparable to those for PISA or TIMSS, but it was designed to reflect a broad understanding of some main environmental concepts. Related to the knowledge test is the priming effect. We avoided priming through the test's application (students filled in the questionnaire a few days ahead or on the bus ride to the facility, and back in class, which allowed time between the test and program), by informing the students that their teachers would neither see nor grade the tests, and by the B2 program set-up: Students first experienced a tour throughout the facility, which generally raises excitement, so paying attention to non-graded facts is less likely.

5. Conclusion

Short-term informal learning shows promising potential to foster motivation and fascination and to increase system knowledge (e.g., Liefländer et al., 2015). We confirmed the prevalent structure of the Fascination with Science scale via Rasch modelling, introduced its factor analytical approach, and revealed the scale's comparability with the Science Motivation scale, while the latter appeared to have more predictive power on system knowledge. Both instruments appeared to measure analogous constructs, which yet have a moderate effect on knowledge scores. The moderate effect may be due to a ceiling effect, the nature of the scales, which tend to measure motives instead of motivation, the program-duration, or the fact that we only monitored system knowledge with few items. There is, nevertheless, an impact of either fascination or motivation on knowledge scores, so we expect stronger relationships with the application of a manifold knowledge scale or a more intense program (e.g., in-classroom preparation and follow-up activities). The students gained knowledge for the specific items, which test facts, and the general items, which test concepts, rendering the educational Biosphere 2 programs fruitful to induce environmental system knowledge. This is important because system knowledge is relevant for developing attitude and behavior (Roczen et al., 2014; Cheng & Monroe, 2012; Ernst & Theimer, 2011; Hines, Hungerford, & Audrey, 1987), and thus a more sustainable lifestyle. Mediating parameters are science engagement and authentic learning. Socioeconomic factors showed less predictive potential than fascination, motivation, and the item which is an indicator for informal learning (talking about school at home). Shifts in grade motivation signal a reorientation from external to internal motivation based on a Biosphere 2 trip. Educators should thus be encouraged to shift from external to internal motivators based on authentic learning approaches; it is not only that teachers need to create purposeful learning, but parents should bring scientific topics into casual conversations to enhance engagement in science. Acknowledging environmental knowledge and attitude empowers students to combat environmental issues. The gap between knowledge and performance can be overcome through meaningful learning by bringing curricular topics closer to everyday life and by lowering performative costs, and thus fosters a path towards sustainability.

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Declaration of Competing Interest

The authors report no declarations of interest.

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Appendix A

Fig. A1. Learning station of the Sustainability program: Aquaponics is a soil-less, sustainable food production system to couple aquaculture (fish giving off nutrients) and hydroponics (cultivation of plants in water), in which nitrifying bacteria convert the ammonia the fish release into nitrates for the plants to absorb. Once the water reaches the lowest level of the four stairs, it is pumped back into the aquarium and reintroduced in a circular way. The poster lists the cultivated plants.

Fig. A2. Learning station of the Sustainability program: Olla is a water saving irrigating system. The clay pots have a glassed top and cap so water cannot evaporate. The buried lower part is unglazed and porous, so the roots of surrounding plants can gradually absorb the water, which is pulled out of the jars via osmosis.

Fig. A3. Learning station of the Systems in Space and the Sustainability program; the Lunar Greenhouse is a soil-less, water saving agricultural system designed for space exploration.

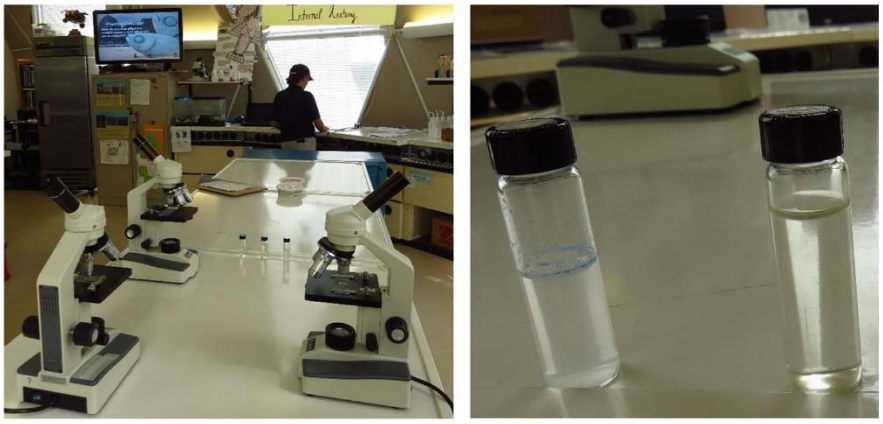

Fig. A4. Ocean lab to differentiate microplastics from plankton under the microscope (Sustainability program). In the tubes on the desk, students can see that microplastics float close to the surface, so predators easily confuse them with plankton.

Fig. A5. Learning station to investigate the cause of ocean acidification (Marine Science program); students are reintroduced to the concept pf pH. They cause the water to be more acidic through their exhaled, CO_2-enriched breadth and draw conclusions on the marine ecosystem with a focus on corals: They learn about the coral life cycle, coral bleaching, and how B2 research aims at combating this global problem (e.g., dying reefs, loss of ecosystems, disruption of the marine food network).

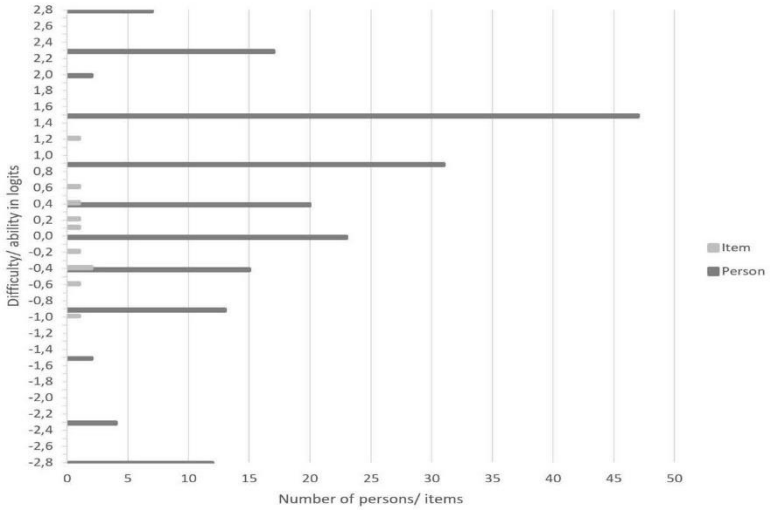

Fig. A6. Person item map of the ten Rasch analyzed knowledge items. We calibrated the pre and post data together for uniform calibration to determine program effects (n = 454). The higher the score, the more challenging the item or the higher the person ability is.

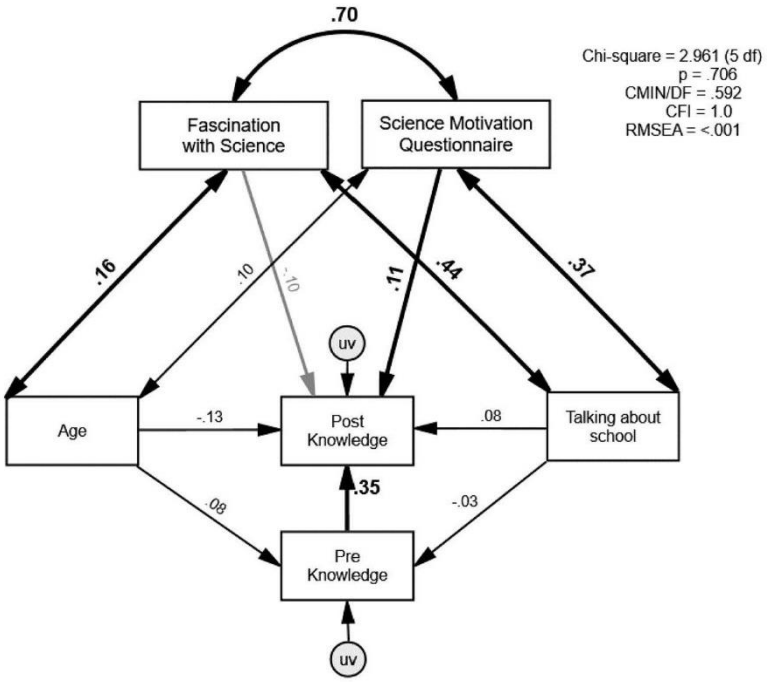

Fig. A7. AMOS path model to relate the constructs of fascination and motivation with knowledge in a multivariate context. Both constructs were factor analyzed and their factor analysis hidden to focus on the main relationships; separate factor analysis are more clearly displayed in Figs. 2 and 3.

Table A2
All system knowledge items, which cover general and specific aspects, and their multiple-choice answers; the higher an item difficulty (Rasch output), the more demanding the item is to perform.

Knowledge items	Multiple choice answers	Item difficulty (*SD*)	Mean score (*SD*)
Which of the following statements about science is most true?	• Science is an unchanging body of facts. • Science is a way of understanding the natural world that is based on belief instead of evidence.	−.99 (.14)	.59 (.49)

(*continued on next page*)

Table A2 (*continued*)

Knowledge items	Multiple choice answers	Item difficulty (*SD*)	Mean score (*SD*)
	• Science is open to changes as more information is gathered and new technologies allow for new observations and new experiments.		
The carbon that plants use for photo-synthesis comes primarily from the	• water. • soil. • air.	−.36 (.13)	.51 (.5)
Sustainable food production methods, such as hydroponics and aquaponics,	• use less water over time than traditional soil-based agricultural production. • always keep animal waste away from growing plants. • produce food that is less healthy than traditional soil-based agriculture.	−.38 (.13)	.54 (.5)
Which factor threatens the world's coral reefs most?	• An excess of carbon dioxide • Nutrient pollution from agriculture • Scuba diving	.19 (.12)	.34 (.47)
What is a regulating service of dense forests?	• Carbon storage and climate control • Timber for furniture and firewood • Recreation like mountain biking and hiking	.10 (.12)	.44 (.5)
Climate is mostly driven by	• soil type and wind speed. • water availability and temperature. • temperature and biodiversity.	.44 (.12)	.40 (.49)
How much of the oxygen in the Earth's atmosphere does plankton provide?	• less than 10 %. • about 30 %. • more than 50 %.	1.22 (.13)	.15 (.36)
Which molecules form carbonic acid when combined?	• Water and carbon • Water and carbon dioxide • Vinegar and carbon	.63 (.12)	.32 (.47)
The current value and importance of Biosphere 2 for scientific research is primarily its	• large scale when compared to most science laboratories. • small scale with uncontrollable environmental conditions. • space-frame construction material.	−.23 (.13)	.48 (.5)
Which statement about life on Earth is most correct?	• The planets in the solar system provide the energy that allows plants to grow. • Energy flows and nutrients cycle. • Molecules like carbon, nitrogen, and oxygen are used once and then destroyed.	−.61 (.13)	.57 (.5)

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5.4 Teilarbeit B

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Plastic Pollution:

Learning Activities from Production to Disposal – From Where Do Plastics Come & Where Do They Go?

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INQUIRY & INVESTIGATION

Plastic Pollution: Learning Activities from Production to Disposal – From Where Do Plastics Come & Where Do They Go?

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Abstract

Plastic pollution is ubiquitous and there is growing concern about its consequences. Given that current research findings often reach the public insufficiently, the issue should be addressed at school. To create a fruitful learning experience, we propose three associated hands-on, inquiry-based learning activities that require little equipment. Students learn about the origins and properties of plastics, investigate everyday sources, learn about recycling, address and reflect upon the materials' (dis)advantages, and are encouraged to consider solutions. All activities align with the Next Generation Science Standards *and are primarily designed for the middle school classroom; we further provide modifications for elementary and high school settings.*

Key Words: *plastic pollution; microplastics; recycling; hands-on; inquiry-based; sustainability.*

○ Introduction

Plastic pollution receives growing media attention but little consideration at school. To prepare students for the multifaceted challenge (e.g., the cost-benefit relationship of plastic applications), we propose activities to provide key information about the origins and production of plastics, to investigate plastic fragmentation and interactions, to address recycling, and to consider solutions to plastic pollution. Supplemental Material adding to the ideas presented in this article are easily accessible online (see Figure 1). Experimental setups and further activities can be conducted with everyday objects; lesson plans delineate suggestions to introduce, elaborate on, secure, and deepen each activity.

○ Plastic Pollution

Each year, 6–12 million tons of plastics enter the oceans, and plastics have reached the most remote places (Vince & Hardesty, 2017). The synthetic polymers are often derived from crude oil and resistant to degradation; they can accumulate and pose a threat to the (a)biotic environment. Conventional waste management can exacerbate the problem (Alshehrei, 2017); although most plastics could be recycled, their recovery is challenging and not profitable (Subramanian, 2000). Certain plastic waste is mismanaged and enters the ocean through inland waterways (e.g., via landfills). Without infrastructure improvement, Jambeck et al. (2015) estimate a 22% increase in mismanaged plastic waste in the United States by 2025.

There are degradable alternatives, such as polyhydroxyalkanoates, but production costs prevent commercial application (Koller et al., 2010). Degradability itself could even turn into the opposite once xenobiotics or certain additives are involved: compounds like softeners are more likely to leach when plastic beomes fragmented, and microplastics are more difficult to recover from the environment. During biodegradation, materials are completely reintroduced into natural systems; this, however, requires specific parameters, including humidity, that are rarely all prevalent in the natural environment (Wolf et al., 2010), and definitions for terms such as *(bio)degradable* vs. *bio-based* are often unclear (Hermann et al., 2011). Since there is no simple solution to plastic pollution, it demands a multiperspective approach that reflects on both the benefits and the drawbacks of plastics. Students need to learn about plastic distribution, recycling, and implications, and adopt different perspectives (e.g., economic vs. environmental, egoistic vs. biospheric) to use plastics responsibly.

○ Educational Background

Hands-on Activities

These activities allow learning by doing (e.g., experimenting, modeling) and facilitate engagement with material and understanding of concepts (Scharfenberg & Bogner, 2011). They entail collaborative group work that enables students to exchange ideas, acknowledge different performance levels and learning styles, and provide feedback. Thus, the activities described below embrace group work, offer adjustable degrees of complexity, and address various learning styles.

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Inquiry-Based Learning

The American Association for the Advancement of Science and the National Research Council advocate an inquiry-based science approach (Gibson & Chase, 2002). The key element is constructive student engagement. Building on preexisting knowledge, students are encouraged to ask questions, formulate hypotheses, conduct meaningful experiments, interpret data, draw conclusions, estimate limitations (e.g., of the study design), and exercise metacognitive reflection (Keys & Bryan, 2001). There are positive effects of inquiry-based learning on science achievement, cognitive development, science process skills, attitudes toward science, interest in science careers, and deeper learning (Gibson & Chase, 2002). The activities described below aim at such student engagement while increasing the difficulty of tasks in a stepwise manner.

○ Student Objectives

All activities are embedded in the *Next Generation Science Standards* (NGSS) framework (Table 1) and follow Bloom's taxonomy. Students will be able to

- define the terms *(micro)plastics*, *polymers*, *nurdles*, *microbeads*, and *marine debris*;
- recall basic information about the history and current use of plastics;
- distinguish between primary and secondary microplastics;
- explain one scenario for how microplastics enter the ocean;
- explain two ways in which plastics affect the environment;
- identify relationships between human activities and negative environmental impacts (MS-ESS3-3);
- use a model to explain plastic fragmentation, its implications, and toxin interactions;
- identify the six common types of plastics and their recycling symbol;
- acknowledge the importance of proper recycling as a solution to minimize human impacts on the environment (MS-ESS3-3);
- relate the "six Rs" (refuse, reduce, reuse, recycle, rethink, and redesign) to everyday items; and
- evaluate the necessity of plastics by acknowledging societal needs or desires and environmental effects (MS-ESS3-3).

○ Learning Unit

Although the activities build on each other, each can be implemented independently to focus on key aspects. Some materials such as dice and voting cards link the activities. The students use dice for playful revision and as a model to visualize the process and effects of fragmentation; they use the voting cards to respond to questions and quizzes or to signal to the teacher that a task has been completed (placing the green card on their table) or that help is needed (red card). This is a time-efficient, subtle way to check on the students. A workbook (WB) and PowerPoint presentation

Table 1. Links to the NGSS for the middle school classroom.

NGSS	Title	Code	Disciplinary Core Ideas	*Focus*	Crosscutting Concepts	Science and Engineering Practices
Primary Topics	EARTH AND HUMAN ACTIVITY: HUMAN IMPACTS **(ES)**	MS-**ES**S3-3	**Human Impacts on Earth**	*Plastic Pollution*	Cause and Effect	Constructing Explanations and Designing Solutions
		MS-**ES**S3-4			Influence of Science, Engineering, and Technology on Society and the Natural World	Engaging in Argument from Evidence
		MS-**LS**2-5	**Evaluating Solutions**	*Recycling*		
Additional Topics		MS-**LS**2-3	**Energy Transfer and Food Webs**	*Marine Ecosystem*	Energy and Matter	Developing and Using Models
	ECOSYSTEM: INTERACTIONS, ENERGY, AND DYNAMICS **(LS)**	MS-**ES**S3-1	**Natural Resources**	*Fossil Fuels, Pollution*	Cause and Effect; Influence of Science, Engineering, and Technology on Society and the Natural World	Constructing Explanations and Designing Solutions
		MS-**LS**2-4	**Ecosystem Dynamics, Resilience**	*Plastic Accumulation*	Stability and Change	Scientific Knowledge is Based on Empirical Evidence

(PPT) guide the unit. Detailed lesson plans go hand in hand with the presentation and suggest student-teacher interactions (e.g., questions, think-pair-share, flashlight). The students consistently make predictions, which they confirm or refute through experimental investigations or other activities. There is a focus on activating all students with short, playful activities. The incorporation of case studies and everyday objects further facilitates learning and promotes authentic science. See Figure 1 to easily access all Supplemental Material.

Activity 1: What Are Plastics?

With newspaper articles about plastic pollution (e.g., "Microplastics are now in the air"), students are led to the question of what plastics actually are. They watch a short video clip to learn about the origins, history, manufacturing, and main applications of plastics, guided by a table with key terms (*plastic*, *polymer*, *microplastics*, *microbeads*, *nurdles*, *marine debris*, *PVC*, *acrylic*, and *nylon*) and questions about its history and current use (WB p. 1). A memory activity helps fill in the table; each student receives one card with either a term, question, definition, or answer. They have to pair up, match the cards on the board, check all matches, and copy the information. Some terms may seem redundant at this point (e.g., *nylon*), but they help elaborate a feeling for the distribution and variety of plastics. To deepen their knowledge, the students play a game of dice. Allocating a number to each term, in pairs they throw the dice and recap the terms the numbers represent. The game could be played in subsequent lessons for playful revision. Elaborating on plastic distribution, the students extract microbeads and fibers from cosmetics and clothes (see Raab & Bogner, 2020). Or they can use their voting cards for a quiz: the teacher shows everyday items (examples in the PPT), and the students have to raise a green or red card to indicate whether they think the item contains plastics.

- Video: "Plastic Pollution: How Humans Are Turning the World into Plastic" (Kurzgesagt–In a Nutshell, 2018)
- Memory activity
- Dice
- Voting cards

Figure 1. Link to Supplemental Material (PDF and DOC files); the activities are guided by a workbook (WB) and can be embellished by the PowerPoint presentation. Further learning materials provided include the voting, memory, and sorting cards.

Activity 2: Are Plastics Harmful?

This activity is introduced by the question of how microplastics can be harmful if they are hardly visible to the naked eye. After brainstorming (use mind maps; the answers serve as hypotheses to be confirmed or refuted after the activity), the students learn about microplastics and their environmental impact (primary vs. secondary microplastics, process of fragmentation, plastics entering the ocean, toxins leaching, and surface interaction with toxins) through a short informative text (WB p. 2). A model and a soil experiment help visualize those processes (WB p. 3). The model demonstrates the change in surface area once large plastics become fragmented. In groups of four to eight, the students build one large cube with all their dice, which represent macroplastics. They calculate the surface area, pull the cube apart, and calculate the increased surface area; relating it to plastics, they understand that this allows more toxins to leach or attach, while small pieces can accumulate in the environment. Linking this to daily life, they conduct the soil experiment (Figure 2; WB p. 5). They choose common materials to be buried in the soil and develop hypotheses regarding visible impacts after two to three weeks of exposure. Additionally, they produce their own biodegradable "plastic" film, also to be buried or used at home (Figure 3; WB p. 4). The biodegradable film shows typical features of plastics, yet it breaks down more quickly in moist environments. The key message is that there are less harmful, compostable, and easily producible alternatives. The students discuss parallels of the biodegradable vs.

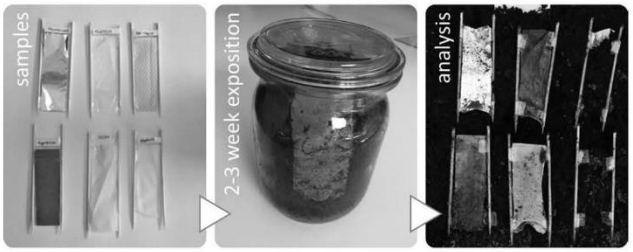

Figure 2. Stages of the soil experiment. The students choose everyday materials and formulate hypotheses regarding their visible impacts after soil exposure. Then they place the samples in a jar, keep them moist, and analyze the samples to confirm or refute their hypotheses.

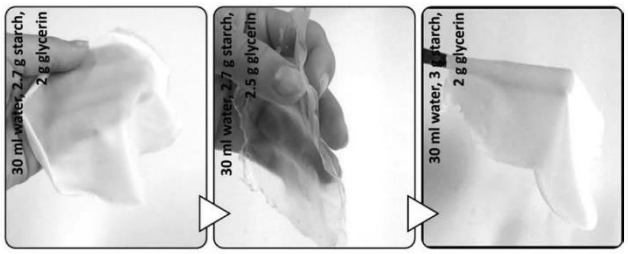

Figure 3. Three similar biodegradable "plastic" films made of glycerin, starch, and water as alternatives to conventional plastics. Students can use their films at home and investigate their degradation in another experiment (see Figure 2).

conventional film and elaborate on their benefits and drawbacks. At home, they can explore various applications.

- Dice
- Soil experiment
- Biodegradable plastic experiment
- Voting cards

Activity 3: What about Recycling?

A few striking figures about the percentage of actually recycled products lead to the six main types of plastics (PET, HDPE, PVC, LDPE, PP, and PS) and their recycling potential (including upcycling and downcycling). To deepen this knowledge, the students participate in the following memory activity. Everyone receives a piece of paper showing jumbled plastic shreds and related information (type of plastic, its abbreviation, recycling symbol and potential, and common things made of it), which they have to cut, match in pairs or groups, and paste into their WB (p. 7). After a TEDx-Talk introduces the "six Rs" (see above; WB p. 8), students receive pictures of common things and match each to one R-category on the board. Subsequently, they discuss alternative allocations (e.g., a thing could be reused instead of recycled). This fosters creativity and engagement in elaborating sustainable ideas. The 3-Day-Challenge at Home further encourages students to reflect on household waste by assigning throwaway items to one "R" (WB p. 9). Finally, a discussion and the soil experiment analysis summarize the topic, identifying relationships between human activities and their environmental impacts.

- Memory activity
- Video: "Microplastics Are Everywhere" (Dudas, 2018)
- Sorting activity
- Voting cards

○ Alignment with the NGSS

We designed the module for middle school students, but it can be adapted for other age groups. The disciplinary core idea is *Earth and Human Activity* while focusing on *Human Impacts on Earth*. The topic *Natural Resources* is subordinate. Therefore, the main cross-cutting concepts are *Cause and Effect* and *Influence of Science, Engineering, and Technology on Society and the Natural World* regarding the invention, management, and (irrevocable) effects of plastics. Consequently, *Constructing Explanations and Designing Solutions* and *Engaging in Argument from Evidence* are at the heart of the science and engineering practices, since the whole unit's design is inquiry-based and aims at developing and evaluating solutions (Table 1; NGSS Lead States, 2013).

○ Experiences with Students

The students loved to produce their own biodegradable film and use it at home. Older students formulated hypotheses and varied the amounts of starch, water, and glycerin to generate the best outcome; this could turn into a competition. Teachers embraced the soil experiment to build on the biodegradable "plastic." Then, the students buried not only common things but their own "plastic," both relating the topic to everyday life. Two teachers suggested making this an experimental demonstration instead, which would save time and resources. The majority, however, would allow students to conduct the experiment, for it promoted scientific thinking, engagement, and responsibility.

○ Summary

Inquiry-based, hands-on learning links theory to everyday life by placing scientific topics in a broader context and by providing opportunities for constructive engagement. Although designing such activities may require more preparatory work, they are worth their effort, prompting cognitive, affective, social, and deeper learning. As science continually changes, educational programs need to adapt accordingly, faster than the school curriculum can. Scientific expertise about environmental threats needs to reach the younger generation, which is best accomplished at school. Since the NGSS (2013) are open in nature and embrace current global issues, all activities align with the standards and create a coherent learning experience to allow for profound insight into a major environmental issue, plastic pollution.

○ Acknowledgments

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5.5 Teilarbeit C

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Assessing Environmental Attitudes and Cognitive Achievement within 9 Years of Informal Earth Education

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Assessing Environmental Attitudes and Cognitive Achievement within 9 Years of Informal Earth Education

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Abstract: Given the multitude of attitude scales, we examined the relationship between the 2-Major Environmental Values model (2-MEV) and the New Environmental Paradigm scale (NEP) based on a 6585 child sample over a 9-year period. The students participated in a three-day outdoor earth education program at field centers in three different US states (Arizona, Pennsylvania, and Louisiana). We further investigated the scales' sensitivity to program effects, relating cognitive achievement and attitude with respect to a pro-environmental indicator of behavior (Y key). The NEP and Preservation correlated highly, while the subscales Utilization and Preservation showed a strong inverse relationship. Based on further reliability and validity scores, and in line with the literature, this pointed to a unidimensional Preservation of Nature scale as a concise attitude measurement. In structural equation modelling, Preservation related to knowledge gains and the Y key, and effects from Preservation on knowledge held true for all three states. This suggests Preservation as one factor influencing cognitive achievement and environmentally conscious performance. Regarding program effects, the Earthkeepers program seemed to induce pro-environmental shifts based on knowledge gains and attitude changes (Preservation increasing and Utilization decreasing). Pro-environmental shifts were most prominent for those who received the Y key.

Keywords: 2-Major Environmental Values model; New Environmental Paradigm scale; environmental attitude; Preservation; system knowledge; earth education; Earthkeepers

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1. Introduction

Environmental attitude is among the key concepts of environmental psychology, often referring to environmental concern. It forms a set of beliefs, affects, and behavior intentions towards the environment [1]. Eagly and Chaiken [2] refer to attitude as a person's evaluation of or affection towards an object or topic, which is associated with cognitive, psychosocial, and demographic variables [3]. There is consensus about the multidimensionality of environmental attitudes on the primary level, while the second order structure is less evident [4,5]. Some argue for one higher order factor [6,7]. Xiao and Dunlap [8], for instance, proposed eight primary level factors pointing toward one higher order factor, which is environmental concern. Others advocate two dimensions. The 2-Major Environmental Values model (2-MEV) reflects the dilemma of whether to protect or exploit nature on two orthogonal scales [9]. Milfont and Duckitt [10] confirmed the two-dimensional structure but added primary level factors. Thompson and Barton's [11] ecocentrism-anthropocentrism scales showed a similar pattern; they designed an instrument with three underlying perspectives but later merged the altruistic and egoistic dimension. Building on Stern and Dietz' [12] value-basis theory, which derives attitude from values, others differentiated between the three higher order dimensions of the self (egoistic), other people (altruistic),

and the biosphere [13,14]. Next to the question of dimensionality, there is a multiplicity of program-specific scales, which often lack comparability because of their application in isolated settings or with small sample sizes [15]. In research, questionnaires on attitude are often time-consuming. Particularly for children, they need to be compact so the quality of responses is not at the expense of item numbers. We contrast two widely used instruments based on a large, age-homogenous but state-diverse sample size, with the New Environmental Paradigm scale (NEP) pointing towards one higher order factor and the 2-MEV pointing towards two, aiming at a concise environmental attitude scale. We then investigate program effects of an established earth education program to see to what extend the attitude scales are sensitive to its effects, and finally test the predictive power of the attitude scales on knowledge and behavior.

In the 1990s, the 2-MEV was developed, as there had been no appropriate tool to measure environmental attitude of adolescents; previous studies were mainly used with adults [9]. While at that time many scales were competing, the 2-MEV received the privilege of independent cross-cultural confirmation from different disciplines (e.g., [5,10,16–18]). Subsequently, the model has been used around the globe and translated into 33 languages, the very basis for its consistency being those bi-national studies; recently, e.g., Regmi et al. [19] applied the 2-MEV with 200 rural Nepalese students and confirmed its validity and reliability. The instrument's worldwide acceptance is rooted in its compact format and two-dimensionality, which covers preservation of nature (a biocentric perspective to protect our natural environment) and utilization of nature (an anthropocentric perspective to exploit nature) [20]. It allows the placement of individuals on a biocentric and an anthropocentric scale independently. This means individuals could score high in Preservation although they show tendencies to exploit nature (Utilization). Johnson and Manoli [21] and Schneller et al. [22] adapted the 2-MEV to American fifth to sixth graders who participated in earth education programs and cut the original number of items. This reduced scale showed stability and validity in an 8-year comparison [23]. Despite modifications regarding locality or length, the instrument has been shown to be internally consistent and reliable (e.g., [14]).

The NEP is among the most frequently used environmental attitude instruments, as it is less topic-specific than comparable ones introduced at that time, e.g., the Environmental Concern scale [24] or the Ecology scale [25]. Dunlap and Van Liere [26] had developed the 12-item NEP but eventually revised it to assess a key set of ecological worldviews, to balance pro- and anti-environmental items, to update terminology [27], and because the scale had faced disputes about its dimensionality. The modified 15-item NEP aimed at the new relationship between humans and nature in Western countries and placed individuals on a scale between feeling separated from or as an internal part of nature through its five interrelated domains. Since it relies on the social-psychology theory and on Rokeach [28], it reflects primitive or fundamental environmental beliefs and allows for predicting attitude or behavior [29]. Several studies yielded two to four latent factors, and with an increasing number of items, more but not necessarily reasonable factors are likely to emerge; if the eigenvalue of the main factor far exceeds the remaining ones, it should be treated as unidimensional. According to Dunlap [29], the NEP's dimensionality depends on the study purpose, and the potential to be used either way turned into a strength as it reflected the cohesion of a person's belief system. Based on this, we treat the NEP unidimensionally and use its modified version for children [30].

In a preceding paper, Manoli et al. [31] related the 2-MEV to the NEP and concluded that the two-dimensional 2-MEV allowed assessment and prediction of attitudes more accurately than the unidimensional NEP. They suggested that a person with high Preservation and low Utilization scores (2-MEV) is placed at the upper end of the NEP, which corresponds with a biocentric worldview. Low Preservation and high Utilization scores are at the opposite end of the NEP, which reflects an anthropocentric view on nature. Consequently, the NEP is restricted to place an individual on a continuum between biocentrism (pro-environmental) and anthropocentrism (anti-environmental), whereas the

2-MEV allocates a person to one of four quadrants (high Preservation and high Utilization scores, high Preservation and low Utilization scores, low Preservation and low Utilization scores, or low Preservation and high Utilization scores). The 2-MEV acknowledges that a person could score low or high in both Preservation or Utilization, while those aspects would merge on the NEP and result in a medium or zero score. Although the NEP is a valid and reliable instrument to assess environmental perceptions and useful to determine extremes (biocentrism vs. anthropocentrism), the 2-MEV can identify attitude sets, which allows for designing learning activities accordingly. We build on those findings by further relating both instruments.

Environmental knowledge faces the issue of measurement and conceptualization. One approach is to regard environmental knowledge from three perspectives [32]: System knowledge covers facts and fundamental concepts, which reflect a basic, factual understanding. Action-related knowledge refers to understanding and implementing individual (pro-) environmental behaviors (e.g., turning off the lights when you leave the room, or taking a shower instead of a bath). Effectiveness knowledge is more abstract and enables students to reflect on the efficiency of pro-environmental actions on a broader scale (e.g., reducing carbon emissions by promoting public transportation). In general, factual knowledge about environmental issues appears to be low; yet it is challenging to draw conclusions as many studies use program-specific ad-hoc questionnaires, which often lack comparability, validity, or reliability (e.g., [33]). Providing such quality criteria requires time-consuming piloting and stepwise revision, which promotes the development of a universal scale. We therefore use a broadly applicable environmental knowledge scale that covers basic conceptual understanding (system knowledge), with action-related and effectiveness knowledge to be added in future studies.

From a traditional approach, knowledge is essential to environmental attitudes (e.g., [3,34,35]). This linear function of knowledge raising awareness evokes attitude and, finally, ecological behavior (e.g., [36,37]). This is reasonable given that, e.g., people are more willing to reduce carbon emissions if they realize the impact of rising carbon dioxide levels. There is reason to look at knowledge from the opposite direction, which is knowledge resulting from attitude, as you are more willing to learn if you have a certain mindset [38]. Pro-environmental behavior is the main goal of environmental education, but there is uncertainty about which parameters contribute most [39]. Many researchers claim only a low to moderate relationship between attitude and behavior, but this perceived relationship might stem from the unclear dimensionality of environmental attitude or from methodology (e.g., [3]). Based on this, we investigated attitude effects on knowledge.

We conducted our study at similar earth education centers in three US states, where four to six grade students experienced the same three-day outdoor program, Earthkeepers. This is important because the more intense an informal learning program, the more likely it is to induce attitude changes [33,40,41]; once formed, attitudes are enduring and resistant to change [35,42,43]. Meaningful outdoor learning is presumed to enhance affectively based attitudes, which are associated with intrinsic motivated behavior, while the traditional school setting instead establishes cognitive attitudes associated with extrinsic motivated behavior [44]. Moreover, the younger the students are, the more fruitful it is to introduce pro-environmental attitudes [36,45,46], as positive attitude towards science declines in secondary schooling and is difficult to generate in older students [47,48]. This renders the earth education program not only the foundation of our study, but a key feature to further investigate environmental learning.

Objectives of the Study

Based on the large sample size, the present study focused on a multi-perspective approach to compare two established attitude scales (2-MEV to the NEP). This refers to (1) assessing the quality of the scales; (2) relating both scales; (3) determining their sensitivity to program effects; and (4) relating them to knowledge scores and the Y key, while we tested if our postulated structural equation model held true for three subsamples

(students in Arizona, Pennsylvania, and Louisiana). This further allowed us to investigate program effects of the Earthkeepers. Our research questions were:

1. How do the 2-MEV subscales and the NEP relate based on a large, age-homogeneous but state-diverse sample?
2. What changes does the three-day residential earth education program induce on attitude and knowledge scores with regard to the behavioral indicator Y key?
3. How does attitude affect knowledge scores and behavior (Y key)? To what extend can we confirm our postulated structural equation model in a state comparison (AZ, PA, and LA)?

2. Materials and Methods

2.1. Participants and Procedures

We compiled the data of 6585 4th to 6th grade students (age: $MS \pm SD$: 9.96 ± 0.812) in three different states (27.2% in Arizona (AZ), 25.8% in Pennsylvania (PA), and 47% in Louisiana (LA)), all of whom participated in the same three-day outdoor earth education program, Earthkeepers. We further included control subjects from the same schools, who did not participate in the Earthkeepers. Gender showed an even distribution with 40.9% females and 39.2% males (19.9% provided no information). It was not possible to collect demographics on race/ethnicity or economic status from individual students. The school districts, however, provided us with general information: most students came from a low to middle socioeconomic environment. In Arizona, the students were from 33 urban schools with a majority of Hispanic and non-Hispanic white students. Louisiana is represented with 34 schools, which are mostly from an urban area with a majority of African American students, with others from suburban areas with a majority of white students. In Pennsylvania, predominantly white students from 19 elementary and middle, (sub-) urban and rural schools participated in the study. The questionnaire was administered 1–2 weeks prior and 4–6 weeks after the three-day outdoor experience, which was a residential program in AZ and PA while students in LA commuted daily to the earth education center.

2.2. Earthkeepers Program

Framed as a "magical learning adventure", the earth education program Earthkeepers aims at gaining a deeper understanding of our natural environment and at developing pro-environmental behavior through outdoor activities. Organized around the work KEYS (for Knowledge, Experience, Yourself, and Sharing), the program consists of (1) a three-day outdoor experience at an environmental learning center and (2) follow-through back in the classroom (for detailed information, see [49]). The students can earn four keys (K, E, Y and S) to become an Earthkeeper. Students are invited to participate through a letter they receive from a mysterious character known only by the initials E.M. Each time a student earns one of the keys, they are able to open a locked box to reveal one of the secret meanings of E.M.'s name. For example, opening the K box shows that E.M. means Energy and Materials, the overall focus of the Knowledge portion of the program. Earning keys and opening boxes helps to create a sense of magic and adventure while also reinforcing the main points of the program.

During the three days at the center, participants receive two keys, Knowledge (K) and Experience (E), for learning about ecological concepts and for engaging in experiences like observations or discoveries. There are four knowledge activities, each a participatory experience outdoors lasting 75–90 min, with a focus on big picture understanding. One focuses on the flow of energy in ecosystems, one on the cycling of materials, one on the interrelationships between living and nonliving things, and the final one on change over time. All aim to make abstract ecological concepts more concrete for the learners, and each includes an application component. Experience also consists of four outdoor, participatory activities, focusing on observation, discovery, immersion and solitude. These activities aim to help the students develop environmentally positive feelings, values, and attitudes. Other activities during the three days help the students to process what they are learning and

experiencing and learn about ways that they can lessen their impact on the environment when they return home to work on the next two keys.

Back at school, the students earn the Y (Yourself) key if they lessen their impact on and deepen their feelings for the earth. They select individual tasks to save energy and to save materials and spend time in nature, all on a regular basis for at least one month to form new habits. Some suggestions are introduced during the program, e.g., saving energy by riding a bicycle instead of getting a ride in a car. Examples to reduce resources refer to water (taking a shower instead of a bath), electricity (turning off lights or heating), packaging (choosing environmentally friendly products at grocery stores), or recycling. The S (Sharing) key is for sharing experiences with others. It is important to note that not all students earn the Y and S keys; only those who provide evidence that they have done the required tasks receive the last two keys and become an Earthkeeper. Teachers encourage the students to do so, but completion is not mandatory.

2.3. Instruments

We used The Environment Questionnaire (TEQ) (e.g., [50]), which comprised the modified 16-item 2-MEV [21] and the 10-item NEP [30] slightly modified to use with children in the US. Language and content were simplified without changing the meaning of the items, and the 2-MEV was shortened to nine Preservation and seven Utilization items. In line with the literature, the students rated their answers on a five-point scale ranging from strongly agree to strongly disagree with a neutral middle of not sure [23,51].

Since using both scales resulted in a longer questionnaire, we restricted the knowledge items to system knowledge, as this is the focus of most environmental knowledge studies (e.g., [32]). The 13 items are applicable to the Earthkeepers program and address basic ecological concepts [52]: energy (e.g., "Which of the following shows a food chain in proper order?"), materials cycling (e.g., "Take a look at your pencil. Were the materials that make your pencil ever part of something else?"), interrelationships (e.g., "I can do just one thing without affecting anything else."), and change (e.g., "If a place is now a desert it may someday be an ocean") (Table A1, Appendix A).

Environmental behavior is difficult to measure, particularly in children, and studies show little association between children's environmental attitude and self-reported behavior (e.g., [53]). In the present study, we used whether or not students earned the Y key as a proxy for environmental behavior, because they need to provide evidence that they have made behavior changes to earn the key.

2.4. Statistical Analyses

We used the Statistical Program for Social Sciences (SPSS, 24th version) and IBM SPSS AMOS 24th version [54]. Confirmatory factor analyses (CFA) and structural equation models (SEM) visualize standardized values of correlations (double-headed arrows) and regression weights (single headed arrows). Since we did not have complete information on the Y key, we used Maximum-likelihood solution, which is the recommended method for treating missing data. The models include random measurement errors, synonym to error terms or unobserved variables; they help to differentiate the true score from unobserved parameters by compensating for unobserved distractors to allow a more accurate measurement, and it is possible to draw correlations among those to define further relationships [55]. Good models should provide a range of fit indices, e.g., a low Chi-Square (χ^2) relative to the degrees of freedom followed by an insignificant p value (testing the null hypothesis). The Root Mean Square Error of Approximation (RMSEA) should be below 0.07 and values smaller than 0.03 present ideal fit. We chose the Comparative Fit Index (CFI) as a baseline comparison because it is not overly sensitive to sample size. The CFI should exceed 0.9 [56]. Though the Chi-Square is a valuable indicator, it is sensitive to sample size [57]. We therefore report the relative or normed Chi-Square, which relativizes the impact of sample size by dividing the Chi-square by the degrees of freedom. Ideally, the score is below 5.0 [55]. There is no standard referring to the ratio of SEM complexity and

sample size, but Kline [58] recommend a 10:1 (number of subjects: number of parameters) relationship, allowing us to draw complex models. For those, we first modelled CFAs for the scales separately to then relate them in a SEM, and to draw parameters among the latent variables to reflect our hypothesized relationships between attitude, knowledge, and behavior.

3. Results

We examined the relationship between the two attitude measurements (2-Major Environmental Values model [2-MEV], New Environmental Paradigm scale [NEP]) based on the earth education program Earthkeepers. We first related the two instruments using CFA, correlation coefficients, and further validity and reliability scores. We then investigated program effects on attitude and knowledge to elaborate on the attitude scales when applied to an environmental education program which demonstrated success, to then position them in the attitude-knowledge-behavior relationship. Since we had a large sample size, we ran several analyses with subsamples to provide measurement invariance tests.

3.1. How Do the 2-MEV Subscales and the NEP Relate Based on a Large, Age-Homogeneous but State-Diverse Sample?

The CFA confirmed the theoretically proposed structures of the 2-MEV with its proposed two orthogonal subscales and the NEP (Figure 1). The primary factors (items) formed the higher order factors of Preservation, Utilization, and the NEP (one-dimensional construct of environmental concern), which we correlated to reveal their relationships. To indicate the primary order factors (first level latent variables) of the secondary order factors Preservation and Utilization (2-MEV), we drew correlations among their error terms. Preservation comprises the primary order factors of Intent of Support (Item no. 1, 8, and 15), Care with Resources (Item no. 2, 9, and 16), and Enjoyment of Nature (Item no. 3, 10, and 17). Utilization consists of Altering Nature (Item no. 4, 11, and 18), and Human Dominance (Item no. 5, 12, and 19). To account for measurement invariance, we tested the CFA with two similar large subgroups by splitting our sample in those aged 10 and those not aged 10. Simultaneous fit indices and identical correlations and regression weights indicated good configural invariance (CMIN/DF = 3.670, CFI = 0.906, RMSEA = 0.029).

The factor analyses enabled us to estimate the relationships among the latent constructs (ellipses), which are assessed via multiple indicators (items or manifest variables and the error terms associated with them) [55]. Construct validity consists of convergent and discriminant validity [59]. Convergent validity (AVE) should exceed 0.5, which was true for Preservation (0.716) and Utilization (0.541) in contrast to the NEP (0.369), indicating that the 2-MEV subscales are similar enough to fall under one dimension. Discriminant validity is the square root of the AVE and should outnumber the correlation (Preservation: 0.846, Utilization: 0.735, and NEP: 0.609). The correlations of the 2-MEV subscales with the NEP exceeded the score, while the correlation between Preservation and Utilization was below the threshold, indicating insufficient disparity among both. Pearson coefficients (r) confirmed the AMOS correlations, which was $r = -0.874$ ($p < 0.001$) for Preservation and Utilization, $r = -0.831$ ($p < 0.001$) for Utilization and the NEP, and $r = -0.817$ ($p < 0.001$) for Preservation and the NEP. With both latent variables inversely correlating, we ran an exploratory factor analysis in SPSS and a CFA in AMOS for the 2-MEV. The first yielded two factors explaining 51.94% of the total variance (Bartlett's test of Sphericity: $p < 0.001$, KMO = 0.915) with good loadings between 0.520 and 0.844 for Preservation but inconsistent loadings for Utilization (0.139 to −0.625), supporting the results of Figure 1. The eigenvalue of Preservation (6.845) exceeded the eigenvalue of Utilization (1.466), indicating one-dimensionality. The CFA with all items pointing at one factor to test one-dimensionality presented acceptable fit indices (CMIN/DF = 15.134, CFI = 0.964, RMSEA = 0.046), but three loadings from Utilization were below the internal consistency threshold [60]. The CFA thus pointed at one-dimensionality and inconsistencies of the latent construct Utilization.

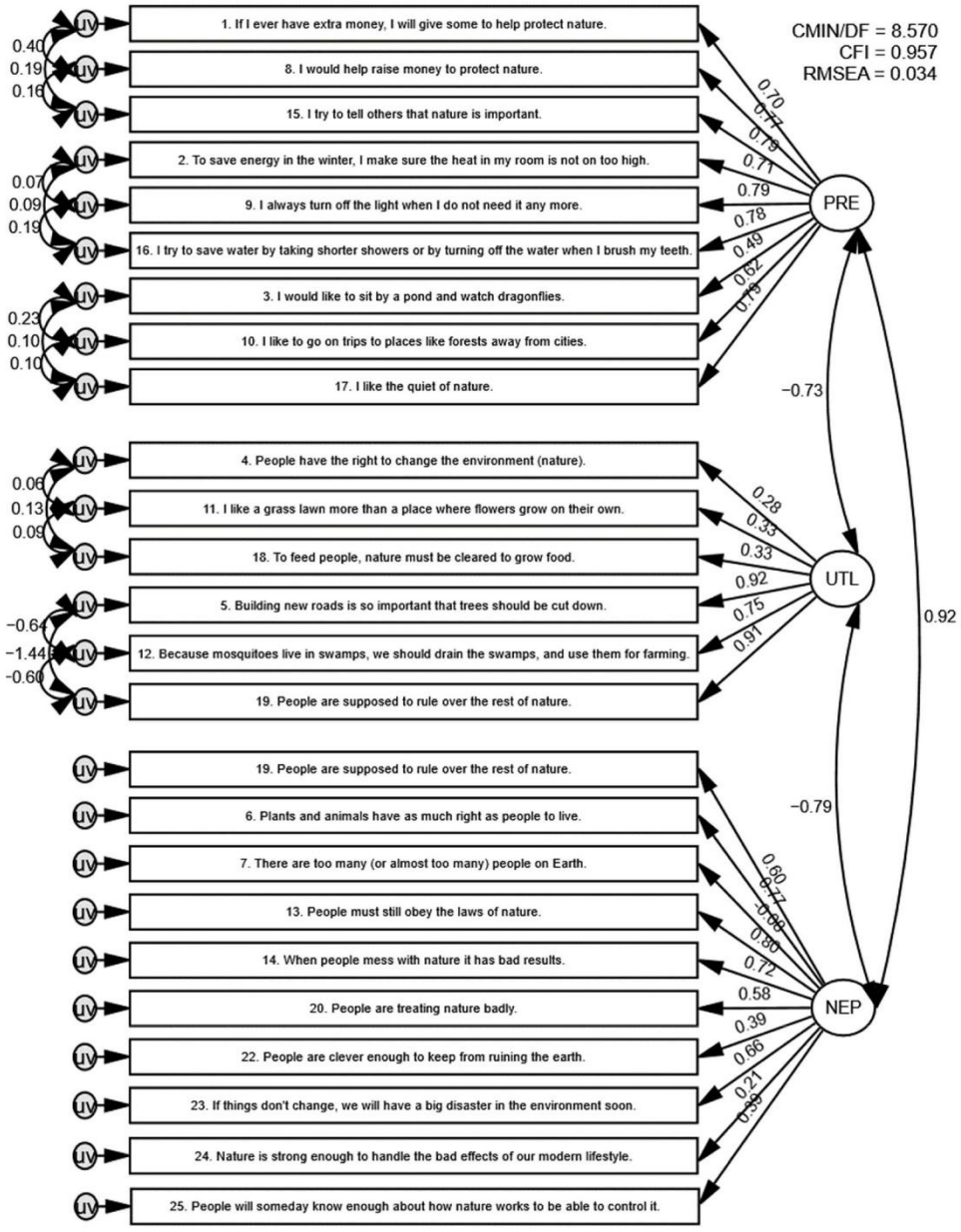

Figure 1. Confirmatory factor analysis to relate the latent factors of the 2-Major Environmental Values model (Preservation [PRE] and Utilization [UTL]) and the NEP (negative items inversely recoded). The unobserved variables (uv) illustrate disturbing factors, which would otherwise affect the measurement. Double-headed arrows are correlations; single-headed arrows represent regression weights (factor loadings). The correlated unobserved variables indicate the first order latent variables of Preservation (Intent of Support, Care with Resources, and Enjoyment of Nature) and Utilization (Altering Nature, and Human Dominance). Fit indices are good with the Chi-Square relative to the degrees of freedom (CMIN/DF) below 5.0, the Comparative Fit Index (CFI) above 0.95, and the Root Mean Square Error of Approximation (RMSEA) close 0.03.

To elaborate on the constructs' reliability, we calculated McDonald's Omega (ω), as it does not require tau-equivalence, which we did not expect within our scales [61]. Omega

coefficients for Utilization were low for the pre ($\omega = 0.642$) and acceptable for the post ($\omega = 0.716$) data. After excluding one item from the Utilization scale, which is "Weeds should be killed because they take up space from plants we need", reliabilities increased (pre: $\omega = 0.677$, post: $\omega = 0.734$), so we excluded it from further analyses, which is in line with previous findings having eliminated the same item (e.g., [62]). Preservation (pre: $\omega = 0.878$, post: $\omega = 0.921$) and the 2-MEV (pre: $\omega = 0.922$, post: $\omega = 0.972$) showed strong reliabilities, while the NEP (pre: $\omega = 0.785$, post: $\omega = 0.771$) yielded weaker Omega coefficients. Cronbach's alpha depends on the assumptions that each item contributed equally to its latent factor and error variances were uncorrelated; if those are violated, reliabilities are underestimated [61]. This is supported by the lower alpha scores (Utilization: pre $\alpha = 0.632$, post $\alpha = 0.710$; Preservation: pre $\alpha = 0.877$, post $\alpha = 0.911$; 2-MEV: pre $\alpha = 0.914$, post $\alpha = 0.922$; NEP: pre $\alpha = 0.709$, post $\alpha = 0.711$), indicating that particularly the NEP fell less under one-dimensionality, whereas the proposed orthogonal scales of the 2-MEV pointed at one-dimensionality. Based on Manoli et al. [31], who had already recommended use of the 2-MEV instead of the NEP, the high correlation between the 2-MEV subscales and the NEP, which indicate that both measure an identical construct, and further reliability and validity scores, we proceeded with the 2-MEV as a more robust tool.

3.2. What Changes Does the Three-Day Residential Earth Education Program Induce on Attitude and Knowledge Scores with Regard to the Behavioral Indicator Y Key?

In a pre-post comparison with listwise exclusion, *T*-tests revealed statistically significant program effects on students who received the Y key and on those for whom we had no information on the Y key (Table 1). The students who did not earn the Y key showed smaller increases (Preservation and knowledge) or decreases (Utilization). Knowledge gains were most prominent, and Table 2 illustrates the item difficulties. Lower numbers indicate difficult and higher numbers easier questions, so the items covered a wide range of difficulties, aligning with a good distribution [63]. Since Table 1 merges all nine years, we provided examples of two subsamples in Table 3, which illustrate the same trend of pro-environmental shifts. We included but are not reporting exhaustive details on control groups as controls have repeatedly shown no considerable changes for either the Earthkeepers (e.g., [64]) or other environmental programs (e.g., [37,65]). Furthermore, pro-environmental shifts are mostly prevalent right after program completion but drop later, so we deem it more important to focus on long-term effects than on controls. We therefore used the same questionnaire 6–8 weeks after the outdoor program to assess longer-term effects. We will nevertheless give some examples of controls: In 2008–2009, control subjects from Louisiana showed no pro-environmental shifts (knowledge: $n = 155$, $p = 0.171$; Preservation: $n = 109$, $p = 0.566$; Utilization: $n = 151$, $p = 0.097$), with the same pattern in another Louisiana control group in 2010–2011 (knowledge: $n = 100$, $p = 0.824$; Preservation: $n = 79$, $p = 0.233$; Utilization: $n = 79$, $p = 0.141$), whereas 545 students who participated in the Earthkeepers in the same year revealed considerable increases for Preservation ($p > 0.001$) and knowledge ($p > 0.001$), while Utilization decreased ($p > 0.001$).

Table 1. *T*-tests for a pre-post comparison of attitude and knowledge scores for those who gained or did not gain the Y key, which is an indicator of pro-environmental behavior; panels show the 2-Major Environmental Values model's (2-MEV) latent factors (Preservation and Utilization) and environmental knowledge scores.

		Preservation	Utilization	Knowledge	*n*
Y key	*MS* pre	3.501	2.678	0.522	1797
	(*SD*)	(0.955)	(0.793)	(0.176)	
	MS post	3.586	2.568	0.634	
	(*SD*)	(0.989)	(0.767)	(0.182)	
	p	<0.001	<0.001	<0.001	
	Cohen's *d*	0.087	0.141	0.626	
	CI	0.022–0.153	0.076–0.206	0.559–0.693	

Table 1. *Cont.*

		Preservation	Utilization	Knowledge	n
No Y key	*MS* pre	3.667	2.594	0.531	421
	(*SD*)	(0.687)	(0.604)	(0.178)	
	MS post	3.726	2.508	0.617	
	(*SD*)	(0.711)	(0.636)	(0.189)	
	p	n.s.	0.005	<0.001	
	Cohen's *d*	/	0.139	0.468	
	CI	/	0.003–0.274	0.332–0.605	
No dataon Y key	*MS* pre	3.671	2.669	0.513	1972
	(*SD*)	(0.780)	(0.664)	(0.181)	
	MS post	3.754	2.534	0.594	
	(*SD*)	(0.662)	(0.565)	(0.186)	
	p	<0.001	<0.001	<0.001	
	Cohen's *d*	0.115	0.219	0.441	
	CI	0.052–0.177	0.156–0.282	0.378–0.505	

Note: *MS* = Mean Score; *SD* = Standard Deviation; CI = 95% Confidence Interval; n.s. = not significant.

Table 2. Item difficulties of the 13 multiple-choice system knowledge items to cover basic ecological concepts.

Number	9	2	1	13	5	4	8	7	12	3	6	11	10
Difficulty	0.81	0.71	0.65	0.62	0.59	0.51	0.44	0.42	0.32	0.26	0.25	0.22	0.09

Table 3. Program effects illustrating the trend of pro-environmental shifts on attitude (2-MEV latent factors Preservation and Utilization) and knowledge for two subsamples within a nine-year period; number 1 and 2 in panels display two subsamples.

		Preservation		Utilization		Knowledge	
	Sample	**1**	**2**	**1**	**2**	**1**	**2**
Y key	*MS* pre	3.643	3.956	2.467	2.451	0.500	0.480
	(*SD*)	(0.675)	(0.605)	(0.595)	(0.612)	(0.151)	(0.150)
	MS post	3.882	4.035	2.246	2.366	0.688	0.595
	(*SD*)	(0.600)	(0.554)	(0.515)	(0.668)	(0.164)	(0.175)
	p	<0.001	0.006	<0.001	0.009	<0.001	<0.001
	Cohen's *d*	0.374	0.136	0.397	0.133	1.193	0.706
	CI	0.221–0.528	0.003–0.27	0.243–0.551	0.001–0.266	1.016–1.369	0.538–0.873
	n	331	431	331	431	290	290
No Y key	*MS* pre	3.643	3.921	2.467	2.499	0.515	0.464
	(*SD*)	(0.759)	(0.568)	(0.582)	(0.603)	(0.141)	(0.167)
	MS post	3.882	3.864	2.246	2.430	0.616	0.594
	(*SD*)	(0.654)	(0.612)	(0.533)	(0.643)	(0.169)	(0.214)
	p	0.015	*n.s.*	0.011	n.s.	<0.001	<0.001
	Cohen's *d*	0.337	/	0.396	/	0.649	0.677
	CI	0.001–0.673	/	0.059–0.733	/	0.285–1.013	0.282–1.073
	n	69	89	69	89	61	52
No data on Y key	*MS* pre	3.557	3.891	2.585	2.581	0.429	0.428
	(*SD*)	(0.735)	(0.572)	(0.577)	(0.643)	(0.167)	(0.145)
	MS post	3.711	3.867	2.504	2.511	0.628	0.525
	(*SD*)	(0.603)	(0.546)	(0.523)	(0.607)	(0.186)	(0.174)
	p	0.005	n.s.	n.s.	n.s.	<0.001	<0.001
	Cohen's *d*	0.229	/	/	/	1.126	0.606
	CI	0.019–0.439	/	/	/	0.832–1.42	0.412–0.799
	n	175	376	175	376	103	215

Note: *MS* = Mean Score; *SD* = Standard Deviation; CI = 95% Confidence Interval; n.s. = not significant.

3.3. How Does Attitude Affect Knowledge Scores and Behavior (Y Key)? To What Extend Can We Confirm Our Postulated Structural Equation Model in a State Comparison (AZ, PA, and LA)?

In structural equation modelling, path coefficients (beta regression weights; *b*) reflect the predictive power of explanatory variables. Figure 2 confirmed the high negative correlation between Preservation and Utilization already revealed in Figure 1. Both latent

factors strongly related to their post scores, indicating program effects. The model showed a statistically significant effect from Utilization to knowledge. By pointing identical but inversely correlated constructs at the same variable, a suppression effect might appear where the stronger construct represses the regression weight of the second one [66,67]. The model showed a plausible regression weight ($b = -0.14$) from Utilization but repressed the effect from Preservation and caused it to be statistically insignificant.

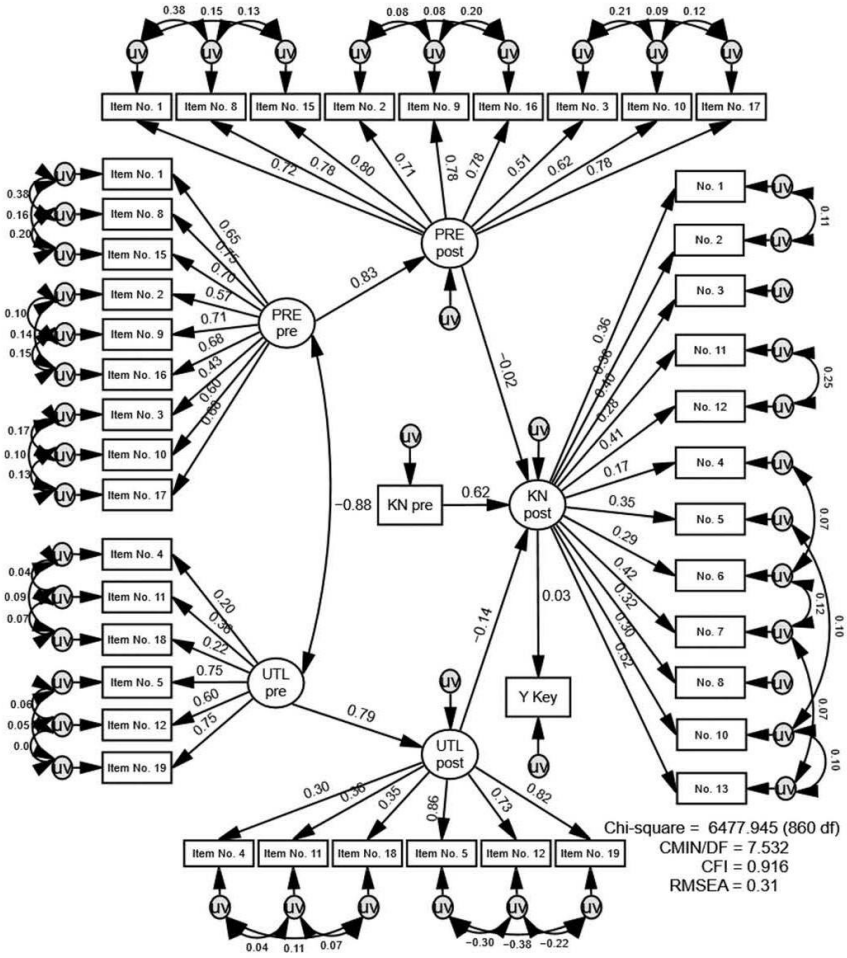

Figure 2. Structural equation model to relate Preservation (PRE) and Utilization (UTL) in a pre-post comparison, and to estimate their effects on environmental knowledge scores (KN). The proxy of behavior (Y key) is the model's last instance. All ellipses are factor-analyzed latents. The pre-knowledge score is also factor-analyzed, but its item structure is not depicted due to place restrictions. The error terms (uv) are correlated and illustrate the first higher order structure of Preservation and Utilization, which is Support, Care with Resources, and Enjoyment of Nature (Preservation), or Altering Nature, and Human Dominance (Utilization). Fit indices are within the thresholds (the Chi-Square relative to the degrees of freedom [CMIN/DF], the Comparative Fit Index [CFI], and the Root Mean Square Error of Approximation [RMSEA]).

Regarding knowledge, we excluded item no. 9 from the factor analysis due to its low loading, its non-significant increase in a pre-post comparison, and because it was by far the most difficult item (Table 2). We then correlated the error terms of the knowledge items belonging together (energy, materials cycling, interrelationships, and change). In a

further step, we excluded all non-significant error-term correlations. Since Preservation and Utilization highly correlated, which suggested Utilization is the reversed measurement of Preservation, and since Preservation showed stronger reliability and validity scores, and since Utilization yielded weaker and inconsistent factor loadings, while there is the notion of one-dimensionality, we proceeded with Preservation only.

Figure 3 illustrates the tailored structural equation model without Utilization. Fit indices increased and the effect of Preservation on knowledge became visible. Our large sample size might produce marginal but still significant effects, so we split our cohort in three subsamples (participants in Arizona, Pennsylvania, and Louisiana) to further test for measurement invariance. Multigroup analyses in AMOS provide simultaneous fit indices, so all four models relied on the indices in Figure 3 and indicated that the data fit the model well and thus had good configural invariance. Table 4 shows the regression weights for each state. The regression coefficients of the pre-post comparison (Preservation and knowledge) were statistically significant throughout all groups. The relationship from Preservation to knowledge was only non-significant for Pennsylvania ($p = 0.061$). Numbers from knowledge to the Y key were statistically significant for two states and slightly above the threshold ($p = 0.083$) in the merged model.

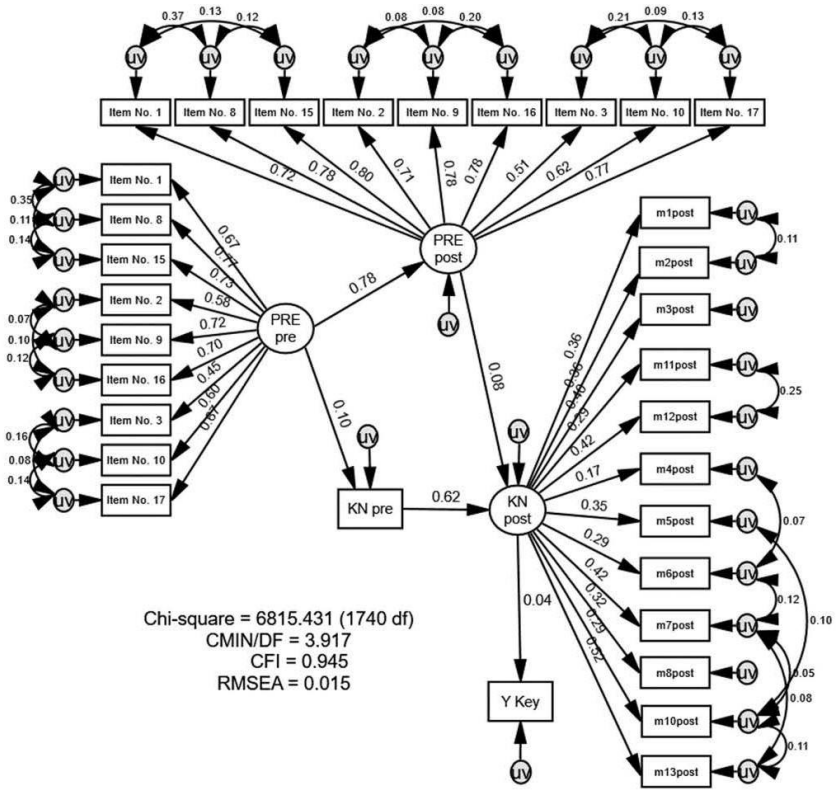

Figure 3. Optimized SEM to relate Preservation (PRE, 2-MEV subscale) to knowledge scores. The multiple group analysis estimates simultaneous fit indices for all models (three state subsamples: AZ, PA, and LA). Error terms (uv) represent disturbing factors. For clarity, the factor analyzed pre-knowledge score (KN pre) is depicted in a rectangle, while all other latent constructs have their factor structure within the model. Fit indices are good with the Chi-Square relative to the degrees of freedom (CMIN/DF) below 5.0, the Comparative Fit Index (CFI) close to 0.95, and the Root Mean Square Error of Approximation (RMSEA) below 0.03.

Table 4. Regression weights (b) between Preservation, knowledge, and the Y key (behavior-indicator) scores of the main model (Figure 3) and its three subsamples Arizona (AZ), Pennsylvania (PA), and Louisiana (LA).

			All	State Comparison		
				AZ	PA	LA
		n	6585	1789	1702	3094
Preservation pre	→ Preservation post	*b*	0.78	0.52	0.77	0.79
		p	<0.001	<0.001	<0.001	<0.001
Preservation pre	→ Knowledge pre	*b*	0.10	0.13	0.18	0.03
		p	<0.001	0.001	<0.001	n.s.
Preservation post	→ Knowledge post	*b*	0.08	0.09	0.05	0.06
		p	<0.001	0.032	n.s.	0.025
Knowledge pre	→ Knowledge post	*b*	0.62	0.47	0.97	0.42
		p	<0.001	<0.001	<0.001	<0.001
Post knowledge	→ Y key	*b*	0.04	0.16	0.12	0.05
		p	n.s.	<0.001	<0.001	n.s.

4. Discussion

4.1. Preservation as the Strong Subscale of the 2-MEV-NEP Comparison

Both scales, the 2-MEV and the NEP, appear to measure an identical environmental attitude construct. The negative correlation of the NEP with Utilization, inversely correlated with Preservation, support the conformity of both tools. We found only one previous study that identified a correlation between the 2-MEV and the NEP [68]; their relationship is substantive (0.51) but not robust as it refers to just 100 participants. It might be sufficient to apply either scale for assessing environmental attitude. The NEP is an established tool that can discriminate between (non-)environmentalists cross-culturally [51] and can be used with children [30], adolescents, and adults [29] alike; however, we chose the 2-MEV (for further arguments, see below). The NEP consisted of more items, yet the 2-MEV subscales showed superior validity and reliability scores (confirmed, e.g., by [62]), with the NEP scoring worse than in previous studies [29]. Comparisons of the NEP, however, are difficult because many researchers do not use a standard number of items and sometimes merge the old and new NEP versions [51]; the old 12 NEP items and the new 15 NEP items differ substantially, though both scales fall under the same acronym. Typically, unidimensional scales provide strong reliability values because all items contribute to one higher order factor. It thus seems that the NEP yielded more latent factors, which might turn the strength of its potential multidimensionality into a weakness; the instrument's dimensionality appears to depend too much on the setting and participants, although there is consensus to use the NEP unidimensionally [29]. Then, the factor analyzed 2-MEV including its construct validity appears to be more stable than the NEP, the latter showing several weak factor loadings. Validity and reliability scores might improve when cutting low loading items; however, others have also raised concerns about the NEP. According to Kaiser et al. [69], the unidimensional NEP insufficiently captures ecological behavior. Schultz and Zelezny [13] deem the NEP deficient as it only reflects environmental concern and disregards further attitudinal concepts, while the 2-MEV might produce a clearer analysis since it attributes a person with a Preservation and Utilization score [31]. Regarding educational recommendations, these two perspectives provide a dual approach. From an anthropocentric perspective (utilization of nature), personal rewards (e.g., money for recycling) can lead to environmentally friendly actions [70]. From an ecocentric or social-altruistic perspective (preservation of nature), an incentive caring for others or the environment can be helpful [13].

When pointing the 2-MEV subscales Preservation and Utilization to knowledge, our structural equation model was supportive for the postulated model. Since both subscales strongly and inversely correlated, and Utilization repressed the regression weight from

Preservation on knowledge, we ran the same model without Utilization. Then, the repressed score between Preservation and knowledge turned into a statistically significant positive effect and fit indices increased. Our decision to proceed without Utilization is based in its weaker reliability and validity scores, the improved model fit indices without Utilization, and is in line with literature. Milfont and Duckitt [10], for instance, confirmed the two-dimensional structure but argued that Preservation had more predictive power. They also found a strong inverse correlation, which pointed towards a bipolar scale with Preservation and Utilization at opposite ends. Yet, the authors did not confine to one-dimensionality as the semantic network technique supported the two-dimensionality despite slight overlaps of both constructs; however, even with this approach, participants were more familiar with Preservation as they showed a more coherent, exhaustive, and positive semantic network opposed to Utilization [71]. Others like Stokols [72] provided a similar but unidimensional scale. He differentiated between a spiritual and instrumental view on the environment. The first regards the environment as an end itself, associated with conservation, protection, and preservation. An instrumental perspective points at an exploitative use of nature where humans dominate the object-like environment. Then, there is a trend of decreasing anthropocentrism and increasing biocentrism with age [73], rendering Utilization alone insufficient to broadly capture environmental attitude. Gardner [74] claimed that good instruments need to be unidimensional and internally consistent, and factor analysis provides the best evidence for dimensionality [75]; loadings with Preservation outnumber those with Utilization [20], indicating the strength of the underlying construct. Higher reliability scores of Preservation have been shown several times (e.g., [10,68]), and some Utilization items were difficult to use with children, probably due to misunderstandings (e.g., [37]). The 2-MEV with its two higher order factors showed moderate fit indices as Preservation and Utilization appear associated rather than orthogonal. As a solution, the Utilization scale could be modified to perfect correlation or omitted. In this study and in the face of a concise attitude scale, we proceeded with Preservation only.

4.2. Effects of Attitude and a Behavior-Indicator (Y Key) on Knowledge Gains, and the Y Key as a Behavior-Measurement for Upper Elementary School Students

Our third model is restricted to Preservation, knowledge, and the Y key, to reflect the components of the knowledge-attitude-behavior relationship. The model was stable and the results were persistent for all states with slight variations. The overall positive effect of Preservation on cognitive achievement is not new [36] and indicates that the stronger a student's pro-environmental attitude, the more they are likely to learn in the areas of energy, materials cycling, interrelationships, and ecosystem changes. This renders Preservation a useful tool to analyze and strengthen pro-environmental attitude. We suggest the moderate effect in the present study could be caused by several factors: US students showed a weaker pro-environmental attitude in a cross-cultural comparison [13]. This corresponds with international polls stating that US citizens were less concerned about environmental problems [53]. We also face the issue of a restricted system knowledge scale, which covers thirteen items of conceptual knowledge but disregards action-related and effectiveness knowledge, which might relate stronger to attitude and behavior [38].

Although the effects on the Y key as a proxy of behavior were statistically significant for the Arizona and Pennsylvania subsamples, they were not for Louisiana. The score for the whole sample is therefore slightly above the significance level. There are various approaches to assess behavior, and we chose the Y key as it is not a momentary self-reported single response but is earned over the course of a month. This is the time required to manifest new habits. The longer and more immersed a person is, and the more opportunities to practice action skills, pro-environmental attitude and behavior will be encouraged [76]. Evans et al. [53] found no substantive relationship between attitude and behavior among 6–8-year students cross-culturally, and they reason it might be too difficult to assess behavior within that age group developmentally and methodologically. We suggest the Y key a useful tool with children as it allows choosing and implementing pro-environmental engagement in individual, more flexible terms, and as it involves

actual performance instead of self-reported behavior. Self-reports imply the risk of social desirability [37,77], and correlations between environmental attitude and behavior are deemed higher with actual behavior [3]. The Y key also demands parent and teacher engagement and collaborative group work, which are contributing factors to environmental education [33]. Indeed, all students who earned the Y key considerably increased their Preservation and knowledge scores, while the Utilization level decreased, indicating a shift from anthropocentrism to ecocentrism. There are only marginal changes for those who did not gain the Y key. It thus might be a motivator to induce pro-environmental behavior. We nevertheless do recognize the additional work to introduce the Y key and collect data a month later.

We had anticipated a stronger relationship between knowledge and the Y key. The modest effect might relate to its measurement, or because we used a narrow knowledge scale, which insufficiently captured cognitive achievement. We also have to be aware that neither knowledge nor attitude directly translate to behavior but are mediated, for instance, through situational constraints (e.g., perceived social pressure, task difficulty) [78] and are only preconditions to behavior [3]. Kaiser et al. [69] refer to such constraints as performance costs and regard knowledge as only one factor that insufficiently determines attitude or behavior. Nevertheless, knowledge is a more proximal outcome of learning, while attitude and behavior develop, e.g., by putting knowledge into practice [39]. In future studies, we aim at extending knowledge at the expense of attitude items to incorporate the tripartite environmental knowledge scale introduced by Frick et al. [32]; these include action-related and effectiveness knowledge items.

4.3. Effects of the Earth Education Program Earthkeepers on Attitude and Knowledge

In a pre-post comparison based on a three-day outdoor earth education program and follow-up pro-environmental engagement, knowledge scores considerably improved. Attitude became more environmentally friendly with Preservation increasing and Utilization decreasing. This is in line with previous findings of the Earthkeepers (e.g., [52]), of extensive exposure to a 10-day environmental program [36], and other long- or short-term educational out-of-class experiences [39,65,79,80]. The earth education program Earthkeepers aims at meaningful outdoor learning and underlines human dependence on nature. It is more effective for students to engage in activities that induce personal relevance, particularly when dealing with complex topics such as (global) environmental issues [81], and feeling dependence increases personal commitment to its welfare [82]. Attitudes are then formed by personal experience [83], and outdoor activities are often cited as a catalyst for engagement [76] especially with long-term experiences [33] as attitude and behavior change slowly [35]. Direct learning opportunities prompt affective learning and contextualize cognitive knowledge [44], which supports the knowledge gains and attitude changes of our study. Encouraging others to behave in an environmentally conscious way is thought to be another useful strategy for long-lasting attitude changes [15], which is assessed with the Earthkeepers S key. This renders the Earthkeepers and similar programs fruitful educational programs to engage students in meaningful learning and to induce attitude shifts with the ultimate goal to foster pro-environmental performance.

4.4. Study Limitations

As indicated in the previous paragraphs, study limitations are mainly methodological. At the expense of using two attitude instruments (2-MEV and NEP), we used a narrow knowledge scale, which was confined to system knowledge and disregarded other types of knowledge (action-related and effectiveness knowledge). Shorter scales generally fall short on predictive power, and those other types of knowledge might relate stronger to pro-environmental behavior. The main purpose of this study was to suggest a concise attitude scale, so in future studies, we aim at elaborating on an environmental knowledge scale. Secondly, though the Y key as a proxy of behavior appears to be a promising predictor for use with children, it is time-efficient to introduce the concept and to collect data one

month after program completion. The Y key further relies on teacher and parent support, which might impact the Y key performance. We therefore lack knowledge on whether the children' pro-environmental engagement was intrinsically motivated, or whether teacher and parents acted as extrinsic motivators. This means we cannot differentiate between students having understood or merely having applied knowledge. Third, we used a large sample-size within 9 years of assessment. Although this allows us to draw robust conclusions as our results hold true for individual years and the total cohort, it entails some drawbacks. Each year was exposed to various environmental issues, e.g., through the media, which might have affected the results. Some tests might produce marginal but still statistically significant effects; we therefore ran several analyses with subsamples (years, states, or schools) to attenuate for such an effect. Lastly, the Earthkeepers program was implemented at three different centers in three different areas of the country. While the activities and overall program did not differ, there are certainly some differences in the details of how the program was enacted, the natural environment and climate, and the backgrounds of the participating teachers and students. Those differences do not appear to be substantial enough to cause significant differences in results between the three areas. This way, having three locations turned into a strength as it implies the program itself contributed to pro-environmental changes.

5. Conclusions

Since there are various measurement tools to assess environmental attitude, and since there is uncertainty about its dimensionality, we aimed at relating two established tools, which is the two-dimensional 2-Major Environmental Values model (2-MEV) and the one-dimensional New Environmental Paradigm scale (NEP), based on the earth education program, Earthkeepers, which has demonstrated success. We used a quantitative approach to include a large sample-size based on three US states (Arizona, Pennsylvania, and Louisiana) to determine the better attitude scale. Although there is sufficient evidence that the 2-MEV and the NEP are valid, reliable tools to assess environmental attitude, in the face of a concise scale, our study points at the advantages to confine to Preservation (2-MEV subscale) as a unidimensional measurement. In a stepwise reduction based on AMOS modelling, reliability and validity tests, and supported by the sensitivity to program effects, we cut the 2-MEV-NEP comparison to Preservation, while both latent factors (Preservation and Utilization) appear to be bipolar rather than orthogonal. As such, Preservation showed a positive effect on system knowledge, rendering it a contributing factor to cognitive achievement. System knowledge related to an indicator of pro-environmental behavior (Y key), and we confirmed our structural equation model in a state comparison with three subsamples (AZ, PA, and LA).

Investigating effects of the three-day earth education program, shifts towards pro-environmental attitude were most prevalent for those who earned the Y key and thus showed pro-environmental engagement within a month after program completion. This suggests assessing the attitude-behavior relationship for children through actual behavior; it also renders the outdoor experience and its incorporation in the classroom setting helpful to induce knowledge and attitude changes towards an environmentally friendly, sustainable lifestyle. Attitude and knowledge assessment follow the goal of program development to promote pro-environmental behavior. We suggest measuring attitude with the Preservation scale (or additional perfectly inversely correlated Utilization items) in order to create more room for further variables within future assessment designs, in which the lengths of questionnaires is a crucial issue.

Author Contributions: T.-M.B.: Conceptualization, Methodology, Formal analysis, Writing—Original Draft, Visualization; B.J.: Resources, Conceptualization, Writing—Review and Editing; F.X.B.: Conceptualization, Methodology, Writing—Review and Editing, Supervision. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: Ethical review and approval were waived for this study, due to a determination that the data were from a pre-existing, de-identified data set and so not considered to be human subjects research.

Informed Consent Statement: Participant consent was waived for this study, due to a determination that the data were from a pre-existing, de-identified data set and so not considered to be human subjects research.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to EU data protection.

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Appendix A

Table A1. Thirteen system knowledge items and their multiple choice answers; there is always one correct answer, so the students could score up to thirteen points.

	Questions	Multiple Choice Answers
1	Only _____ can turn sinlight energy into food.	○ Animals ○ Plants ○ Water ○ Air
2	Which of the following shows a food chain inproper oder?	○ Sun → animals → plants ○ Plants → sun → animals ○ Animals → sun → plants ○ Sun → plants → animals
3	Which of the following would there be the greatest number of in a food chain (munchline)?	○ Plants ○ Animals that eat plants ○ Animals that eat animals ○ They are all equal
4	Which of the following is most true	○ I am made of new materials that have never been part of anything else before. ○ I am made of recycled materials that have been part of other things in the past.
5	The materials that everything is made of:	○ Stay in one place forever. ○ Move in a line, never returning to where they started. ○ Move in circles, often returning to where they started.
6	"I can do just one thing wihtout affecting anything else." This statement is:	○ True ○ False ○ Sometimes true, sometimes false
7	Which of the following is most true?	○ Everything is constantly changing. ○ Nothing is changing. ○ Some things change, but some never do.
8	If a place is now a desert,	○ It could never be an ocean. ○ It may someday be an ocean. ○ It will for sure someday be an ocean.

Table A1. *Cont.*

	Questions	Multiple Choice Answers
9	Where do plants get the energy they need to live and grow?	○ Sun ○ Water ○ Soil ○ Sun, water, and soil
10	Take a look at you pencil. Where the materials that make your pencil ever part of something else?	○ Yes, the materials were once part of something else. ○ No, they were never part of something else.
11	Animals use energy that helps their bodies to live and grow. They get that energy directly from:	○ Sun and water ○ Plants and sun ○ Plants and animals ○ Water and plants
12	People use energy that helps their bodies to live and grow. They get that energy directly from:	○ Sun and water ○ Plants and sun ○ Plants and animals ○ Water and plants
13	Imagine a ship has wrecked at sea spilling toxic chemicals into the ocean. Could those chemicals end up inside your body?	○ Yes ○ No ○ Not sure

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5.6 Teilarbeit D

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The supportive role of environmental attitudes for learning about environmental issues

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ABSTRACT

People's commitment to environmental preservation (i.e., environmental attitude) appears to be critical for manifest engagement. Correspondingly, it seems advisable that environmental scientists, educators, and policy-makers also pay heed to environmental attitude's role in learning, another form of manifest behavior. In our research, we tested the hypothesis that people with stronger environmental attitudes learn comparatively more about environmental issues than people with weaker such attitudes. In a sample of 1,896 students ($M = 14.2$, $SD = 1.8$), we identified people's environmental attitudes in their verbal expressions of support for preserving the environment and their self-reports of past behavior aimed at preserving the environment. We corroborated our hypothesis and found that people's preexisting environmental attitudes supported their acquisition of new knowledge. We also corroborated the characteristic developmental trajectory of adolescents' environmental attitudes with an early maximum at around age 11 or 12, a minimum at around age 16, and a subsequent recovery.

1. Introduction

People's commitment or lack of commitment to environmental preservation and climate change mitigation (i.e., environmental attitude) is a mental entity that can directly be seen in what people do or fail to do to preserve earth's climate and other aspects of our environment (see, e.g., Kaiser et al., 2020; Taube et al., 2018; Taube & Vetter, 2019). Less clear is environmental attitude's role in knowledge acquisition and learning. For some, expanding environmental knowledge appears decisive for changing people's environmental attitudes (e.g., Dresner & Gill, 1994; Indriani et al., 2019; Mittelstaedt et al., 1999; Smith & Paladino, 2010), whereas others argue for the opposite, namely, that what people know about the environment is contingent upon their environmental attitudes (see Henn et al., 2019; Taube et al., 2021).

In this study, we tested environmental attitude's significance for learning about environmental issues, which can be seen in the amount of preservation-relevant knowledge that students eventually retain. To do so, we propose a view of environmental attitude that is grounded in Bogner and Wiseman's (1999) well-established notion that people's attitudes reflect their commitment to environmental preservation. Expectedly, this commitment becomes recognizable in people's verbal expressions of support for preserving the environment and their self-reports of past behaviors that were aimed at preserving the environment (see, e.g., Kaiser & Wilson, 2019).

1.1. Environmental attitude: a reflection of people's commitment to preservation

Scholars have not always agreed on the proximate psychological causes (i.e., people's personal reasons) for environmental preservation. Whereas some believe that environmental preservation depends on people's commitment to preserving the environment (e.g., Dunlap et al., 2000), others see it as a function of people's esteem for and commitment to utilizing nature (e.g., Thompson & Barton, 1994). When the two perspectives have been integrated into a single theoretical framework, it has repeatedly though illogically been found that people who value nature and its use actually *do not* value environmental preservation (see, e.g., Bogner & Wiseman, 1999; Milfont & Duckitt, 2004).

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In contrast to these typical findings, with their version of Bogner and Wiseman's (1999) theoretical framework, Kaiser et al. (2013) achieved the expected strong ($r \geq 0.50$) positive association between preservation-related environmental attitude (termed preservation by Bogner and Wiseman [1999]) and use-of-nature-related environmental attitude (termed utilization by Bogner and Wiseman [1999]). Thus, Kaiser et al.'s (2013) version of the model fittingly suggests that people with favorable views of environmental preservation simultaneously hold favorable views of the natural environment and activities in nature and vice versa. This newly proposed variant of Bogner and Wiseman's (1999) model is based on the Campbell paradigm (see, e.g., Kaiser, 2021; Kaiser et al., 2010).

The Campbell paradigm provides a theoretical framework that proposes that people's attitudes become apparent in what they say and do to attain the goal implied by an attitude (see Kaiser & Wilson, 2019). This goes against the conventional view that attitudes are conveyed only by what people say, for example, "preserving the environment is essential" or "people should not abuse the environment" (see, e.g., Dunlap et al., 2000; Milfont & Duckitt, 2004). If a favorable view of environmental preservation is the attitude, preserving the environment is the attitude-implied goal. Goals are attained through verbal and other forms of behavior, and behaviors come with costs.

Costs are generally effective barriers to behavior (e.g., time, money, effort, inconvenience). For example, turning off the lights when leaving a room is an action that comes with few behavioral costs. By contrast, regularly donating time and money to environmental organizations is rather demanding. Accordingly, if someone strives to preserve the environment, they can be expected to accept costs to an extent that is congruent with the strength of their environmental attitude (Kaiser, 2021; Kaiser & Lange, 2021). In other words, an attitude becomes obvious in the face of increasingly demanding barriers. If someone avoids purchasing single-use products, buys seasonal produce, and contributes to environmental organizations, we can conclude they have a comparatively strong environmental attitude. But if the tiniest obstacle or inconvenience is enough to stop people from making environmentally friendly choices, their environmental attitude is probably rather weak. In summary, people's attitudes—as mental entities—become manifest in their verbal and nonverbal actions. The more obstacles someone is willing to overcome to attain an attitudinal goal, the stronger the attitude (i.e., the commitment to the goal; see, e.g., Campbell, 1963; Kaiser, 2021; Kaiser et al., 2010).

So far, individual differences in people's environmental attitudes and the costs of specific behaviors have repeatedly been found to jointly, but separately, affect people's likelihood of engaging in manifest behavior aimed at preserving the environment: their sustainable mobility (Taube et al., 2018), green consumption (Taube & Vetter, 2019), and vegetarian lunch choices (Kaiser et al., 2020). Accordingly, Kaiser (2021) argued that environmental attitude and the costs that come with a behavior cooperatively—in a complementary fashion—shape the likelihood that behaviors aimed at preserving the environment will occur (see also Kaiser et al., 2010). Expectedly, only people with comparatively strong environmental attitudes engage in behaviors that impose severe personal restrictions or require serious monetary sacrifices (see Kaiser, 2021).

1.2. Environmental attitude's relevance for learning

One effective way to change people's manifest behavioral engagement is to disseminate information, for example, through school systems (for reviews, see Boerschig & Young, 1993; Heimlich & Ardoin, 2008; Leeming et al., 1993; Zelezny, 1999) or through campaigns or on-site instruction (see, e.g., Dresner & Gill, 1994; Duerden & Witt, 2010; Jordan et al., 1986). Thus, it seems safe to conclude that providing information is an effective way to promote various preservation-related activities (see Osbaldiston & Schott, 2012). Environment-related information typically refers not only to the factual understanding of environmental topics but also to reasons why and instructions on how to perform preservation-related behaviors (e.g., Frick et al., 2004; Roczen et al., 2014). However, the critical questions are different ones: What makes people learn about environmental issues and, given the chance, do all people learn equally well?

Initially, we need to understand what makes people seize learning opportunities. In the logic of the Campbell paradigm, seizing learning opportunities involves various manifest behaviors (e.g., reading a text, absorbing information, writing a paper). These behaviors can be regressed on two sources: costs and attitudes (see Fig. 1). Accordingly, learning activities become more probable when the behavioral costs of learning get smaller. Lowering the costs of learning entails actions, such as (a) adapting a teacher's vocabulary by, for example, reducing the complexity of the terminology, (b) providing visualizations and illustrations of facts and theories, and (c) organizing content in a stepwise, constructive manner (for recommendations, see Rickinson, 2001). In summary, students grasp information better when it is presented to them in a pedagogical manner.

Another way to facilitate learning is by providing information in and of itself because students will not need to search for the information themselves. In other words, learning becomes more likely in an environment in which students are more or less forced to spend time with and engage with a topic (e.g., in a classroom).

Besides responding to the costs of learning, according to the Campbell paradigm, students will also seize learning opportunities more readily when they care about a topic (e.g., DeHouwer, Barnes-Holmes, & Moors, 2013). Thus, the Campbell paradigm explains engagement in learning with the costs of a specific learning activity and with students' personal commitment—the strength of their environmental attitudes (see Fig. 1). For any behavior (including learning activities) to have a reasonable chance of manifesting, an individual's environmental attitude must offset the costs of the specific activity (Kaiser, 2021; Kaiser & Lange, 2021). Expectedly, Taube et al. (2021, Study 4) found that people with more pronounced environmental attitudes seized the opportunity to voluntarily learn about climate change more readily by exposing themselves to longer and more elaborate videos.

As the seizing of learning opportunities by itself and, thus, engagement in learning activities as such are not enough to fully understand

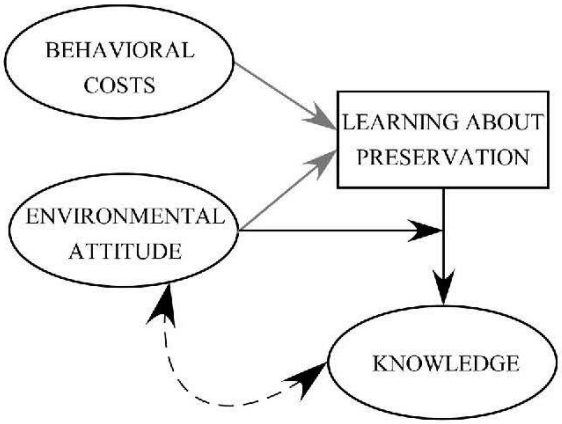

Fig. 1. Environmental attitude's two roles in learning preservation-relevant information adapted from Henn et al. (2019). In the first role implied by the Campbell paradigm, people's attitudes and the costs of learning jointly control the likelihood that learning as a form of behavior will occur. In the second role suggested by Henn et al. (2019), people's attitudes generally moderate the efficacy of learning activities. In other words, the amounts of knowledge students retain are contingent on how intensely students engage in their learning opportunities. Arrows indicate directed relationships, whereas the double-headed arrow indicates the positive correlation between the consequence of learning (i.e., knowledge) and people's preexisting attitudes.

how much students eventually learn, the Campbell paradigm as a behavior model is somewhat incomplete. We also need a better grasp of the forces that influence the *consequences of students' learning activities* (i.e., how much knowledge they retain). To fully understand how much knowledge about a certain topic students actually retain, it is important to understand that learning opportunities can be implemented *in more or less rigorous ways* (see Henn et al., 2019). Students can be more or less attentive, they can expend more or less time or effort on assignments, and so forth. Expectedly, how much students eventually learn about preservation-relevant issues—the consequences of the various learning activities—depends on the intensity with which people make use of learning opportunities (see Fig. 1).

In other words, learning can be seen in its consequences—in the amount of knowledge a person retains. Retained knowledge depends not only on whether or not people engage in learning activities but also on the rigor with which people make use of learning opportunities (i.e., the intensity with which they learn). According to Henn et al. (2019), this rigor depends on students' commitment to the very topic, for example, to environmental preservation—apparent in their environmental attitudes. Here, attitude operates as a moderator of the various learning activities (see Fig. 1). Consequently, people with strong environmental attitudes—people strongly committed to environmental preservation—also know disproportionately more about environmental preservation than people with weak environmental attitudes (see, e.g., Maurer & Bogner, 2020; Schneiderhan-Opel & Bogner, 2020).

In summary, people's environmental attitudes are supportive of learning about environmental preservation in two ways: They promote not only whether people engage in a specific behavior (e.g., a learning activity) but also how rigorously they engage in it—that is, how rigorously they learn and consequently how much knowledge they retain (see Fig. 1). This is why there is usually at least a weak but reliable positive correlation between people's commitment to environmental preservation and their actual knowledge about preservation-relevant issues (see, e.g., Arbuthnot, 1977; Frick et al., 2004; Roczen et al., 2014).

Because of environmental attitude's supportive role in learning, environmental attitude's characteristic development throughout adolescence (see Buttel, 1979; Krettenauer, 2017; Olsson & Gericke, 2016) might also be an important aspect for understanding what makes adolescents seize learning opportunities or not. Specifically, at around ages 11 and 12 when people's environmental attitudes consolidate as a trait-like feature, people's environmental attitudes seem to reach an early maximum (Otto et al., 2019). Afterward, they drop to a minimum before they recover and reach the level of mature adults.

1.3. Research goals

We conducted a secondary analysis of four empirical studies that all had research ambitions that differed from the three goals of this research (detailed below). Whereas all the original studies had explored effects of environmental education programs (learning modules about climate change, the forest ecosystem, abiotic and biotic interactions, and renewable energies) on students' knowledge levels, they had done so without using a Campbell-paradigm-based environmental attitude measure.

Goal 1. The primary goal of our secondary analysis of the four previously collected data sets was to better understand environmental attitude's role in knowledge acquisition and learning. More specifically, we followed Henn et al.'s (2019) logic and went beyond the Campbell paradigm in order to show that people with stronger environmental attitudes learn more rigorously and, thus, typically retain more environmental knowledge than people with comparatively weaker environmental attitudes (even when exposed to the same information and learning environment). In other words, what people gain in terms of knowledge about the environment depends on their commitment to environmental preservation (i.e., their environmental attitudes; see Fig. 1).

Goal 2. One secondary goal of this research concerned the common practice of operationally defining measures by their indicators (see DeHouwer, Gawronski, & Barnes-Holmes, 2013). Specifically, in line with Kaiser et al. (2018; see also Kaiser & Wilson, 2019), we aimed to show that the measurement of environmental attitude does not need a particular, predefined set of indicator items. People's environmental attitudes can be derived from various manifest and verbal acts: expressions of esteem for, intentions to engage in, and self-reports of (past) environmental preservation. For this purpose, we merged items from two well-established environmental attitude measures—the preservation-relevant items from Bogner and Wiseman's (1999) scale and the environmental attitude measure proposed by Kaiser et al. (2007)—into one joint scale.

Goal 3. Another peripheral goal was to validate the newly developed measurement instrument. Should this new instrument indeed validly capture environmental attitude, we expected to find the characteristic attitude trajectory throughout adolescence with an early maximum at around ages 11 to 12, a drop to a minimum, and the suspected subsequent recovery.

2. Method

We confirm that this paper reports on all studies, measures, and conditions that we used in our research. We provide the specific inclusion criteria for the employed studies and report all data we excluded. Because we conducted a secondary analysis, we had no influence on the original sample sizes. For our research, an overall sample size of $N = 100$ was deemed minimally necessary. This was because data from 100 individuals are expected to yield reasonably precise cost estimates within a Rasch scale calibration (see Wright, 1977).

2.1. Participants and procedure

For our secondary analysis, we included studies that were conducted with coincidentally selected classes within schools that covered an age range from upper elementary to high school. All studies addressed different topics (see Table 1) but used a pre-post design to explore educational interventions with environmental knowledge as the criterion. In addition to administering environmental knowledge scales before and after the intervention, studies had to have minimally employed 14 of the 40 items from Kaiser et al. (2007) and 15 of the 20 items from Bogner and Wiseman (1999) as indicators of environmental attitude before the intervention. In our main analyses, we ignored all the other measures used in the original studies (e.g., the Big Five, inclusion of nature). The four original studies took place in the same geographical region (i.e., Upper Franconia) and in a similar time period (i.e., between 2011 and 2014) with German-speaking students from one type of school (i.e., lower secondary). Therefore, students were likely exposed to comparable contextual conditions (e.g., policies, media content, social norms). No study that would have met the specific inclusion criteria was disregarded.

Our sample originated from four data sets (see Table 1). It consisted of 1,592 students between the ages of 11 and 19 ($M = 14.47$, $SD = 1.78$). Gender was evenly distributed: 49.9% ($n = 795$) male and 49.6% ($n =$

Table 1
The Four Studies Included in our Secondary Analysis.

Original study	Type of instruction	M_{Age} (*SD*) age range	*N*	Year	Duration	$M_{Attitude}$ (*SD*)	Items
Schneiderhan-Opel and Bogner (2021)	In- and out-of-class module about the forest ecosystem	12.72 (0.74) from 11 to 18	688	2011	3 days	−0.23 (0.54)	55 (40/15)
Sattler and Bogner (2017)	On-site module about (a-)biotic interactions in a zoo	15.71 (0.76) from 14 to 19	337	2011	3h	−0.76 (0.89)	55 (40/15)
Bissinger and Bogner (2018)	On-site (botanical garden) and eLearning module about climate change and the tropical rainforest	15.77 (1.39) from 13 to 19	319	2014	4–5h	−0.84 (0.51)	35 (20/15)
Schumm and Bogner (2016)	In-class module about renewable energies	16.02 (0.57) from 15 to 18	248	2014	3h	−1.35 (0.77)	29 (14/15)

Note. Year refers to the year in which the data were collected. Duration refers to the duration of the specific educational intervention. Attitude refers to environmental attitude. Items refers to the number of attitude items in each study (# of items from Kaiser et al., [2007]/# of items from Bogner and Wiseman [1999]).

790) female students (seven students provided no gender information). The youngest sample ($N = 688$) contained comparatively fewer older students but still covered the entire age range needed to retrace the trajectory of environmental attitude from ages 12 to 18 (see Table 1).

2.2. Measures

With our study, we aimed to connect students' environmental attitudes with their gains in environmental knowledge. Thus, we needed measures of students' preexisting environmental attitudes and their environmental knowledge levels before and after an educational intervention.

Environmental attitude was calibrated in its typical way as a Rasch scale using the dichotomous Rasch model (for more details about Rasch models, see Rasch, 1960/1980; for a more recent example, see Wilson, 2005). The specific measure that we used is a variant for adolescents of a well-established instrument for adults (see Kaiser et al., 2007). This variant consists of 40 self-reports of behavior, such as "I am a member of an environmental organization" and "I collect and recycle used paper" (for the full list of items, see Table 1A in the Appendix). Respondents reported on each specific item using either a 5-point frequency format ranging from 0 (*never*) to 5 (*always*) or a yes-no format. "Not applicable" could be chosen when participants were—for whatever reason—unable to provide an answer. The not applicable responses were treated as missing values.

As an extension of the 40 behavioral self-reports, we adopted 15 of Bogner and Wiseman's (1999) items that we thought revealed a person's commitment to environmental preservation equally well. They consisted of expressions of personal opinions about environmental preservation (e.g., "We must set aside areas to protect endangered species") and self-reports of past environmental preservation activities (e.g., "I save water by taking showers rather than baths"; for all 15 items, see Table 1A in the Appendix). People responded to Bogner and Wiseman's (1999) items on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*).

In three of the four original studies, the environmental attitude items were split into two distinct sets (with some overlapping items) to reduce the lengths of individual surveys. The two sets were randomly administered to students *before* each educational intervention (for more details about item administration, see the original studies in Table 1). Due to the specific features of Rasch models (i.e., uniform item discrimination), participants can still be quantitatively compared, even when they do not respond to the same number of items or even to the same items as long as all the items can be calibrated on a single scale (see Kaiser et al., 2018). Accordingly, Rasch scale calibrations and thus cost and attitude estimates can be attained even with incomplete data records that contain missing values, as the estimation procedure is based on a maximum likelihood approach (for more details, see, e.g., Embretson & Reise, 2000).

Of the 55 items, 22 were negatively formulated (see Table 1A in the Appendix). All these negatively formulated items, which represent a lack of commitment to environmental preservation, were reverse-coded before we calibrated the Rasch scale. To use the classical Rasch model, the 55 polytomous items also had to be converted into a dichotomous format. To do so, the responses never, seldom, occasionally, strongly disagree, disagree, and not sure/neutral were coded as expressions of a lack of commitment to environmental preservation (0). The responses often, always, agree, and strongly agree were coded as expressions of commitment to environmental preservation (1). Reducing the absolute number of response options before calibrating the scale is a well-established and justified approach for preventing unreliable measurement due to excessive measurement error (for more details and some supporting evidence, see Kaiser & Lange, 2021). Note that this procedure differs from dichotomizing person scores after establishing an attitude scale as a continuous measure (DeCoster et al., 2009).

Environmental knowledge, as with any other form of knowledge, involves a specific attainment, namely, correctly answering questions about a topic. Thus, a typical way to explore interindividual differences in knowledge is to present individuals with increasingly demanding tasks or questions. As the Rasch model is based on this notion, it is often the model of choice in the educational assessment of knowledge differences (e.g., Wilson, 2005). Kaiser and Frick (2002) developed an environmental knowledge measure as a Rasch scale with which they distinguished between items representing environmental system knowledge, action-related knowledge, and effectiveness knowledge (see also Frick et al., 2004; Roczen et al., 2014).

System knowledge refers to questions about how ecosystems operate or to knowledge about environmental problems. A typical example is knowledge about the mechanisms behind global warming (see, e.g., Taube et al., 2021). Action-related knowledge is knowing how, that is, knowledge of behavioral options and possible courses of action (see Frick et al., 2004). People may know all about microplastic pollution (i.e., system knowledge) without knowing what actions to take to reduce their personal share of microplastics. Effectiveness knowledge captures the ecological impact (e.g., in the amount of CO_2 emissions) that is associated with various behavioral alternatives (see Frick et al., 2004). For example, in some circumstances, buying an electric car can be a better way to cut down on one's personal CO_2 emissions than driving a conventional car less frequently.

Due to miscommunications, the order and coding details for the knowledge items in the respective data records could not be reestablished in three of the four original studies. Accordingly, we were unable to recalibrate the knowledge scales in these studies. Thus, we had to limit our exploration of students' gains in environmental knowledge to only one of the four studies (i.e., Schneiderhan-Opel & Bogner, 2021). In this study, which used a 3-day environmental education program,

students dove into the forest ecosystem using a multisensory approach.

First, they learned facts about ecosystem fundamentals (e.g., key plants and animals in the forest ecosystem and how they are related in the food chain). Subsequently, they explored the forest with their senses (e.g., feeling tree bark) and learned about the importance of forests (e.g., ecosystem services, such as paper production) and their preservation. Finally, students were encouraged to reflect on this new information and derive knowledge about preservation options (e.g., how they could reduce their personal carbon footprint).

Seven of the 15 questions asked about forest ecosystem knowledge, four about action-related knowledge, and four about effectiveness knowledge. Nine of the 15 questions were presented in a multiple-choice format with four response options, one of which was correct. Another six questions were presented in a dichotomous correct/incorrect format. Unanswered questions were coded as missing; 17.61% of all answers to the knowledge questions presented to students had missing responses. All knowledge questions were presented twice, before and after the educational intervention.

Environmental knowledge was calibrated as a unidimensional Rasch scale (for computational details, see Adams & Khoo, 2015). Knowledge was measured in logits such that more positive logit values indicate more pronounced environmental knowledge. Logits represent the natural logarithm of the ratio between the relative frequencies of correct and incorrect responses. The environmental knowledge values fell between −3.19 and 2.95 logits and were approximately normally distributed ($M = -0.04$, $SD = 1.01$, skewness = 0.18, kurtosis = 0.34). The separation reliability indicated that the scale was fairly accurate in distinguishing students ($rel = 0.59$). Fit values reflect the relative discrepancy between the Rasch model's predicted responses and students' actual responses. With mean square (*MS*) values—weighted by the item variance—that fell between 0.84 and 1.26 (a list of items and their fit statistics is available upon request), the Rasch model's predictions showed a fair fit to the knowledge item responses (see Wright et al., 1994).

3. Results

We report the results in two sections. In the first section, we document the Campbell-paradigm-based environmental attitude measure's ability to capture interindividual differences, its applicability across different groups of people, and its ability to retrace the typical trajectory of environmental attitude throughout adolescence. In the second section, we present results from our test of environmental attitude's role in knowledge acquisition and learning. Specifically, we expected environmental attitude to be correlated not only with students' environmental knowledge but also with their respective gains in environmental knowledge.

Table 2
Psychometric features of two environmental attitude measures: The well-established original and the extended scale.

	Original scale	Extended scale
ITEM FIT STATISTICS:		
Number of items	40	55
M(MS)	0.98	0.99
SD(MS)	0.07	0.08
Minimum (MS)	0.84	0.81
Maximum (MS)	1.27	1.22
PERSON FIT STATISTICS:		
Number of participants	1,592	1,592
M(MS)	1.02	1.01
SD(MS)	0.22	0.18
% people with poor fit (t > 1.96)	3.1%	4.2%
Separation reliability	.60	.72

Note. The original scale refers to 40 binary-coded behavioral self-reports. The extended scale refers to the original scale plus 15 more binary-coded preservation-related items. Mean square (*MS*) values were weighted by the item variance. They reflect the relative discrepancy between the model predictions and the observed data and were used to assess model-data fit (see, e.g., Wright & Masters, 1982).

3.1. Measurement of environmental attitude

To demonstrate that environmental attitude does not need a predefined set of items to be measured validly, we calibrated two separate instruments. In addition to calibrating the original 40-item measure of the environmental attitude scale for adolescents (see Kaiser et al., 2007), we also calibrated the version of the instrument that included Bogner and Wiseman's (1999) 15 preservation-relevant items. The two versions of our environmental attitude measure were calibrated separately as Rasch scales.

3.1.1. Capturing interindividual differences

Table 2 shows that the two calibrations—the original and the extended environmental attitude measures—yielded quite comparable overall fit statistics. In our assessment of fit (i.e., the correspondence between Rasch-model-predicted and actual response patterns in the data), we relied on the mean square (*MS*) values as our fit statistic. *MS* values are less sensitive to sample size than *t* values (both reported in Table 1A in the Appendix). An *MS* value > 1.20 corresponds to an excess in variability of more than 20% in the data than predicted by the Rasch model.

If anything, the overall psychometric features regarding items and persons of the new longer scale (55 items) was a slight improvement over the original scale (40 items; see Table 2). The fit statistics for the individual items were also reasonable in general with *MS* values—weighted ($_w$) and unweighted ($_u$) by the item variance—that fell within an acceptable range of fit in 52 cases: $0.80 \leq MS_w \leq 1.20$ and $0.60 \leq MS_u \leq 1.40$ (see Wright et al., 1994). Only three items violated our benchmarks to a minor extent. These somewhat poorer item fit statistics point to behaviors that are not well-connected to students' environmental attitudes. Apparently, adolescents—even when they are committed to preserving the environment—use battery-operated appliances (e.g., cell phones), travel abroad, and do not discard batteries properly (Items 3, 7, and 14, respectively, in Table 1A in the Appendix).

Logits are the units with which the proposed scale reflects people's environmental attitudes and the estimated behavioral costs that are thought to obstruct engagement or agreement reflected by items. More positive logit values correspond with stronger environmental attitudes and with items reflecting more challenging behavioral costs. Logits represent the natural logarithm of the ratio between the relative frequencies of expressions of commitment and expressions of a lack of commitment. People's environmental attitudes fell between −3.59 and 1.39 logits ($M = -0.68$, $SD = 0.78$), and the proposed measure's ability to accurately distinguish the environmental attitudes of adolescents was reasonable—with a separation reliability of $rel = 0.72$ (considerably higher than the original scale's reliability of 0.60; see Table 2). For a summary of the new scale, see Fig. 2.

Two indistinguishable orders of people with respect to their environmental attitudes can be seen in a Pearson correlation of $r_{corr} = 1.0$ (i.e., $r = 0.79$ without correcting for measurement error attenuation). This correlation speaks of the convergent validity and perhaps even the "specific objectivity" (e.g., Rasch, 1977) of the extended and original environmental attitude measures. Specific objectivity in this context means that two people's environmental attitudes can be quantitatively compared with each other even when different measurement instruments were used to assess these attitudes (for more details, see Kaiser et al., 2018). With this invariance in the measurement of environmental attitude from the specifics of any single measurement instrument, we can be more confident that our two scales reflect an objectively recognizable reality that differentiates people.

Another quality indicator of measurement instruments is their "fairness" when measuring different groups of people (see, e.g., Fischer,

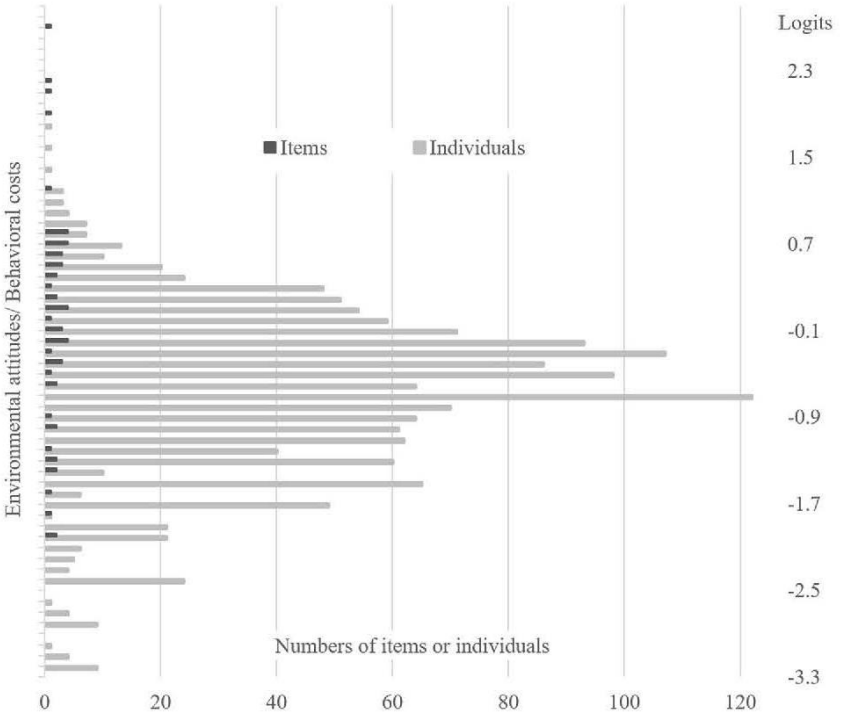

Fig. 2. Map of items and individuals for the newly developed environmental attitude scale. Items (I 55) are ordered from those reflecting low (negative logits) to high costs (positive logits). Individuals (*N* 1,592) are ordered from those with weak (negative logits) to strong attitudes (positive logits).

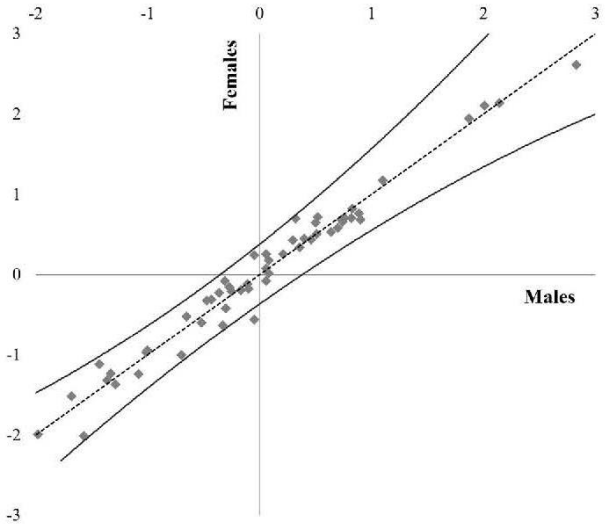

Fig. 3. Cost estimates reflected by items for female (*n* 790) and male (*n* 795) adolescents. The cost estimates for both subsets were comparable as only one fell outside the 95% confidence interval (solid black lines). The dotted line is the identity line.

1987). For example, if items were comparatively less inviting for women than for men to approve or reject, then a more pronounced level of environmental attitude for the advantaged group would be an artifact of the instrument rather than a reflection of differences in men's and women's commitment to environmental preservation. In the following, we test the new scale's fairness in assessing male and female adolescents.

For this fairness test, we formally examined the items for differential item functioning (DIF) by separately calibrating the instruments for males and females. Fig. 3 illustrates that the cost estimates reflected by the items for the two gender groups were fairly similar such that all fell within or very close to the 95% confidence interval around the identity line. This correspondence between the cost estimates for males and females can additionally be seen in a Pearson correlation of $r = 0.99$. Therefore, we can safely conclude that the cost estimates from our new Campbell-paradigm-based measure were comparable—and thus, fair—indicators of the respective environmental attitudes of male and female adolescents.

According to the Campbell paradigm—the theoretical framework on which the proposed environmental attitude measure is based—the behavioral costs reflected by the items can indeed be seen as informative benchmarks for the required strength of people's environmental attitudes (e.g., Kaiser, 2021; Kaiser & Wilson, 2019). Consequently, people's attitudes can be recognized in the behavioral costs (represented by an item) that people accept (see Kaiser et al., 2021; Kaiser & Lange, 2021). The more obstructions people overcome, the stronger their

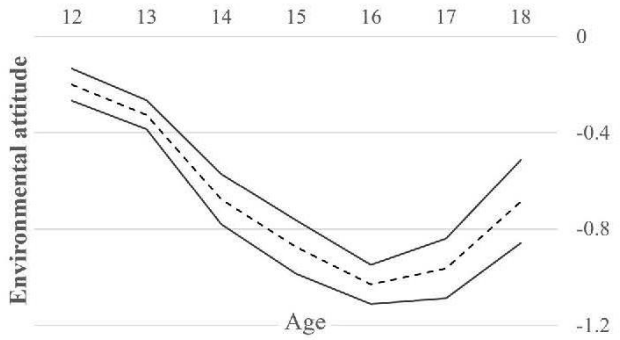

Fig. 4. Environmental attitudes of 12- to 18-year-old students (12: n 272; 13: n 325; 14: n 146; 15: n 235; 16: n 424; 17: n 120; 18: n 36). The mean trend is depicted by the dashed line; the solid lines represent the 95% confidence interval.

attitudes (see, e.g., Campbell, 1963; Kaiser, 2021; Kaiser et al., 2010). Rather fittingly, only people who are strongly committed to preserving the environment—people with strong environmental attitudes—claim to be members of an environmental organization and to read about environmental problems (the two items with the highest cost estimates, see Table 1A in the Appendix). At the other extreme, only people with very weak commitment do not even claim to save water by taking showers or to collect their garbage after a picnic (the two items with the lowest cost estimates).

3.1.2. *Retracing environmental attitude throughout adolescence*

As one more element in our endeavor to validate our proposed measurement approach, we tried to retrace environmental attitude's suspected trajectory throughout adolescence (see Krettenauer, 2017; Otto et al., 2019). With our data, we initially corroborated Krettenauer et al.'s (2020) medium-sized negative correlation (in a Canadian sample) between age and environmental attitude ($r = -0.39$, $p < .001$, $R^2 = 0.15$; $r_{Krettenauer} = -0.26$, $p < .001$, $R^2 = 0.07$).

Subsequently, we directly tested the curvilinear relationship between age and environmental attitude, with an early maximum at around ages 11 to 12, a drop to a minimum, and a subsequent recovery (see Fig. 4), with a nonlinear regression model. Due to small numbers of individuals, we dropped the 11- and 19-year-olds from our analyses (11: $n = 9$; 19: $n = 10$). Similar to what could be expected on the basis of Krettenauer (2017) and Otto et al. (2019), we found that a quadratic regression significantly described the trajectory depicted in Fig. 4, $F(2, 1522) = 157.1$, $p < .001$. The quadratic polynomial explained about 2% more variance in people's environmental attitudes across age groups compared with the 15% explained by the linear model: environmental attitude $= 0.04*age^2 - 1.30*age + 9.93$ ($R^2 = 0.17$).

3.2. *The supportive role of environmental attitude for learning*

Finally, we tested environmental attitude's role in knowledge acquisition and learning. In a first step, we corroborated the expected (see Fig. 1) small but substantial correlation between students' preexisting environmental attitudes and their environmental knowledge levels before ($r = .14$, $p = .001$, $N = 585$) and after ($r = 0.25$, $p < .001$, $N = 583$) the educational intervention.

In a second step, we regressed the environmental knowledge levels students attained after the educational intervention ($M = 0.41$, $SD = 1.04$) on their preexisting environmental attitudes ($M = -0.23$, $SD = 0.54$) while controlling for their previous environmental knowledge ($M = -0.48$, $SD = 0.72$). In this multiple regression, we found that students' postintervention knowledge was systematically related to their prior environmental knowledge levels and to their preexisting environmental attitudes, $F(2, 579) = 36.5$, $p < .001$, $R^2 = 0.11$. Both relationships were significant ($ps < .001$) with fairly comparable magnitudes: the connection was marginally stronger for prior knowledge ($\beta = 0.24$) than for preexisting environmental attitude ($\beta = 0.21$).

4. Discussion

With our research, we found that prior knowledge and preexisting environmental attitudes are both relevant for environment-related learning to similar extents. People who know comparatively more before an educational intervention continue to know more after the intervention. This connection between prior and later knowledge seems to confirm persistent differences in students' general "store of knowledge" (i.e., sometimes called crystallized intelligence; see Nisbett et al., 2012). One straightforward explanation might be that knowledge in general or environmental knowledge in particular are mental facilities that become recognizable in persistent differences in the amounts of knowledge that students can instantaneously access. An alternative explanation could be that the persistent differences in students' knowledge derive from differences in people's abilities to learn—also called fluid intelligence (see Nisbett et al., 2012). In other words, differences in what students know and retain are typically due to differences in the ease with which they learn.

Apart from representing a mental ability in and of itself or representing a more general mental facility (e.g., intelligence), persistent knowledge differences could also result from persistent differences in students' reasons for acquiring knowledge. The same reasons that accounted for why some students knew more about environmental issues prior to the intervention might have continued to be effective and made students more enthusiastic about seizing a new learning opportunity. In other words, the persistence of knowledge differences could speak of the continued efficacy of what made and makes students differentially inclined to learn about environmental preservation. Such reasons could involve, among other things, gaining a teacher's respect or one's peers' admiration (see, e.g., Urdan & Maehr, 1995).

Although students' commitment to preserving the environment (i.e., their environmental attitudes) could have been such a persistent reason too, our data speak against this particular explanation. The connection between prior and later knowledge did not disappear when we controlled for students' environmental attitudes in a multiple regression. In other words, the continued efficacy of students' commitment to preserving the environment cannot be held accountable for the fact that students who knew more about environmental issues before the intervention continued to know more afterward.

However, the connection between preexisting environmental attitude and environmental knowledge after the intervention—over and above what people knew beforehand—seems to speak of the supportive role of environmental attitude for acquiring new environmental knowledge. Thus, people's environmental attitudes are critical for not just what people do to preserve the environment (see, e.g., Kaiser et al., 2020; Taube et al., 2018; Taube & Vetter, 2019) but also how vigorously

they pursue new opportunities to learn (see Taube et al., 2021) and how rigorously they learn about preserving the environment (see Henn et al., 2019). If people differ in how intensely they learn, it is no surprise that they also differ in how much knowledge they retain even when exposed to the same learning opportunities in the same learning environment.

As expected, after an educational intervention, people with stronger environmental attitudes knew more about the environmental content of the intervention than people with weaker such attitudes. As a consequence, we were able to confirm the typical positive correlation depicted in Fig. 1 between people's environmental attitudes and their knowledge about preservation-relevant issues (see also, e.g., Arbuthnot, 1977; Roczen et al., 2014). Because the knowledge-attitude correlation was even more pronounced after the educational intervention, we can conclude that the gains in knowledge about the environment somehow rest on people's commitment to environmental preservation. The stronger students' environmental attitudes, the more knowledge they gained from the educational intervention. In this manner, our research speaks of the supportive role of people's environmental attitudes for knowledge acquisition and for learning.

Despite its plausibility, the connection between preexisting environmental attitude and environmental knowledge after the intervention can nevertheless be explained in alternative ways as we cannot be certain that the relationship between environmental knowledge and environmental attitude is not spurious (see, e.g., Shannon, 2004). For instance, students from a higher socioeconomic background are typically more diligent or compliant in any learning environment and, thus, they learn better and more (see Sirin, 2005). And the higher socioeconomic background of students might also contribute to a comparatively higher commitment to environmental preservation (see Evans et al., 2018; Gifford & Nilsson, 2014). Predictably, the connection between preexisting environmental attitude and environmental knowledge after the intervention could simply represent the fact that socioeconomic status is correlated with both of them simultaneously. When we included the one theoretically sensible confounding factor that was available to us (i.e., inclusion of nature) in our regression model, both prior knowledge's and environmental attitude's relationships with postintervention knowledge remained unaffected. Thus, and as far as we were able to verify, the two relationships we identified in our research were not spurious.

As a prerequisite for our exploration, we had to corroborate that people's environmental attitudes—a mental entity—can reliably be derived from verbal expressions of support for preserving the environment (e.g., by disagreeing with the assertion that our planet has unlimited resources; Item D in Table 1A in the Appendix) and from self-reports of past behavior aimed at preserving the environment (e.g., by claiming to turn off the lights when leaving a room, Item 33 in Table 1A in the Appendix). Because both measures of environmental attitude—the original 40-item and the extended 55-item versions—were virtually indistinguishably able to capture individual differences in people's environmental attitudes, we believe we can conclude that we do not need a fixed set of items that operationally define a commitment-to-environmental-preservation measure when we use the Campbell paradigm to measure it (Kaiser et al., 2018).

Due to the fact that we were also able to document the characteristic trajectory throughout adolescence, we gained confidence in the validity of the proposed Campbell-paradigm-based environmental attitude measure. At the same time, we do not have an explanation to offer for the characteristic shape with an early maximum at around age 11 or 12, a minimum at around age 16, and a subsequent recovery (see Fig. 4; see also Krettenauer, 2017; Otto et al., 2019). Olsson and Gericke (2016) suggested that a teaching tradition that is too normative for adolescents should be held accountable for the dip at age 16. However, the hypothesis awaits further empirical testing.

As always, shortcomings could have affected our findings. First, the data that we used in our secondary analysis originated from studies that all had different research goals, employed different educational interventions in different settings, and involved samples from different schools and students with somewhat varied age ranges (see Table 1). As all these influences could attenuate the relationship depicted in the Campbell paradigm by adding measurement error, they could have handicapped the calibration of our environmental attitude measures and, subsequently, our ability to identify learning effects.

Second, we used cross-sectional data to retrace the trajectory that has been suggested to describe the development of adolescents' environmental attitudes. This is a minor concern, as the trajectory has historically been derived from longitudinal (see Otto et al., 2019) and cross-sectional data (see Krettenauer, 2017). Nevertheless, we should acknowledge some inconsistencies in the actual turning points in the trajectory. Both Otto et al.'s and Krettenauer's data suggested that the minimum occurs much later than age 16. Our reliance on a nonrandom sampling of schools and a comparatively small number of schools could explain these inconsistencies. In other words, we cannot dismiss sampling error—and, thus, sample particulars (e.g., a curricular focus on sustainability issues, sociocultural student background)—as potential sources of the specific turning points we found in our research. Future research will have to resolve these issues.

Third, attitude measurement occurred with a reduced set of items (see Table 1). This means that we had missing data by design, which negatively affected the accuracy of our measures of people's environmental attitudes by generally inflating the standard errors of measurement. Once again, this decrease in measurement accuracy was a handicap that could have compromised our ability to find learning effects. Accordingly, replicating environmental attitude's relevance for learning with other data sets is certainly sensible and continues to be an open task.

The knowledge that students retain after some instruction or educational intervention seems, as we have demonstrated, to depend on the rigor (i.e., the intensity) with which students seize their learning opportunities (e.g., about a forest ecosystem and how to preserve it; see also, Taube et al., 2021). And because this rigor expectedly requires personal commitment, students' preexisting environmental attitudes (i.e., their personal commitment to environmental preservation) are presumed to play a supportive role in students' abilities to acquire new knowledge and, thus, for learning.

CRediT authorship contribution statement

Tessa-Marie Baierl: Writing – original draft, Data curation, Formal analysis, Visualization. **Florian G. Kaiser:** Conceptualization, Writing – review & editing. **Franz X. Bogner:** Funding acquisition, Writing – review & editing.

Appendix

Table 1A
The 55 Environmental Attitude Items Ordered by Their Estimated Costs

		δ	MS_w	MS_u	t_w	t_u
1	I am a member of an environmental organization.	2.74 (.18)	.98	1.15	-.1	.8
2	I read books, publications, and other materials about environmental problems.	2.18 (.14)	.95	.84	-.4	−1.1
3	I refrain from using battery-operated appliances.	2.09 (.18)	1.02	**1.43**	.2	**2.1**
4	I contribute financially to environmental organizations.	1.94 (.14)	.95	.84	-.4	−1.1
5	I buy products in refillable packages.	1.15 (.13)	.95	.93	-.6	-.6
6	I prefer products with eco-labels.	.83 (.09)	.95	.92	-.9	−1.0
7	*I put used batteries in the garbage.*	.82 (.06)	1.15	**1.92**	**3.9**	**11.8**
A	*People worry too much about pollution.*	.79 (.06)	1.07	1.11	1.9	1.7
8	I have pointed out unenvironmental behavior to someone.	.77 (.07)	1.08	1.21	**2.2**	**3.2**
9	I buy certified organic foods.	.74 (.09)	.97	.94	-.5	-.8
10	I keep gift-wrapping paper for reuse.	.72 (.06)	1.05	1.06	1.6	1.1
11	*If I am offered a plastic bag in a store, I take it.*	.72 (.09)	1.00	.99	.0	-.1
12	*In hotels, I have the towels changed daily.*	.65 (.08)	1.01	.98	.3	-.2
B	*Society will continue to solve even the biggest environmental problems.*	.61 (.06)	1.12	1.21	**3.7**	**3.5**
13	I have tried to persuade my parents to buy an energy-efficient car.	.59 (.08)	1.11	1.35	**2.6**	**4.6**
C	We must set aside areas to protect endangered species.	.59 (.06)	1.08	1.12	**2.5**	**2.1**
14	I insist on vacations close to home.	.51 (.08)	**1.22**	**1.64**	**5.6**	**8.5**
15	I collect and recycle used paper.	.51 (.06)	1.03	1.00	1.1	.0
16	I use writing pads made from recycled paper.	.45 (.07)	.97	.95	−1.0	-.9
17	*After one day of use, my sweaters or pants go into the laundry.*	.43 (.09)	1.02	1.05	.7	.7
D	*Our planet has unlimited resources.*	.35 (.06)	.93	.87	**−3.1**	**−2.8**
E	Industrial smoke from chimneys makes me angry.	.34 (.09)	1.00	.99	.1	-.2
18	I ask my parents to buy seasonal produce.	.23 (.08)	1.01	1.06	.4	1.0
19	*I prefer markers to crayons for drawing.*	.16 (.06)	1.01	1.00	.4	.1
20	I learn about environmental issues from the media (newspapers, apps, and TV).	.12 (.07)	1.13	1.32	**4.1**	**5.2**
F	*To feed people, nature must be cleared to grow food.*	.09 (.06)	.90	.88	**−5.1**	**−3.0**
G	*Worrying about the environment often holds up development projects.*	.06 (.06)	.94	.90	**−3.3**	**−2.5**
21	*I eat at fast-food restaurants, such as McDonalds and Burger King.*	.05 (.07)	1.00	1.00	.2	-.1
22	*In the winter, it is warm enough in my room to only wear a T-shirt.*	-.01 (.06)	.97	.95	−1.6	−1.1
23	*I leave electrically powered appliances (TV, stereo, printer) on standby.*	-.05 (.06)	1.05	1.10	**2.6**	**2.0**
24	*I order take-out pizza.*	-.06 (.07)	1.05	1.04	**2.3**	.9
25	To make notes, I choose paper that has already been used on one side.	-.12 (.08)	.94	.93	**−3.1**	−1.6
26	*I kill insects with a chemical insecticide.*	-.19 (.07)	1.04	1.03	1.8	.7
27	*At my parties, we use plastic silverware and paper cups.*	-.21 (.07)	1.00	.99	-.1	-.2
H	*Building new roads is so important that trees should be cut down.*	-.23 (.05)	.87	.82	**−8.2**	**−5.1**
28	*I am driven around by car.*	-.24 (.05)	1.13	1.18	**7.6**	**4.6**
29	In the winter, I turn down the heat when I leave my room for more than 4 h.	-.30 (.08)	.99	1.00	-.3	-.1
30	*On fieldtrips, I bring beverages in single-use packages.*	-.37 (.08)	.97	.95	−1.3	-.9
I	*Nature is always able to restore itself.*	-.38 (.05)	.91	.90	**−5.7**	**−3.0**
J	*Human beings are more important than other creatures.*	-.42 (.07)	.95	.92	**−2.3**	−1.5
K	Humankind will become extinct if we don't live in tune with nature.	-.50 (.06)	1.14	1.17	**9.1**	**4.6**
31	I eat seasonal produce.	-.58 (.07)	1.00	1.00	.1	.0
L	*People have the right to change the environment (nature).*	-.61 (.05)	.92	.89	**−5.3**	**−3.3**
32	*I buy beverages in cans.*	-.86 (.09)	.93	.90	**−2.7**	−1.8
M	It makes me sad when nature is cleared to be used by humans.	−1.00 (.06)	.88	.86	**−6.3**	**−4.3**
N	*Only plants and animals of economic importance need to be protected.*	−1.02 (.05)	.89	.85	**−6.2**	**−4.4**
33	When I am the last person to leave a room, I turn off the lights.	−1.20 (.08)	.81	.78	**−6.6**	**−4.4**
34	I buy beverages in returnable bottles.	−1.32 (.11)	1.03	1.03	.7	.4
35	I bring empty glass bottles to a recycling bin.	−1.32 (.10)	.99	.99	-.2	-.1
36	I reuse my shopping bags.	−1.36 (.08)	.96	.94	−1.1	−1.0
37	For short distances (within 15 min), I walk or ride a bike.	−1.38 (.07)	.90	.87	**−3.8**	**−2.9**
38	I ride a bicycle, take public transportation, or walk to school.	−1.64 (.07)	.90	.87	**−3.1**	**−2.7**
39	I separate waste from recyclables.	−1.80 (.12)	.97	.94	-.4	-.7
O	I save water by taking showers rather than baths.	−2.02 (.08)	.97	.93	-.7	−1.1
40	After a picnic, I leave the place as clean as it was before.	−2.04 (.09)	.90	.81	−1.9	**−2.6**

Note. Items *in italics* represent negatively formulated items; they were recoded and should be read as "I refrain from … " or "I contest that …". The 15 grey-shaded items are from Bogner and Wiseman (1999). The other 40 items are from Kaiser et al. (2007). Cost estimates (δ) are expressed in logits along with their corresponding standard errors of measurement (*SEM*). Mean square (*MS*) and *t* values—unweighted ($_u$) and weighted ($_w$) by the item variance—reflect the relative discrepancy between the model's predicted and students' actual responses and were thus used to assess item fit (see, e.g., Wright & Masters, 1982). **Bold numbers** highlight either statistically significant *t* values ($p < .05$) or MS_w values that did not fall within an acceptable range of fit even for test items ($0.80 \leq MS \leq 1.20$) and MS_u values that did not fall within the acceptable range for typical survey items ($0.60 \leq MS \leq 1.40$; see Wright et al., 1994). A value of $MS > 1.20$ corresponds to an excess of more than 20% variation in the data than what was predicted by the Rasch model.

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Informal Earth Education:

Significant Shifts for Environmental Attitude and Knowledge

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Informal Earth Education: Significant Shifts for Environmental Attitude and Knowledge

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Environmental education aims to affect environmental knowledge and attitude to ultimately induce pro-environmental behavior. Based on 247 upper elementary school students, we tested the impact of an outdoor-based earth education program on environmental knowledge and attitude with a pre-post design. Both outcome measures were Rasch scales. Environmental knowledge is a composite of 27 system, action, and effectiveness knowledge items, and environmental attitude is a composite of 13 evaluative statements and 11 self-reported behaviors about nature preservation. Our analysis revealed gains in environmental knowledge and attitude. The convergence between knowledge and attitude increased significantly from pre- to post-program, and attitude played a significant role in knowledge acquisition.

Keywords: earth education, informal learning, environmental attitude, environmental knowledge, Campbell paradigm, Earthkeepers

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INTRODUCTION

For the past decades, the world has been facing increasing environmental challenges of threats, including climate change, resource scarcity, waste accumulation, plastic pollution, and deforestation. Several initiatives attempt to promote environmental awareness and a sustainable lifestyle (UNEP, 1978; UNESCO, 2003), including environmental education at an early age. School curricula have been slow to embrace environmental issues, and short-term interventions in the traditional classroom setting seem to have little impact on long-term pro-environmental shifts, so more intense outdoor programs, such as the Earthkeepers earth education program, become increasingly attractive. Earthkeepers is a 3-day residential earth education program with 1-month or more follow-up activities; it is an informal teaching approach that has shown to result in environmental knowledge and attitude shifts (e.g., Manoli et al., 2007; Johnson and Manoli, 2008; Činčera and Johnson, 2013; Baierl et al., 2021). This study goes a step further than those studies on Earthkeepers to not only test knowledge and attitude shifts but whether they converged over the course of the program, with measurements framed by the Campbell paradigm (e.g., Henn et al., 2019; Baierl et al., 2022), which would support attitude's critical role for knowledge acquisition.

Earthkeepers is an earth education program framed as a "magical learning adventure" developed for upper elementary school students (Van Matre and Johnson, 1988) that originated in the

United States and is implemented in different states and around the world (e.g., Činčera and Johnson, 2013; Baierl et al., 2021). It aims to affect environmental attitude and three types of knowledge (i.e., system, action, and effectiveness knowledge; Frick et al., 2004; Roczen et al., 2014) through a 3-day holistic outdoor experience and 1-month or more follow-up activities, with the goal of participants becoming more inclined to pro-environmental engagement. In the program, participants can earn four *keys* to unlock the secrets of becoming an Earthkeeper, the word itself being an acronym for the main components of the program (knowledge, experience, yourself, and sharing). During the initial 3 days at the outdoor center, learners engage in participatory activities to learn about four ecological concepts, namely, energy flow, cycling of materials, interrelationships, and change, and to experience the natural world to earn the K and E keys. Back at home and school, participants work on lessening their impact on and deepening their feelings for the environment to earn the Y key, and they also share their experiences with others to earn the S key and become Earthkeepers. Teachers and parents support the participants in documenting behavior changes and provide evidence that they engaged in lessening their impact and deepening feelings for at least 1 month, with the idea that doing something regularly for that long can form new habits. The program thus resonates with a long tradition of sustainability education, which aims at balancing knowledge, attitudes, and practices to guide students toward sustainability (Salas-Zapata et al., 2018). Several studies of the Earthkeepers program report knowledge gains (e.g., Činčera and Johnson, 2013; Manoli et al., 2014) and positive attitude changes in 4–6 weeks after the residential program (e.g., Manoli et al., 2007, 2014; Baierl et al., 2021). Earthkeepers thus show promising potential to foster long-term pro-environmental shifts.

There is a growing research body on the environmental knowledge-attitude relationship framed by the Campbell paradigm that points at attitude's role in knowledge acquisition (e.g., Kaiser and Frick, 2002; Frick et al., 2004; Roczen et al., 2014; Henn et al., 2019; Baierl et al., 2022). Within the Campbell paradigm, one can derive an attitude through self-reported behaviors or opinion-based statements by confining to their underlying goal, rendering goals reflections of attitudes (Kaiser and Wilson, 2019). One behavior can be fueled by several goals (Kaiser, 2021): People could refrain from single-use plastic bags because (1) there is a charge on it, (2) they are inclined toward environmental preservation, or (3) in some countries, it might be socially proscribed to use such bags. Scales should therefore ask for a variety of opinions and behaviors to disentangle an underlying attitude (Kaiser, 2021); in this study, i.e., environmental attitude, which reflects a person's commitment to nature preservation that becomes manifest in protective behaviors or expressions of support for nature preservation. Such behaviors and opinions come with behavioral costs. Costs are the obstacles a person overcomes to carry out behavior, and those are resources, such as time, money, or energy. Reading books and other materials about environmental preservation requires all three of those resources and is, therefore, a behavior that comes with high costs, whereas separating waste from recyclables requires neither money nor a lot of time if done on a regular basis and if the cultural setting provides for it (e.g., government supplying free garbage bins). Costs can thus be imposed by societal constraints or infrastructure (money, time, effort, convenience, or social expectations) and strongly relate to culture, so ecological behavior is not stable but context-dependent, and behaviors can be ordered in terms of costs (Kaiser et al., 2010). We can therefore assume that people agree with increasingly demanding behaviors in a way that is congruent with their attitude. If a person rejects low-cost behaviors, such as reusing shopping bags or turning off the light when it is needed no more, we can conclude a weak environmental attitude. On the contrary, if a person buys products in refillable packages or with eco-labels and contributes to environmental organizations, we can expect a rather strong attitude.

With a Campbellian perspective on attitude that differentiates behaviors in regard to their costs and people's likelihood of engagement in increasingly costly behaviors, attitude's role in learning, i.e., knowledge acquisition as the behavior, becomes more apparent. Then, an attitude affects (1) the probability and (2) the intensity of engaging in learning activities, with knowledge as a somewhat measurable outcome (Henn et al., 2019; Baierl et al., 2022). Following this logic, learning activities can lower costs in two ways: First, through the provision of information, students do not need to make an effort and actively seek information; second, through presenting information in an appealing and exciting way (e.g., acknowledging learning theories, such as the cognitive load theory) that reduce costs (Chandler and Sweller, 1991). It requires, e.g., more cognitive resources if a complex environmental issue is presented in a small-print, long text (i.e., concentration is required to disentangle essential information) than when it is sequenced in blocks, reduced to its essentials, and some information is substituted or embellished by visuals like graphs or pictures. In a Campbellian sense, it would require a stronger attitude to engage in such a small-print, long text, whereas a visually engaging text can capture low-attitude students when the educational goal is to impart and acquire information.

However, information is not all the same but can be separated in system, action, and effectiveness knowledge (Frick et al., 2004; Roczen et al., 2014). System knowledge (i.e., procedural knowledge; Schultz, 2002) corresponds with facts or conceptual understanding (Frick et al., 2004), and in this case, can be knowledge about ecological systems or information on human impact on Earth (Díaz-Siefer et al., 2015). Building on system knowledge, action knowledge covers behavioral choices. A person could know about climate change, e.g., the effects of rising CO_2 and CH_4 levels in the atmosphere (system knowledge) but lack knowledge about climate-friendly actions, such as using public transportation instead of your car (action knowledge). Effectiveness knowledge is on a higher level and asks for general gains and environmental benefits. It points at broader impacts (Schultz, 2002) through concepts, such as saving energy and reducing carbon emissions on a larger scale like political regulations, so those could be ordered hierarchically regarding their effectiveness (Frick et al., 2004). All those categories form environmental knowledge, and, synergistically, they can help guide toward environmental preservation. The Earthkeepers program incorporates this framework of

environmental knowledge, and in this study, we aim to relate it to environmental attitudes.

RESEARCH QUESTIONS

Using a shorter, more practicable version of Baierl et al.'s (2022) scale, which is a Rasch-calibrated compilation of expressions of opinions about nature preservation (Bogner and Wiseman, 1999) and self-reported behaviors to preserve the environment (Kaiser et al., 2007), this study investigated the following questions:

(1) How do knowledge and attitude scores change after participation in the earth education program Earthkeepers?
(2) How do knowledge and attitude scores relate over the course of the Earthkeepers program (T1 = before and T2 = 4–6 weeks after the 3-day residential course)?

MATERIALS AND METHODS

Participants and Procedure

Participants consisted of 247 upper elementary school students (age $M \pm SD$: 9.38 ± 0.51; $n = 235$, 12 students provided no information on age). School classes in the Tucson area in Arizona, United States, visited the earth education center to participate in the Earthkeepers program as part of their education, so participation was not voluntary for students. Gender showed an almost even distribution with 54.7% ($n = 135$) of females and 41.3% ($n = 102$) of males; 10 students provided no information on gender. All participants completed the paper-and-pencil questionnaire 1–2 weeks before (T1) and 4–6 weeks after (T2) the 3-day Earthkeepers program in Arizona, United States. The students experienced nature holistically on-site (i.e., using their senses to tune in on nature, or inquiry-based hands-on explorations) and learned about their natural environment (e.g., system knowledge: how nutrients cycle, action knowledge: the environmental impact of importing fruits, and effectiveness knowledge: hierarchically listing which common electric devices use most fossil fuels). Following the on-site program, educators helped the students put the newly learned knowledge into practice by choosing at least *one behavior* to reduce their energy consumption (e.g., using a bicycle instead of getting a ride by car) and at least *one behavior* to reduce their material use (e.g., re-using paper that has already been used on one site, or taking a shower instead of a bath). The students were encouraged to implement those individual behaviors for at least 1 month after the residential course and to document whether they met their goals in their training manual. Their parents were introduced to the manual and received a four-page explanation on the Earthkeepers and its follow-up tasks. Those tasks referred to the individual behavior changes and nature experiences, so the students were encouraged to regularly spend time outdoors and reflect on their experiences as well as reduce their energy and material use. The manual provided space for the students to document their behavior changes and for recording their thoughts on their nature experiences. Parents then signed whether those things were done, and the teachers talked to the students about the manual. Teachers and parents thus provided evidence that the participants engaged in pro-environmental behavior for at least 1 month after the residential course, and most participants earned the final keys (Y and S) as part of program completion. This helps investigate long-term effects. Since control groups have repeatedly shown no significant changes in knowledge or attitude while Earthkeepers participants did (Johnson and Manoli, 2008; Činčera and Johnson, 2013; Baierl et al., 2021), a control group was not used in this study.

Measures

We are interested in environmental knowledge, environmental attitude, and their relationship. Therefore, we used an environmental knowledge and attitude scale.

Environmental Knowledge

The scale contained 27 items and covered system, action, and effectiveness knowledge (Frick et al., 2004). In total, 13 items involved facts and concepts about our natural environment, such as how energy flows and the materials cycle. Based on this, five action knowledge items asked about behavior options to turn system knowledge into practice: People can, e.g., know about plastic pollution but to protect nature, they further need to know which behaviors reduce their plastic share. In addition, nine effectiveness knowledge items covered the efficiency of conservation behaviors. Studies showed that all three dimensions are helpful for pro-environmental engagement and that all three dimensions work synergistically (e.g., Roczen et al., 2014), so we merged them for our analyses. The participants answered in a multiple-choice format with three to four answer options. For system knowledge, there was one correct answer to gain one point per item. For action and effectiveness knowledge and in line with a partial-credit model, participants could further gain half-points for a good but not the best answer. For the question "Which item is less harmful for the environment to consume?," participants gained no point for ticking "farm-raised meat," half a point for "farm-raised veggies," and one point for "homegrown foods" (see item 11 and all other knowledge items in the **Supplementary Table 1**).

We conducted a Rasch analysis for all 27 items (Rasch, 1980 or Wilson, 2005; for computational details, see Adams and Khoo, 2015). The person separation reliability by Wright and Masters (1982) estimates the ratio between actual performance (observed behavior) minus the mean square errors of those estimates and the variance of behavior scores; it indicates that our scale was acceptable ($rel = 0.63$). Item difficulties (δ) showed an even distribution from −2.27 to 2.24 with the mean arbitrarily set at zero ($M = 0.00$, $SD = 1.03$). Person parameters ranged from −1.44 to 3.09 ($M = 0.56$, $SD = 0.80$). Negative numbers indicate easier items and lower person estimation scores, while the higher the number, the more challenging an item or the higher the probability of that particular person to give the correct answer is (Bond and Fox, 2007). A person's ability score of 0 indicates that a person is likely to answer 50% of all questions correctly. For item fit assessment, mean square values (MS) show the correspondence between our

data and the Rasch-model prediction, and infit MS should fall between $0.80 \leq MS \leq 1.20$ (Bond and Fox, 2007); MS thus indicate the discrepancy between the model's prediction and the observed data. The knowledge items ranged from the value of MS as 0.86 to 1.27, so they were well within or close to the threshold. For an exhaustive list of items and fit indices, refer to **Supplementary Table 1**.

Environmental attitude was assessed using 13 items from Bogner and Wiseman's (1999) scale modified for use with children in the United States (Johnson and Manoli, 2008) and 11 items from Kaiser et al.'s (2007) scale. The item compilation covers opinions about nature preservation (i.e., evaluative statements) and self-reports of past preservation-relevant engagement, and is jointly used to measure environmental attitude. It has been suggested to collapse attitudinal instruments within the Campbell paradigm to one dimension, disregarding whether they relied on evaluative statements or self-reported behaviors (e.g., Kaiser et al., 2013; Kaiser and Wilson, 2019), and Baierl et al. (2022) did so with Bogner and Wiseman's (1999) and Kaiser et al.'s (2007) scales without the need of a predefined fix set of items; both instruments seem to complement each other as Bogner and Wiseman's (1999) scale contains items that are easier to agree with (people only have to agree with expressions about nature preservation, which requires on average fewer costs) and Kaiser et al.'s (2007) scale contains preservation-based items that are more demanding (people have to actually perform pro-environmental behaviors, which requires on average more costs), so we tested a shorter and slightly modified version for use with children in the United States.

Our attitude measure consisted of 24 items and was calibrated using the dichotomous Rasch model (Rasch, 1980; Wilson, 2005). The participants responded to each item on a five-point frequency scale ranging from strongly disagree to strongly agree (Bogner and Wiseman, 1999) or never to always (Kaiser et al., 2007), and we reverse-coded six negatively formulated items reflecting an environmentally harmful tendency before the analysis (**Supplementary Table 2**). We dichotomized those polytomous items with strongly disagree, disagree, and not sure/neutral, or never, seldom, and occasionally representing a low-attitude level, while agree and strongly agree, as well as often and always represent a high-attitude level. Collapsing polytomous scales to a dichotomous format is a well-justified approach to prevent excessive measurement error, particularly in attitude research (Matell and Jacoby, 1971; DeCoster et al., 2009). This way, we assessed environmental attitude through personal parameters, and the higher the score, the stronger the probability for environmental preservation-related engagement—a representation of environmental attitude. Scores ranged from −2.35 to 3.73 ($M = 0.60$, $SD = 1.01$). The separation reliability was reasonably accurate ($rel = 0.73$), and item fit statistics showed a fair model fit with MS ranging from 0.9 to 1.16. Item difficulties (δ) ranged from −1.58 to 2.5, and their perceived costs aligned with previous studies, e.g., trying to persuade parents to buy an energy-efficient car as a rather demanding, and taking a shower instead of a bath as a more effortless behavior (e.g., Kaiser et al., 2007; for all items and further fit statistics, **Supplementary Table 2**).

Statistical Analysis

Our data were not normally distributed; since tests of the Statistical Program for Social Sciences (SPSS, 24 version) yielded identical results for all (non-) parametric calculations, we report parametric outcomes to be consistent with most studies having used these instruments. The *T*-tests were used to identify program effects, correlations were used for trends, and regression analyses were used for investigating attitude effects on knowledge (gains) and their convergence. We further used a Rasch model (Maximum-likelihood estimates) and dichotomized the five-point frequency scale for attitude (Rasch, 1980; Wilson, 2005). The probabilistic Rasch measurement acknowledges individual engagement (number of items answered positively) and item difficulty (number of people answering to an item positively) and allocates each participant a score (Bond and Fox, 2007). To conduct the Rasch analysis, we used the software ConQuest (Adams and Khoo, 2015).

RESULTS

Promotion of Environmental Knowledge and Attitude

Between T1 and T2, knowledge levels increased, and a *T*-test confirmed statistically significant gains (pre: $M = 0.368$, $SD = 0.67$, 95% CI: 0.28–0.45; post: $M = 0.751$, $SD = 0.88$, 95% CI: 0.65–0.87; $p < 0.001$, $d = 0.49$, $n = 246$). A similar pattern, though the increase was not as large, occurred for environmental attitude (pre: $M = 0.495$, $SD = 0.86$, 95% CI: 0.37–0.59; post: $M = 0.706$, $SD = 1.12$, CI: 0.57–0.85; $p = 0.001$, $d = 0.22$, $n = 244$; **Figure 1**). There were no considerable gender differences.

Environmental Attitude as a Lever for Knowledge Acquisition

We correlated knowledge and attitude scores before the program and after the program completion. While both correlations were statistically significant (pre scores: $r = 0.189$, $p = 0.003$, $n = 246$ and post scores: $r = 0.391$, $p < 0.001$, $n = 244$), knowledge and attitude scores correlated significantly stronger after the intervention ($z = -2.438$, $p = 0.007$), which indicates that knowledge and attitude scores converged between T1 and T2. This speaks for a synergistic effect with attitude promoting knowledge acquisition; participants with a stronger pro-environmental mindset seem more likely to learn and to learn more intensely about nature and environmental preservation.

Therefore, we corroborated the dependence of knowledge on attitude levels by conducting a multiple regression analysis. The model showed a high goodness-of-fit ($R^2 = 0.239$; adjusted $R^2 = 0.233$; Cohen, 1988). Both knowledge levels before the intervention and attitude levels were statistically significant predictors of post-knowledge scores: $F(2, 242) = 38.05$, $p < 0.001$. While prior knowledge appeared to be the stronger predictor ($\beta = 0.455$, $p < 0.001$), attitude levels also showed a statistically significant effect ($\beta = 0.114$, $p = 0.045$) on the participants' post-program knowledge scores. We then regressed knowledge gains on environmental attitude, which revealed a statistically

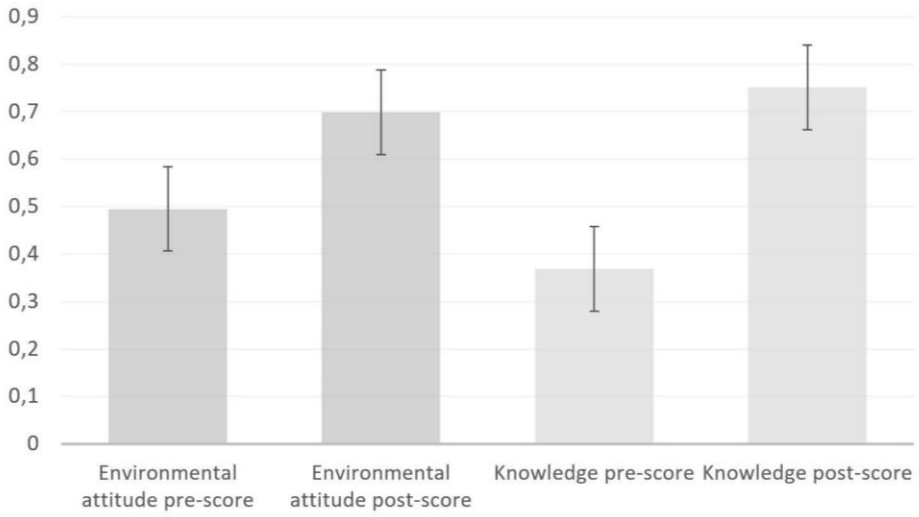

FIGURE 1 | Program effects were statistically significant for environmental attitude and knowledge; error bars indicate 95% confidence intervals. The data were assessed 1 week before and 6–8 weeks after the residential earth education program to determine long-term changes. The *Y*-axis gives the Rasch calibration output, and the higher the score, the more knowledge is prevalent or the stronger the attitude is.

significant effect of attitude on the knowledge participants gained and retained between T1 and T2: $\beta = 0.229$; $F(1, 242) = 13.45$, $p < 0.001$; $R^2 = 0.049$ (**Figure 2**).

To further test attitude's role in knowledge acqisition, we tested the role of attitude changes in knowledge gains (i.e., post-program attitude scores minus attitude scores before the program), which turned out to be statistically significant: $\beta = 0.176$; $F(1, 241) = 7.68$, $p = 0.006$; $R^2 = 0.027$. We then tested the effect of prior knowledge scores on attitude changes ($\beta = 0.102$), which indicated that attitude increases did not depend on what students knew at the beginning of the program, so attitude gains were not significantly related to prior knowledge levels: $F(1, 242) = 2.56$, $p = 0.111$; $R^2 = 0.049$. Quite the opposite, i.e., increases in environmental attitudes seemed to promote knowledge gains.

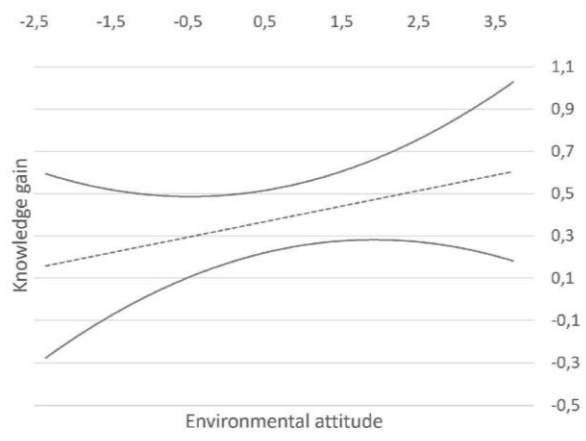

FIGURE 2 | Environmental knowledge gains after the Earthkeepers program regressed on environmental attitude. Their relationship is depicted in the dashed upward trend line. Bold lines show the 95% confidence interval. Both scales are based on a Rasch calibration, so the higher the score, the more knowledge students gained and the stronger the attitude is.

DISCUSSION

We applied an abbreviated version of Baierl et al.'s (2022) proposed scale that builds on opinion-based expressions to preserve the environment and self-reported preservation-related behaviors to jointly capture environmental attitudes. Our analysis confirmed that environmental attitude's sound assessment does not depend on a specific set of verbal statements but can be retrieved from various self-reported opinions and behaviors about nature preservation framed by the Campbell paradigm (Kaiser and Wilson, 2019), even with children in a particular environmental setting (i.e., Arizona desert). Based on the scale's sound calibration, results indicated that it was sensitive to pro-environmental shifts in participants in an earth education program and valuable to knowledge acquisition.

Effects of the Earth Education Program Earthkeepers

Participants showed pro-environmental shifts in environmental knowledge and attitude 6–8 weeks after the 3-day outdoor earth education program and its one-month follow-up activities. The participants gained and retained knowledge about the environment—a composite of understandings (e.g., how materials cycle and energy flows), knowledge about environmentally friendly behavior options (e.g., how to save water and energy), and general strategies for nature preservation

(e.g., how consumer choices affect carbon emissions or waste accumulation). This is in line with previous studies of the Earthkeepers program in different US states and countries (e.g., Činčera and Johnson, 2013; Manoli et al., 2014; Baierl et al., 2021), indicating the outdoor experience and back-in-classroom activities were beneficial in engaging participants in knowledge acquisition. This might be even more important in a society that is faced with growing environmental issues while there is an alienation from nature (Hinds and Sparks, 2008). Pyle (1993, 2003) labeed, and Soga and Gaston (2016) restated and emphasized this trend as the extinction of experience and thus voice the importance of (re-) connecting with nature. This is linked to attitude; pro-environmental shifts can be induced when individuals encounter nature and a sense of connectedness, guided by teachers and parents as role models (Rickinson, 2001; Schultz et al., 2004). Indeed, attitude levels increased over the course of the Earthkeepers program, including not only changes in opinions about nature preservation (assessed *via* evaluative statements) but also became apparent in more frequent environmental engagement (assessed *via* self-reported individual behaviors). Participants changed their perceptions of and engagement in nature preservation. This is underlined by the high rate of participants who earned the Y key, an indicator of frequent pro-environmental engagement based on the newly learned information. Pro-environmental shifts in knowledge and attitude were persistent weeks after program completion, corresponding with other studies about intensive outdoor initiatives (e.g., Bradley et al., 1999; Duerden and Witt, 2010; Fančovičová and Prokop, 2011).

Knowledge and Attitude Convergence

Environmental knowledge and attitude levels converged over the course of the program, which is before and 4–6 weeks after the on-site course, and further analyses indicated that attitude was a key factor for knowledge acquisition. Though knowledge scores before the program contributed more to knowledge scores after program completion, attitude also turned out to be a significant predictor. It is well known that prior knowledge contributes to gains and retention of topic-related information. Multiple learning theories regard previous knowledge as the basis for effectively gaining new information; e.g., new information is integrated with and linked to pre-existing one, which helps information bridging short to long-term memory (e.g., Chandler and Sweller, 1991). Other theories suggest any sort of knowledge can serve as anchors for new information, even if that knowledge might be, from a scientific view, incorrect. In educational settings, misconceptions can even be integrated into the classroom work to serve as a basis for modification toward scientific more correct information (e.g., White and Gunstone, 1989).

Less apparent is attitude's role in knowledge acquisition, which is thought to help overcome behavioral costs and thus increase engagement in learning activities, while it further controls the intensity with which participants learn and thus how much knowledge people gain and retain (Henn et al., 2020; Baierl et al., 2022). Our analysis points at both roles of attitude in knowledge acquisition; the stronger the attitude, the more knowledge participants knew before and after the program and the more knowledge participants gained. In a multilevel regression analysis, in addition to prior knowledge, attitude turned out to be a significant predictor of post-program knowledge scores. The stronger the environmentally-conscious attitude, the more participants knew, learned, and retained about the environment. Further robustness tests revealed that increases in attitude scores affected knowledge gains, while prior knowledge scores were statistically insignificant for attitude gains. Although knowledge is a main goal of environmental education, this points to organizing environmental education programs in a way to strengthen attitudes so knowledge follows. This shifts the focus to the question of how environmental attitude can be best promoted, so environmental knowledge follows. The Earthkeepers program seems to be a platform to promote participants' environmental attitudes, though more research is required as to how attitudes are promoted and how to translate such promotion into the traditional classroom setting.

Study Limitations

Since we asked for self-reports, social desirability could have affected our findings. However, the original scales have been shown to be resistant to social desirability (e.g., Kaiser, 1998; Oerke and Bogner, 2013). In this study, teachers let participants know that the questionnaires were neither graded nor evaluated. Instead, the questionnaires were filled in anonymously, and the teachers did not look at them but put them in envelopes. Second, though we focused on one outdoor environmental learning center in Arizona, we merged different classes that might have been exposed to different conditions. We tried to compensate by compiling a large dataset to determine general trends. Third, parents and teachers kept track and ultimately signed whether students engaged pro-environmentally and whether they reflected on their nature experiences. This way, as a social contextual factor, parent and teacher involvement might have affected attitude shifts (e.g., Gifford and Nilsson, 2014). Finally, though there have been several studies that found significant program effects in knowledge or attitude in Earthkeepers participants, while control groups showed no such effects, we can only draw assumptions because our study lacked a control group.

CONCLUSION

With an environmental attitude measure that builds on preservation-relevant evaluative statements and behavioral self-reports, we were able to document pro-environmental shifts toward more environmentally positive perceptions and a higher frequency of pro-environmental engagement based on the 3-day residential earth education program Earthkeepers with at least 1 month of follow-up activities. The sound assessment of nature preservation, i.e., environmental attitude, does not require a fixed

set of items but appears flexible in terms of length, age-groups, and modifications to the specific environment participants encounter, given the composite of opinion- and behavior-based self-reports framed by the Campbell paradigm. Knowledge levels, a composite of facts, understandings, and knowledge about behavior options and general ecological strategies, also increased significantly. Knowledge and attitude levels converged, and in addition to prior knowledge, attitude accounted for post-program knowledge scores, shifting the focus of environmental education programs to strengthening attitudes. This is further supported by a regression analysis showing that the higher the attitude level, the more knowledge participants gained and retained over the course of the Earthkeepers program, which has been demonstrated to be an effective platform for promoting environmental knowledge and attitude.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article can be made available by the authors on request, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

T-MB contributed to the conceptualization, methodology, formal analysis, writing the original draft, and visualization. BJ contributed to the resources and writing, reviewing, and editing the manuscript. FB contributed to the writing, reviewing, and editing the manuscript and supervision. All authors have read and agreed to the published version of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.819899/full#supplementary-material

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Anhang

Nachfolgend werden die Fragebögen von Teilarbeit A, C und E, das ergänzende Material von Teilarbeit D (tabellarische Detailangaben zu den eingesetzten Wissensitems) sowie die Unterrichtsmaterialien der Unterrichtseinheit von Teilarbeit B angefügt. Darüber hinausgehende Fragebögen zu Teilarbeit D, bei der vier Studien für eine Sekundäranalyse herangezogen wurden, können den entsprechend zitierten Referenzen entnommen werden. Da abgesehen von demographischen Fragen die jeweiligen Vor- und Nachtests identisch sind, werden nachfolgend lediglich die Fragebögen abgebildet, die vor der Intervention eingesetzt wurden. Die Unterrichtsmaterialien von Teilarbeit B gliedern sich wie folgt:

- *Workbook Student Version* (Arbeitsbuch für Schüler:innen)
- *Workbook Teacher Version* (Arbeitsbuch für Lehrkräfte: Musterlösung und Vorlagen)
- *Further Teaching Materials* (zusätzliche Lehrmaterialien, hier nur die Abstimmkarten)
- *PowerPoint® Presentation* (PowerPoint®-Präsentation)

Die funktionelle PowerPoint®-Präsentation ist frei zugänglich via

Didaktik der Biologie (2021). ABT Material. Abgerufen am 18.11.2021 von https://www.bayceer.uni-bayreuth.de/didaktik-bio/de/lehrer/gru/html.php?id_obj=158494.

Auf derselben Webseite sind sämtliche Materialien der Unterrichtseinheit im PDF- und Word-Format frei zugänglich. Dort findet sich auch das vollständige Dokument der zusätzlichen Lehrmaterialien (*Further Teaching Materials*), denn diese sind aufgrund der Übersicht und des Umfangs der vorliegenden Arbeit unvollständig abgebildet. Zudem sind sie für die Unterrichtsimplementation nicht notwendig, sondern dienen vielmehr als Ideenpool und damit als Arbeitserleichterung für Lehrkräfte. Das auf der Webseite als zusätzliche Lehrmaterialien deklarierte Dokument umfasst 45 Seiten mit Abbildungen für Memory- und Sortierspiele, wofür die Schüler:innen einen auf A4-Blättern aufgedruckten Gegenstand erhalten und ihn einer Kategorie der Weiterverwendung (*Refuse*, *Reduce*, *Reuse*, *Recycle*, *Rethink* und *Redesign*) beispielsweise auf der Tafel zuordnen. Das Dokument beinhaltet daher keinen inhaltlich konzeptionellen Mehrwert. Die Abbildungen können seitens der Lehrkräfte leicht modifiziert oder ersetzt werden. Daher sollen diese umfangreichen Materialien, abgesehen von den Abstimmkarten, die als eine Art ‚roter Faden' durch das Lernmodul leiten, kein fester Bestandteil dieser Arbeit sein.

Teilarbeit A: Fragebogen

Do not write here pre

0 0 0 0 0
1 1 1 1 1
2 2 2 2 2
3 3 3 3 3
4 4 4 4 4
5 5 5 5 5
6 6 6 6 6
7 7 7 7 7
8 8 8 8 8
9 9 9 9 9

Name: _____ **Date:** _____

School: _____ **Grade:** _____

Teacher: _____ **Age:** _____

Do you agree or disagree with these statements?	*Strongly disagree*	*Disagree*	*Partially agree*	*Agree*	*Strongly agree*
1. I am curious about discoveries in science.	O	O	O	O	O
2. It is important that I get an 'A' in science.	O	O	O	O	O
3. I enjoy learning science.	O	O	O	O	O
4. I use strategies to learn science well.	O	O	O	O	O
5. My career will involve science.	O	O	O	O	O
6. I study hard to learn science.	O	O	O	O	O
7. Knowing science will give me a career advantage.	O	O	O	O	O
8. I like to do better than other students on science tests.	O	O	O	O	O
9. I am confident I will do well on science labs and projects.	O	O	O	O	O
10. Learning science makes my life more meaningful.	O	O	O	O	O
11. I prepare well for science tests and labs.	O	O	O	O	O
12. Learning science is interesting.	O	O	O	O	O
13. I am sure I can understand science.	O	O	O	O	O
14. I spend a lot of time learning science.	O	O	O	O	O
15. I believe I can earn a grade of 'A' in science.	O	O	O	O	O
16. Scoring high on science tests and labs matters to me.	O	O	O	O	O
17. I put enough effort into learning science.	O	O	O	O	O
18. I will use science problem-solving skills in my career.	O	O	O	O	O
19. Getting a good grade in science is important to me.	O	O	O	O	O
20. Understanding science will benefit me in my career.	O	O	O	O	O
21. I think about the grade I will get in science.	O	O	O	O	O
22. The science I learn is relevant to my life.	O	O	O	O	O
23. I am confident I will do well on science tests.	O	O	O	O	O
24. Learning science will help me get a good job.	O	O	O	O	O
25. I believe I can master science knowledge and skills.	O	O	O	O	O

Choose the best answer

1. Which of the following statements about science is most true?

O Science is an unchanging body of facts.

O Science is a way of understanding the natural world that is based on belief instead of evidence.

O Science is open to change as more information is gathered and new technologies allow for new observations and new experiments.

2. The carbon that plants use for photosynthesis comes primarily from the

O water.

O soil.

O air.

3. Sustainable food production methods, such as hydroponics and aquaponics,

- O use less water over time than traditional soil-based agricultural production.
- O always keep animal waste away from growing plants.
- O produce food that is less healthy than traditional soil-based agriculture.

4. Which factor threatens the world's coral reefs most?

- O An excess of carbon dioxide.
- O Nutrient pollution from agriculture.
- O Scuba diving.

5. What is a regulating service of dense forests?

- O Carbon storage and climate control.
- O Timber for furniture and firewood.
- O Recreation like mountain biking and hiking.

6. Climate is mostly driven by

- O soil type and wind speed.
- O water availability and temperature.
- O temperature and biodiversity.

7. How much of the oxygen in the Earth's atmosphere does plankton provide?

- O Less than 10%
- O About 30%
- O More than 50%

8. Which molecules form carbonic acid when combined?

- O Water and carbon
- O Water and carbon dioxide
- O Vinegar and carbon

9. The current value and importance of Biosphere 2 for scientific research is primarily its

- O large scale when compared to most science laboratories.
- O small scale with uncontrollable environmental conditions.
- O space-frame construction material.

10. Which statement about life on Earth is most correct?

- O The planets in the solar system provide the energy that allows plants to grow.
- O Energy flows and nutrients cycle.
- O Molecules like carbon, nitrogen, and oxygen are used once and then destroyed.

Do you agree or disagree with these statements?	*Strongly disagree*	*Disagree*	*Partially agree*	*Agree*	*Strongly agree*
1. Science is important.	O	O	O	O	O
2. I am curious about scientific topics.	O	O	O	O	O
3. It is necessary for humans to understand nature.	O	O	O	O	O
4. To learn about biology in school is important.	O	O	O	O	O
5. I like to learn about plants.	O	O	O	O	O
6. Scientific discoveries are necessary.	O	O	O	O	O
7. Everybody should know something about science.	O	O	O	O	O
8. Animals are exciting.	O	O	O	O	O
9. Biology is important.	O	O	O	O	O
10. The origin and evolution of life on Earth fascinates me.	O	O	O	O	O
11. To learn about science in school is important.	O	O	O	O	O
12. Everyone should have basic knowledge about the functioning of the human body.	O	O	O	O	O
13. I love science.	O	O	O	O	O
14. New knowledge about science excites me.	O	O	O	O	O
15. I would like to know about heredity, and how genes influence how humans develop.	O	O	O	O	O
16. Science is fascinating.	O	O	O	O	O

How often have you done this outside school?	*Never*	*Rarely*	*Sometimes*	Often	*Very often*
1. Watch animals or nature.	O	O	O	O	O
2. **Plant seeds and watch them grow.**	O	O	O	O	O
3. Collect small animals (for example, lizard, toad, tadpole, or fish).	O	O	O	O	O
4. **Examine small animals or plants under the microscope.**	O	O	O	O	O
5. Play educational video games on scientific topics.	O	O	O	O	O
6. **Watch science shows.**	O	O	O	O	O
7. Read about science in books or magazines or online.	O	O	O	O	O
8. **Visit science exhibitions.**	O	O	O	O	O

Please see other side for final page of questions...

A little about you:

1) **Gender:**

O Male O Female O I prefer not to respond

2) **Choose all of the following that apply to you:**

O White O Black or African American O Asian O Hispanic or Latino

O American Indian or Alaska Native O Native Hawaiian or other Pacific Islander

O I don't know or I prefer not to respond.

3) **How often do people in your home talk to each other in a language other than English (such as Spanish or Chinese)?**

O Never O Once in a while O About half of the time O Most of the time O All the time

4) **How much schooling did your father have?**

O He did not finish high school. O He finished high school. O He got a vocational diploma.

O He graduated from a community college. O He graduated from a university. O I do not know.

5) **How much schooling did your mother have?**

O She did not finish high school. O She finished high school. O She got a vocational diploma.

O She graduated from a community college. O She graduated from a university. O I do not know.

6) **How often do you talk about things you learn at school with someone in your family?**

O Never O Once every few weeks O Once a week O Two or three times a week O Every day

7) **Is there a computer at home that you can use?** O Yes O No

8) **Can you access the internet at home?** O Yes O No

9) **In my opinion, my science grades are:**

O Not so good O Average O Good O Very good O Excellent

10) **In my opinion, my math grades are:**

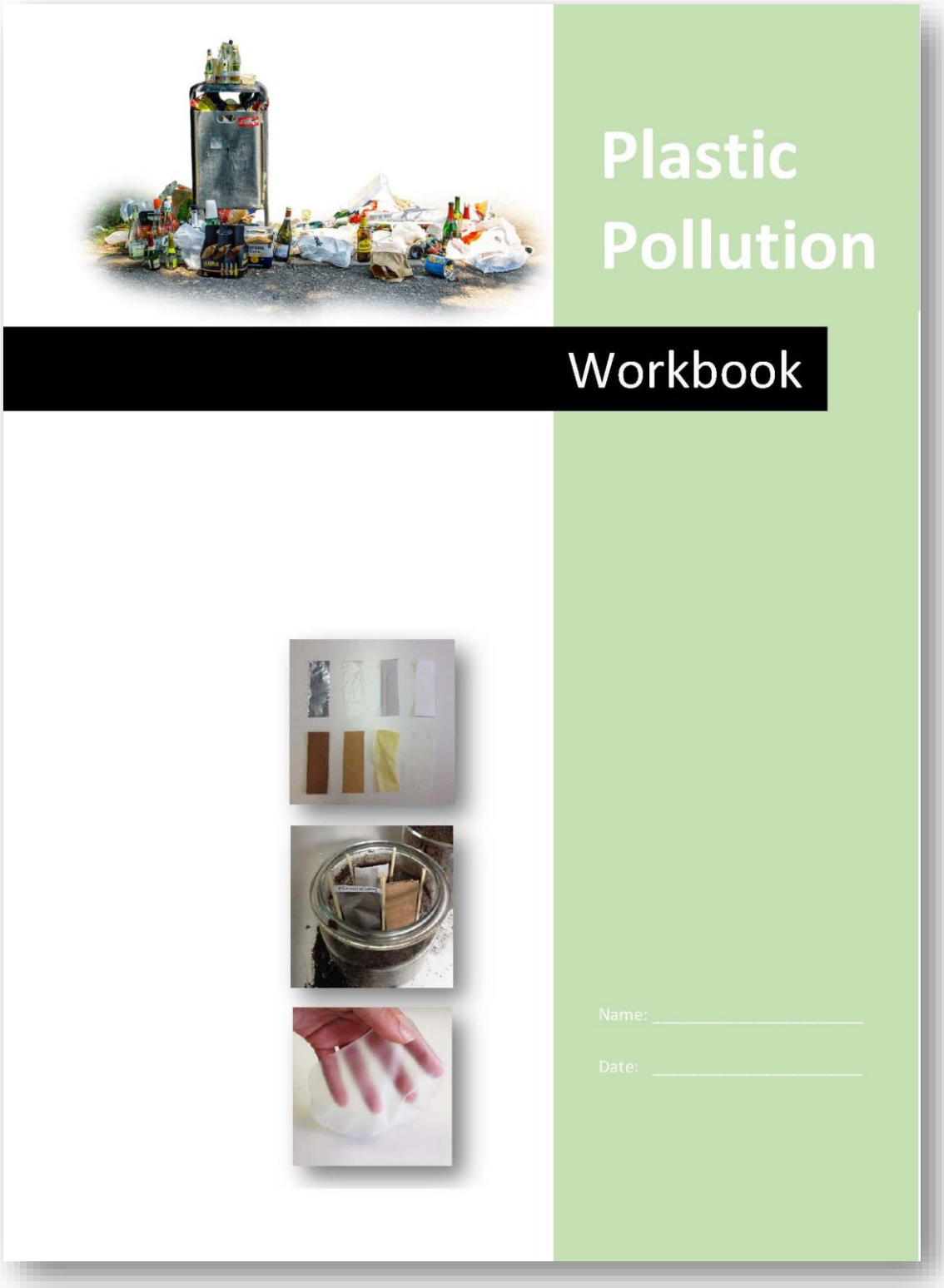
O Not so good O Average O Good O Very good O Excellent

ARIZONA

Thank you!

Teilarbeit B: Unterrichtsmaterialien

Arbeitsbuch – Schüler:innenversion



1 Video Clip **Plastic Pollution: Key Information**

Task: **Read the terms and questions, and pay attention to those while watching!**
After you have watched the clip, complete the table!

Term or question	Definition or answer
Polymers	
Plastic	
Microplastics	
Nurdles	
Microbeads	
Marine debris	
PVC	
Acrylic	
Nylon	
What are some special traits of plastic?	
How long does plastic take to break down?	
When did the mass-production of plastic begin?	
How much of all plastic produced is roughly used for packaging?	

2 Text Work **Plastic Pollution: Environmental Impacts of Plastics**

Microplastics…

… are tiny plastic particles of less than 5 mm in size. If we look at its origin, there are two main types of microplastics:

Primary microplastics are industrially manufactured to fulfil a certain purpose in products. Cosmetics like face washes can contain microbeads to scrub or exfoliate. Other products which might contain microbeads are toothpastes, cosmetics, or cleansers. Often, the beads are made of polyethylene, polypropylene, or nylon.

Secondary microplastics were not designed on purpose. If larger pieces of plastic are exposed to the environment and weathering (UV radiation, wind, wave action, etc.) for a long time, they fragment and become increasingly smaller. This way, much of the marine microplastics originate from larger plastic objects.

But why are microplastics an issue if they will eventually break down?

Microplastics can pass through water filtration systems and eventually end up in the ocean. Although they fragment, plastic is persistent; the small pieces remain in the environment and can accumulate.

Additionally, toxins like pesticides (e.g., DDT[1]) and heavy metals easily attach to the surface of plastics and are magnified. While plastics accumulate chemicals from their surroundings, they often contain toxins like flame retardants themselves, which can leach out into the environment over their whole lifespan.

Answer the questions below:

1. How can microplastics end up in the oceans? _____
2. Which parameters help to break down plastics? _____
3. What can attach to the surface of plastics? _____
4. Which impact can microplastics have on the environment? _____

[1] dichlorodiphenyltrichloroethane = colorless, tasteless, almost odorless, insecticidal organochloride

3 Model

Plastic Pollution: Recycling & Fragmentation

Task: **In your group, put all your dices together to form one large object. This represents a plastic product. Calculate the surface area!**

Then, put the dices apart and calculate the surface area again!

What do the large object and the separate dices represent? Fill in the table!

Surface area:		
What does the model represent?		

1) How do you call the process of materials getting increasingly smaller?

2) How much does the surface area increase? _____

3) What impact does such a surface area increase have?

-
-
-
-

If you need help, look at page 2!

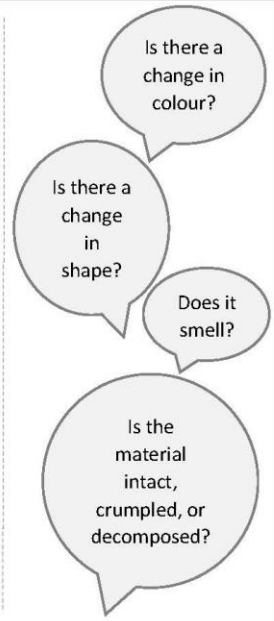
4 Experiment **Plastic Pollution: Recycling**

BIO	Plastic Pollution Biodegradable "Plastic"	Exp
Time required:	10 min	
Resources:	Heating surface, pot or heat resistant beaker (500 ml), glass (150 ml) and matching cover (e.g., Erlenmeyer flask), spoon, scale, plate or bowl with a flat ground, starch (e.g., potato starch), distilled or de-ionized water, safety googles *Optional:* Food coloring	
Chemicals:	Glycerin	
Procedure:	• Fill the pot or beaker with 150 ml water, place it on the heating surface, and bring it to boil. • Take the glass and mix 2.7 g dry starch with 2 ml glycerin, then add 30 ml of distilled water. • *Optional*: For a colored "plastic" film, add 1 ml of food coloring. • Place the glass containing the starch mixture in the heated water. Let it sit for about 5 min and shake it properly several times per minute. • Pour the liquid onto the plate or into the bowl (2-3 mm deep layer) and let it sit overnight. On the following day: Compare your biodegradable "plastic" with a conventional plastic film. Investigate parallels and differences!	
Observation:		
Interpretation:		

5 Experiment **Plastic Pollution: Recycling**

BIO	Plastic Pollution Degradation in the Soil	Exp
Time required:	2-3 weeks	
Resources:	One tall glass jar with a cover (1-2 l), compost or garden soil, test materials (e.g., plastic bag, rubber glove, biodegradable "plastic", paper towel, cardboard box), scissors, skewer, glue strips	
Procedure:	• Cut the test materials in same sized elongated rectangles. • Place the rectangles between two skewers and attach them with strips. • Fill the glass jar with a little compost or garden soil. Note which type of soil you used. • Place the skewers with your test materials on the soil in the jar. Try to create an even distance between your samples. • Fill the rest of the jar with soil, but leave about 0.5 cm of the test material sticking out of the soil. • Water the soil until it is slightly moist. • Place the jar close to the window or at a warm place with the cover on top. Check it regularly (e.g., every other day) to keep the soil to keep it moist. • Empty the jar after 2-3 weeks and compare your samples.	
Hypotheses	**Test item** | What visible impacts do you expect after several weeks of soil exposition?	

6 Experiment **Plastic Pollution: Recycling**

Observation:	
Interpretation:	

7 Sorting Activity **Plastic Pollution: Recycling**

Task: Match the cards to learn more about the six main types of plastics!

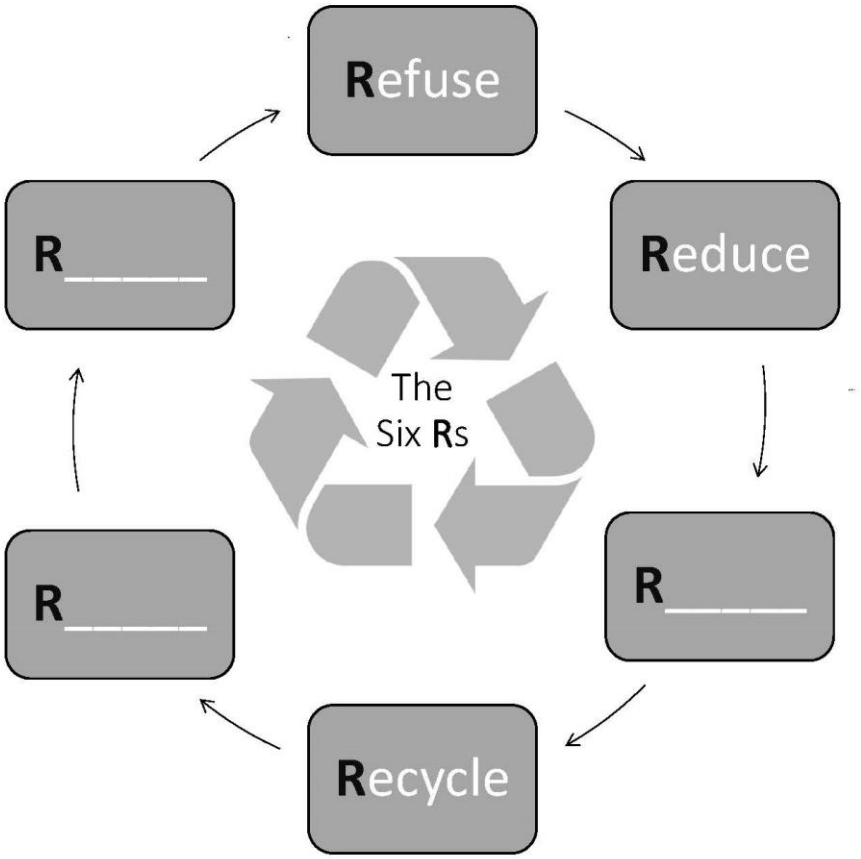
Abbrevi-ation	Full term	Recycling symbol	Examples	Examples of what can be recycled

8 Video Clip **Plastic Pollution: Recycling**

If not all products can be recycled properly, what else can we do?

You may have heard of the three Rs to lead a sustainable life, but there are three more.

Task: Watch the video clip, find out what the remaining Rs are, and write them into the figure!

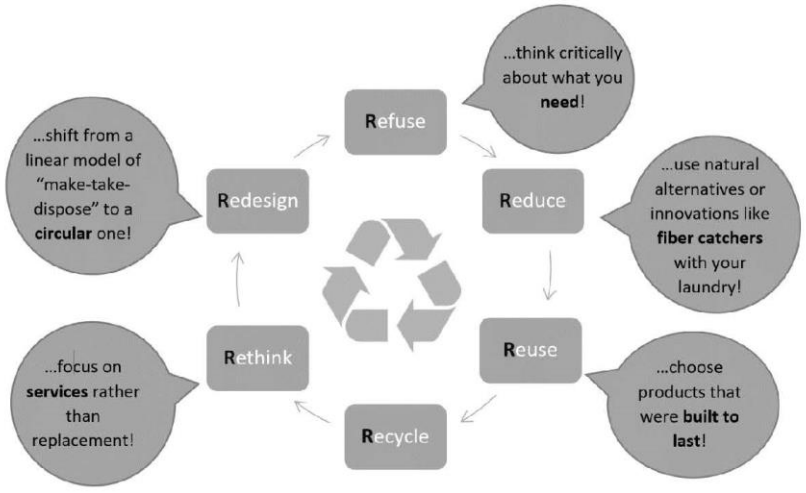


9 Homework **Plastic Pollution: Recycling**

3-Day-Challenge at Home

Task: Each day, pick three products you throw away at home and consider which of the R-categories would work for them. How could you, for example, reuse a plastic bottle instead of throwing it away?

Day	Product	Which R would you suggest, and why?



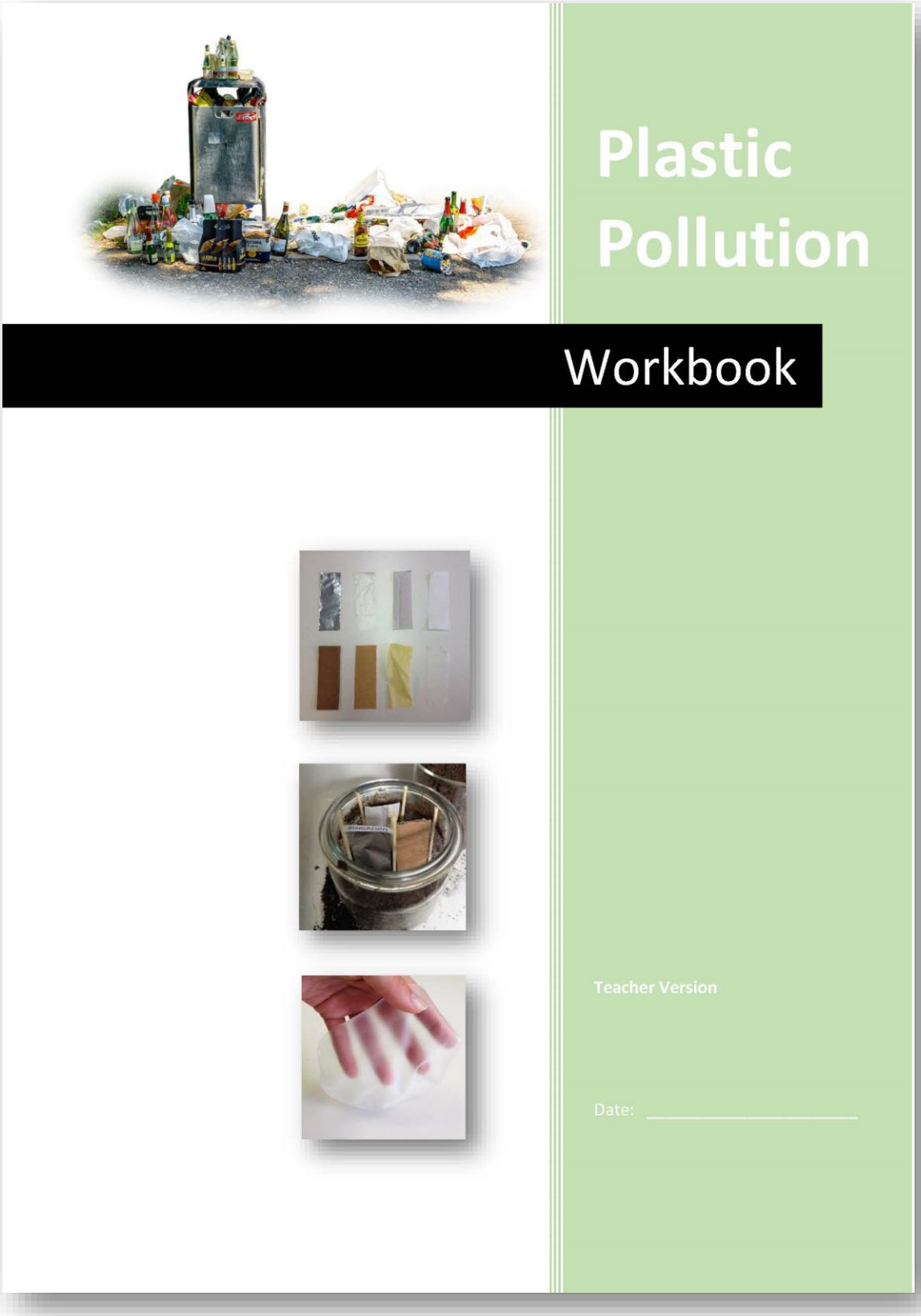
10 Discussion **Plastic Pollution: Recap**

Plastic – Curse, Blessing, or Both?

Task: List key terms (e.g., production, or transportation) and note advantages and disadvantages of plastics regarding this aspect. Then, open up to a discussion.

Key term	Advantages	Downsides

Arbeitsbuch – Lehrer:innenversion



The teacher version is longer than the student version, as it provides all solutions and time-saving alternatives; yet page numbers are adapted to the student version, so it is easier for a teacher to point out the right pages to students.

Overview **Plastic Pollution**

Plastic Pollution: Learning Activities from Production to Disposal

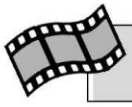
Subject: Science: Biology
Types: Classroom activities (hands-on), experiments, models, video clips, text work, games, quizzes
Grade levels: K 4-8 *(alternatives for further age groups provided)*
Time required: 3 activities: 45 min each

NGSS	Title	Code	Disciplinary Core Ideas	*Focus*	Crosscutting Concepts	Science and Engineering Practices
Primary Topics	EARTH AND HUMAN ACTIVITY: HUMAN IMPACTS **(ES)**	MS-ESS3-3	**Human Impacts on Earth**	*Plastic Pollution*	Cause & Effect	Constructing Explanations and Designing Solutions
		MS-ESS3-4			Influence of Science, Engineering, and Technology on Society and the Natural World	Engaging in Argument from Evidence
		MS-LS2-5	**Evaluating Solutions**	*Recycling*		
Additional Topics		MS-LS2-3	**Energy Transfer & Food Webs**	*Marine Ecosystem*	Energy and Matter	Developing and Using Models
	ECO-SYSTEM: INTER-ACTIONS, ENERGY, AND DYNAMICS **(LS)**	MS-ESS3-1	**Natural Resources**	*Fossil Fuels, Pollution*	Cause & Effect; Influence of Science, Engineering, and Technology on Society and the Natural World	Constructing Explanations and Designing Solutions
		MS-LS2-4	**Ecosystem Dynamics, Resilience**	*Plastic Accumulation*	Stability and Change	Scientific Knowledge is Based on Empirical Evidence

Note: All pictures, images or illustrations without references are…
- …free to use or share (licence)
- …self-made or -taken

Interdisciplinary approaches	
Chemistry	Chemical composition, variation and traits
Politics	Legislation (global comparison)
Geography	Marine pollution (ocean currents, wind streams) Fossil fuels
Arts	Artwork made of plastic trash

1 Video Clip **Plastic Pollution: Key Information**



Task: **Read the terms and questions, and pay attention to those while watching!**
After you have watched the clip, complete the table!

Term or question	Definition or answer
Polymers	*Long repeating chains of molecules (a compound); they can be natural or synthetic*
Plastic	*Made from polymers by breaking down, e.g., crude oil into its components and rearranging them so new synthetic polymers can be formed; manufactured chains of hydrocarbons*
Microplastics	*Pieces of plastic which are 5mm in diameter or smaller*
Nurdles	*Small, pre-manufactured pellets which are used as a raw material to make plastic products*
Microbeads	*Small plastic beads used in personal care products, for instance, as exfoliators*
Marine debris	*Anything man-made that ends up in the ocean but does not belong there; marine litter*
PVC	*A type of plastic that is used for plumbing, electric gears, and cases etc.*
Acrylic	*A type of plastic that is used as a shatter resistant alternative to glass*
Nylon	*A type of plastic that is used in fabric, for cooking utensils, or as a component of food packaging*
What are some special traits of plastic?	*Lightweight, durable, moldable into any shape, easily mass manufacturable, cheaply producible, raw materials yet available in vast amounts*
How long does plastic take to break down?	*Roughly 500 up to 1000 years*
When did the mass-production of plastic begin?	*About 1950*
How much of all plastic produced is roughly used for packaging?	*About 40%*[1]

[1] In the US, packaging makes up one third of all the waste that is generated annually.

Video Clip **Plastic Pollution: Key Information**

Time-saving version for the students to cut and stick into their workbook, so they do not have to copy all the information.

Long repeating chains of molecules (a compound); they can be natural or synthetic
Made from polymers by breaking down crude oil or natural gas into its components and rearranging them so new synthetic polymers can be formed; manufactured chains of hydrocarbons
Pieces of plastic which are 5mm in diameter or smaller
Small, pre-manufactured pellets which are used as a raw material to make plastic products
Small plastic beads used in personal care products, for instance, as exfoliators
Anything man-made that ends up in the ocean but doesn't belong there; marine litter
A type of plastic that is used for plumbing, electric gears, and cases etc.
A type of plastic that is used as a shatter resistant alternative to glass
A type of plastic that is used in fabric, for cooking utensils, or as a component of food packaging
Lightweight, durable, moldable into any shape, easily mass manufacturable, cheaply producible, raw materials yet available in vast amounts
Roughly 500 up to 1000 years
About 1950
About 40%

2 Text Work **Plastic Pollution: Recycling**

Microplastics…

… are tiny plastic particles of less than 5 mm in size. If we look at its origin, there are two main types of microplastics:

Primary microplastics are industrially manufactured to fulfil a certain purpose in products. Cosmetics like face washes can contain microbeads to scrub or exfoliate. Other products which might contain microbeads are toothpastes, cosmetics, or cleansers. Often, the beads are made of polyethylene, polypropylene, or nylon (Motivans, 2018).

Secondary microplastics were not designed on purpose. If larger pieces of plastic are exposed to the environment and weathering (UV radiation, wind, wave action, etc.) for a long time, they fragment and become increasingly smaller. This way, much of the marine microplastics originate from larger plastic objects (Motivans, 2018).

<u>But why are microplastics an issue if they will eventually break down?</u>

Microplastics can pass through water filtration systems and eventually end up in the ocean. Although they fragment, plastic is persistent; the small pieces remain in the environment and can accumulate (Motivans, 2018).

Additionally, toxins like pesticides (e.g., DDT[2]) and heavy metals easily attach to the surface of plastics and are magnified. While plastics accumulate chemicals from their surroundings, they often contain toxins like flame retardants themselves, which can leach into the environment over their whole lifespan (Carrington, 2018).

Answer the questions below:

1. How can microplastics end up in the oceans? _*They cannot be filtered properly (e.g., in sewage plants) and eventually end up in the ocean.*_____
2. Which parameters help to break down plastics? ____ *UV radiation, wind, wave action, and other environmental factors*_____

[2] dichlorodiphenyltrichloroethane = colorless, tasteless, almost odorless, insecticidal organochloride

Text Work **Plastic Pollution: Recycling**

3. What can attach to the surface of plastics? ____*chemicals like pesticides or heavy metals*_____

4. Which impact can microplastics have on the environment? _*They are persistent and can, therefore, accumulate. Toxins can either leach from or attach to microplastics.*_____

References

Carrington, D. (2018). Microplastic toxins leave shellfish at mercy of predators. Retrieved from https://www.theguardian.com/environment/2018/nov/28/microplastic-toxins-leave-shellfish-at-mercy-of-predators-research

Motivans, E. (2018). The down-low on microplastics. ZME Science. Retrieved from https://www.zmescience.com/ecology/pollution-ecology/the-down-low-on-microplastics/

3 Model

Plastic Pollution: Recycling & Fragmentation

Task: In your group, put all your dices together to form one large object. This represents a plastic product. Calculate the surface area!

Then, put the dices apart and calculate the surface area again!

What do the large object and the separate dices represent? Fill in the table!

Surface area:		
What does the model represent?	*Plastic product, or macroplastics*	*Fragmented plastics, or microplastics*

1) How do you call the process of materials getting increasingly smaller?

Fragmentation

2) How much does the surface area increase? _____

3) What impact does such a surface area increase have?
   - *Recovering plastics becomes more difficult*
   - *More toxins could leach into the environment*
   - *More chemicals and heavy metals can attach to the small particles*
   - *Accumulation in the ecosystem (marine food web);*
     large animals eat many small animals, so plastics and the toxins attached accumulate and travel up the food chain

If you need help, look at page 2!

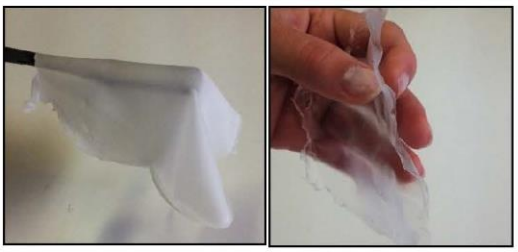
Experiment **Plastic Pollution: Recycling**

Note: In a scientific sense, experiments need to provide at least one interchangeable variable upon stable parameters so the experiment can be conducted several times under different conditions. This allows to deduce information in a scientific sense. In a school setting, simplified and thoroughly described versions are often used to save time and resources. The following experiments can be conducted as outlined, though all of them include interchangeable variables, so the experiments can be adapted to student performance. Some suggestions are provided in footnotes.

BIO	Plastic Pollution Biodegradable "Plastic"	Exp
Time required:	10 min	
Goals:	The students can use an experimental set-up to produce a biodegradable "plastic" film (with varying components of glycerin and starch). The students can list at least two differences between a conventional and their biodegradable plastic film (sensory perception or cognitive aspects). The students can identify at least one (dis-) advantage of the environmentally friendly "plastic" film compared to conventional plastic. The students can reflect on the necessity of using finite resources for some daily applications and acknowledge sustainable alternatives.	
Resources:	Heating surface, pot or heat resistant beaker (500 ml), glass (150 ml) and matching cover (e.g., Erlenmeyer flask), spoon, scale, plate or bowl with a flat ground, starch (e.g., potato starch), distilled or de-ionized water, safety googles *Optional:* Food coloring	
Chemicals:	Glycerin	
Procedure:	• Fill the pot or beaker with 150 ml water, place it on the heating surface, and bring it to boil. • Take the glass and mix 2.7 g dry starch with 2 ml glycerin, then add 30 ml of distilled water.[1] • *Optional*: For a colored "plastic" film, add 1 ml of food coloring. • Place the glass containing the starch mixture in the heated water. Let it sit for about 5 min and shake it properly several times per minute. • Pour the liquid onto the plate or into the bowl (2-3 mm deep layer) and let it sit overnight. On the following day: Compare your biodegradable "plastic" with a conventional plastic film. Investigate parallels and differences!	

[1] *The amount of starch, glycerin, and water can be varied. The more glycerin, the more transparent and flexible the material appears to be. With an increasing amount of starch, the film is more formable and works better to seal containers. The students can elaborate on the concentration of either glycerin, water, and/ or starch. If the experiment is conducted collaboratively, the results (films) can be compared (competition).*

4 Experiment **Plastic Pollution: Recycling**

Observation:	*There are some parallels between conventional plastic and the biodegradable "plastic" film: The material is transparent and fairly flexible. Conventional plastic films, however, are more flexible, and although the biodegradable one appears to be durable at first, it partially dissolves when exposed to water.*  *Changing variables: The "plastic" film on the left contains more starch (3 g) than suggested in the "procedure"-section. The one on the right contains a higher amount of glycerin (2.5 ml).*
Interpretation:	*There are environmentally friendly alternatives to conventional plastic films, which can be produced using simple tools and ingredients. The features of the biodegradable "plastic" resemble those of a conventional film, though both differ regarding, e.g., their durability when exposed to water or a very moist environment.*
Background information:	The proportions of amylopectin and amylose vary in starch grains; both interacting create the characteristically crystal-like structure, which is broken up in boiled water. As a result, the grains swell and form a starch paste (irreversible). To avoid a brittle mass while cooling, glycerin is added. Glycerin molecules bind water and are integrated in the starch molecules via hydrogen bonds, which prevent the reformation of crystal-like structures. Alternatively, sodium alginate could be used, which further increases durability (Córdoba, Cuéllar, González, & Medina, 2008). *Biodegradable* refers to the process of materials being completely broken down and reintroduced into natural systems (Nachtigall, 2002). Since the biodegradable "plastic" produced in this experiment is not water resistant, industries add silane as a water-repellent for commercial application (Xanthos, 2010).
Educational evaluation:	**Positive**: Low error rate (high reproducibility), little time required, reference to everyday life, motivation (students can use their film at home) **Caution**: Source of error: If not mixed properly, the starch mixture can set on the jar's ground; risk of burns (heating surface and boiled waster)

BIO	Plastic Pollution Degradation in the Soil	Exp
Time required:	2-3 weeks	
Goals:	The students can describe at least two stages of degradation using common vocabulary (no specific terminology required). The students can contrast at least three everyday materials regarding their visible impacts (state of degradation) after a 2-3 week soil exposition. The students can create a link between terrestrial microorganisms and environmental parameters and the state of degradation. The students develop an understanding of the value of proper recycling.	
Resources:	Tall glass jar with a cover (1-2 l), compost or garden soil, test materials (e.g., plastic bag, rubber glove, biodegradable "plastic" film, paper towel, cardboard box), scissors, skewer, glue strips	
Procedure:	• Cut the test materials[1] in same sized elongated rectangles. • Place the rectangles between two skewers and attach them with strips. • Fill the glass jar with a little compost or garden soil. Note which type of soil you used. • Place the skewers with your test materials on the soil in the jar. Try to create an even distance between your samples. • Fill the rest of the jar with soil, but leave about 0.5 cm of the test material sticking out of the soil. • Water the soil until it is slightly moist. • Place the jar close to the window or at a warm place with the cover on top. Check it regularly (e.g., every other day) to keep the soil to keep it moist. • Empty the jar after 2-3 weeks and compare your samples.	

[1] *Some variables: Test items (manufactured vs. natural, e.g., orange peel), exposition of the jar (temperature, light,...), duration of the experiment, sample size, position of the items within the jar (if the rectangles are directly attached to the glass wall or placed on top of the soil, the process becomes observable during the test period), type of soil (garden vs. compost soil), degree of moisture*

5 Experiment **Plastic Pollution: Recycling**

Hypotheses	Test item	What visible impacts do you expect after several weeks of soil exposition?

Observation:

1) The test materials show different stages of degradation:

Alu-minum	Plastic bag	Paper towel	Rubber glove	Card-board box	Biode-gradable "plastic"
Un-changed	Un-changed	Highly degra-ded, only a few scraps re-mained	Un-changed	Soaked, degra-dation predomi-nantly on the edges	Greatly de-graded, hardly any scraps re-mained

2) Signs of degradation: Discoloration and fragmentation, but predominantly only on those parts which were

Experiment **Plastic Pollution: Recycling**

	exposed to the soil; the parts covered by plastic strips are hardly affected. *Test materials from the top left to the right: Aluminum, plastic bag, paper towel* *From the bottom left to the right: Cardboard box, rubber glove, biodegradable "plastic" film (see experiment above)*
Interpretation:	*The soil is not a lifeless mass but a highly complex habitat of various organisms. Those can degrade diverse materials to different degrees, but they rely on environmental parameters.* *It seems that the rougher and the more industrially processed the material, the harder it is to be degraded. Therefore, some daily products did not show any signs of degradation. Others have almost disappeared from the naked eye.*
Background information:	Various parameters influence the rate of degradation, e.g., pH, temperature, soil composition, chemical condition, moisture, or the microflora. Moist soils rich in nutrients and microorganisms and exposed to temperatures between 30° and 50 °C support microbiological degradation. Microorganisms such as bacteria or fungi (e.g., actinomycetes) break down and metabolize organic compounds in a preferably aerobic environment (Orhan, Hrenovic, & Büyükgüngör, 2004). Since conditions such as the composition of microorganisms can vary greatly, the experiment should only be carried out semi-qualitatively. There is a difference between corrosion and biodegradation. Corrosion refers to the visible fragmentation of materials, while small particles, e.g., microplastics, remain. During biodegradation, materials are fully metabolized and reintroduced into a biological circular system (Nachtigall, 2002). Biodegradation requires specific conditions and takes longer if parameters such as oxygen are missing (Zheng, Yanful, & Bassi, 2008). Being based on renewable resources does not necessarily mean that a material is biodegradable. It highly depends on the manufacturing process (Nachtigall, 2002). Latex, for instance, often used for rubber gloves, shows a high-molecular phytochemical structure made of isoprene units and

	extracted from the rubber tree (*Hevea brasiliensis*). The raw material is kneaded with sulfur at 130-140 °C to connect polyisoprene chains in a process called vulcanization and is, finally, hardly biodegradable (Trueb, 2015). The chemical structure of the biodegradable "plastic" produced in the experiment above is only slightly changed and more likely to biodegrade. Starch in general is often added to fasten the process of degradation (Orhan, Hrenovic, & Büyükgüngör, 2004). In general, if the backbone structure of synthetic polymers is made of carbon atoms (e.g., thermoplastics), the material is highly resistant to degradation or hydrolytic cleavage; the products can accumulate in the environment. The cross-linked structure (heteroatoms) of thermoset plastics is potentially degradable through hydrolytic cleavage (Zheng, Yanful, & Bassi, 2008).
Educational evaluation:	**Positive**: Low error rate (high reproducibility), clear results, motivation and flexibility since students can choose their samples, reference to everyday life, range of learning objectives, extension towards testing parameters such as the pH, temperature, soil moisture or composition **Caution**: Growing of mold possible, duration (risk of losing the main idea)

References

Córdoba, A., Cuéllar, N., González, M., & Medina, J. (2008). The plasticizing effect of alginate on the thermoplastic starch/ glycerin blends. *Carbohydrate Polymers, 73*(3), p. 409-416.

Nachtigall, W. (2002). *Bionik - Grundlagen und Beispiele für Ingenieure und Naturwissenschaftler [Bionics - Basics and examples for ingeneurs and scientists].* Berlin: Springer.

NGSS. (2013). Safety and the Next Generation Science Standards. Retrieved from http://static.nsta.org/pdfs/SafetyAndNGSS.pdf

Orhan, Y., Hrenovic, J., & Büyükgüngör, H. (2004). Biodegradation of plastic compost bags under controlled soil conditions. *Acta Chimica Slovenica, 51*(3), p. 579-588.

Trueb, L. F. (2015). *Pflanzliche Naturstoffe [Plant-based natural resources].* Stuttgart: Bornträger.

Xanthos, M. (2010). *Functional fillers for plastics.* Weinheim: Wiley-VCH.

Zheng, Y., Yanful, E., & Bassi, A. (2008). A review of plastic waste biodegradation. *Critical Reviews in Biotechnology, 25*(4), p. 243-250.

Both experiments are greatly modified but derived from the following sources:

Biodegradable "Plastic"	Schmidt, M. (2002). Experimentalvortrag Nachwachsende Rohstoffe [Experimental lecture renewable resources]. Retrieved from http://www.chids.de/dachs/expvortr/655uNachwachsendeRohstoffe_Schmidt.pdf
Degradation in the Soil	Schlüter, K. & Kremer, B. P. (2015). *Modelle und Modellversuche im Biologieunterricht [Models and model experiments in the biology classroom].* Baltmannsweiler: Schneider Verlag Hohengehren GmbH, p. 296-298.

7

Sorting Activity **Plastic Pollution: Recycling**

Task: Match the cards to learn more about the six main types of plastics!

Abbrevi-ation	Full term	Recycling symbol	Examples	Examples of what can be recycled
PET	Polyethylene terephthalate	1 *Commonly*	• Plastic bottles • Some takeout containers • Packaging film • Carpet yarn	• Plastic bottles • Carpet yarn
HDPE	High-density polyethylene	2 *Commonly*	• Plastic bottles • Food storage containers • Detergent bottles • Grocery bags • Plastic surgery	• Plastic bottles • Toys • Water pipes
PV(C)	Polyvinyl chloride	3 *Almost never*	• Detergent bottles • Cling film • Product packaging • Milk and juice cartons • Outdoor furniture • Shower curtains	• Shower curtains • Medical tubing
LDPE	Low-density polyethylene	4 *Sometimes*	• Garbage and sandwich bags • Six-pack rings • Lids from tubs • Plastic wraps	• Wrapping films • Grocery or sandwich bags
PP	Polypropylene	5 *Commonly*	• Yogurt cups • Margarine tubs • Clear film • Straws • Banknotes • Thermal underwear	• Car bumpers • Industrial fibres • Food containers
PS	Polystyrene	6 *Almost never*	• Expanded Styrofoam • Egg cartons • Packing pellets • Cutlery and cups • CD cases	• CD cases • Packaging
Mixed Plastics		7 *Almost never*	• Squeezable bottles • Biodegradable plastics • Plastic packaging like trays, tubs, or films	Nothing at this time

Sorting Activity **Plastic Pollution: Recycling**

To copy and hand the students, so they can cut and match the cards in pairs or groups.

HDPE	**PV(C)**	4 *Sometimes*	High-density polyethylene	1 *Commonly*	Low-density polyethylene	**PS**

• Shower curtains • Medical tubing	• Detergent bottles • Cling film • Product packaging • Milk and juice cartons • Outdoor furniture • Shower curtains	• Plastic bottles • Food storage containers • Detergent bottles • Grocery bags • Plastic surgery	3 *Almost never*

• Plastic bottles • Some takeout containers • Packaging film • Carpet yarn	• Squeezable bottles • Biodegradable plastics • Plastic packaging like trays, tubs, or films	6 *Almost never*	2 *Commonly*	**PET**

Polypropylene	• Plastic bottles • Toys • Water pipes	• Expanded Styrofoam • Egg cartons • Packing pellets • Cutlery and cups • CD cases	• Yogurt cups • Margarine tubs • Clear film • Straws • Banknotes • Thermal underwear

5 *Commonly*	7 *Almost never*	**LDPE**	• CD cases • Packaging	Polyvinyl chloride	**PP**

Nothing at this time	• Wrapping films • Grocery or sandwich bags	**Mixed Plastics**	• Garbage and sandwich bags • Six-pack rings • Lids from tubs • Plastic wraps

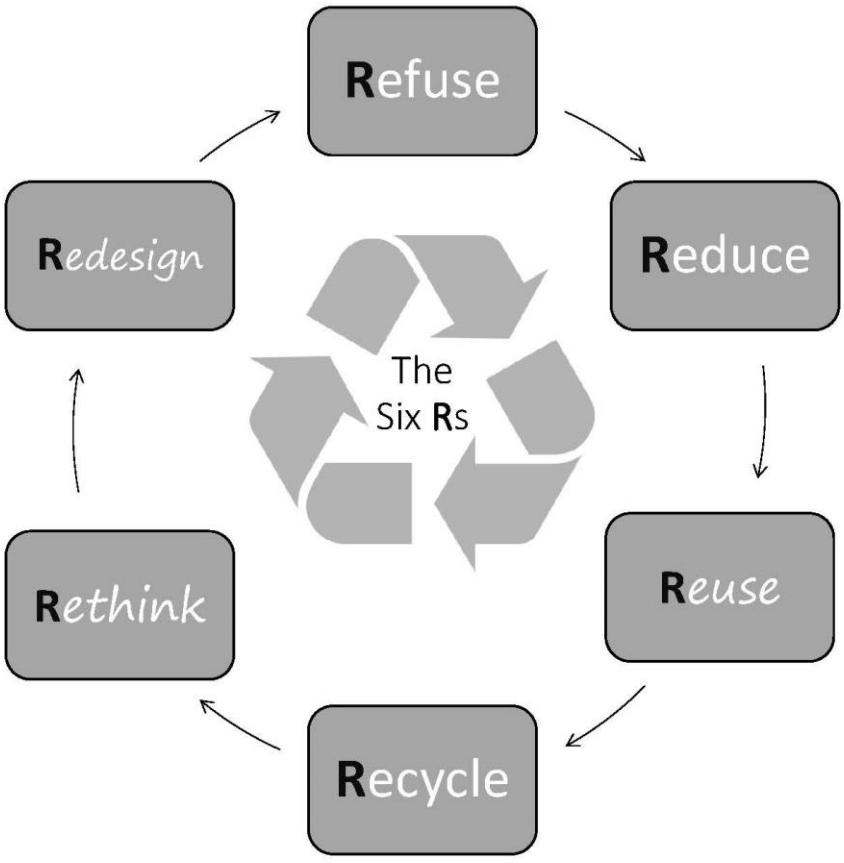
• Car bumpers • Industrial fibres • Food containers	• Plastic bottles • Carpet yarn	Polystyrene	Polyethylene terephthalate

8 Video Clip **Plastic Pollution: Recycling**

If not all products can be recycled properly, what else can we do?

You may have heard of the three Rs to lead a sustainable life, but there are three more.

Task: Watch the video clip, find out what the remaining Rs are, and write them into the figure!



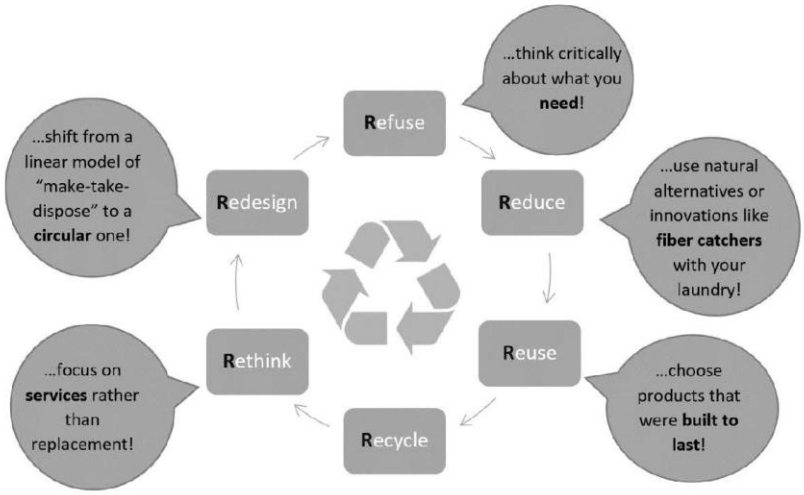
Video Clip: Dudas, S. at TEDx Talks (2018). Microplastics are everywhere. Retrieved from https://www.youtube.com/watch?v=jjsrmFUmyh4

9 Homework **Plastic Pollution: Recycling**

3-Day-Challenge at Home

Task: Each day, pick three products you throw away at home and consider which of the R-categories would work for them. How could you, for example, reuse a plastic bottle instead of throwing it away?

Day	Product	Which R would you suggest, and why?



10 Discussion **Plastic Pollution: Recap**

Plastic – Curse, Blessing, or Both?

Task: List key terms (e.g., production, or transportation) and note advantages and disadvantages of plastics regarding this aspect. Then, open up to a discussion.

Key term	Advantages	Downsides
Production	Little energy needed to manufacture plastic products; inexpensive production	Mass production: Single-used items since it is easy and cheap to produce them → Accumulation
Transportation & storage	Lightweight, take up little space, resistant, practical	Since many plastic products are single used items, they need to be transported to stores etc., and trash needs to be transported to landfills (carbon footprint), …
Traits	Mouldable, durable, stable or flexible, multifunctional, partially reusable	Hardly biodegradable, so often microplastics accumulate in ecosystems or organisms
Durability	Preservation of food, medicine, hospital utensils, …	Products barely biodegradable but accumulate (landfills, environment)
Recycling	Some plastics can be recycled and, therefore, reused (up- vs. downcycling)	Most plastics cannot or are not recycled properly and, therefore, accumulate with a negative impact on the (a-) biotic environment
Resources	Most likely petrochemical: Cheap	Non-renewable resource and predominantly imported
Impact on human lifestyle	Allows flexibility, saves time and energy (washing the dishes, …), has become an amenity and pivotal in modern life, …	Most likely affect our health: Presumed to interfere with the hormonal system, reproduction, etc. since microplastics can pass through biomembranes

Lesson Plans – Plastic Pollution

T	= Teacher	S	= Students
PPT	= PowerPoint® presentation	WB	= Workbook
IS	= Independent work in silence		

Time (min)	Phase	Planned teacher behavior	Expected student response	Forms of teaching and arrangement	Teaching material	Educational background
5	Intro I	**Defining plastic** *(Each lesson's title should always be displayed as such either on the board or the PPT)* **Hook**: The T presents newspaper articles. The lesson sequence's title is introduced on the first slide. T: "What do you think about these headlines?" "Which headline struck you most?" *Alternative to activate the S* (**flashlight method**)*:* *T: "Read the headlines and look at the pictures. Then, I want all of you to stand up. Each of you has to comment on one picture or headline, and you can refer to them by using the number in the green boxes. One sentence is enough, and you can also share an experience or facts you already know. I'll start with throwing a ball to one of you. Once you've made a comment, throw the ball to another person and take a seat. You should not repeat what has already been said."*	The S read the headlines and comment on them. *The S refer to either the headlines or pictures by giving background information, stating facts, expressing thoughts or feelings, or commenting in another way.*	Plenum	PPT (slide 1), computer, projector, *ball*	Activation, participation of all S, internal differentiation[1] (background knowledge), current issue: Catch factor (motivation, authenticity), checking the S' pre-existing knowledge

[1] All methods that refer to internal differentiation are implicit and horizontal (on the same level of performance). Suggestions for vertical differentiation (complexity and difficulty of tasks) can be derived from the *alternative*-sections, which provide further tasks for different age groups, performance levels, or regarding time.

Lesson Plans – Plastic Pollution

T = Teacher				S = Students		
PPT = PowerPoint® presentation				WB = Workbook		
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15	Elaboration I	T: "Before we dive into current issues of plastics, and to be able to participate in the increasingly heated debate, let's take a step back and learn what plastics actually are. We will watch a short video clip; but first we will focus on some questions and terms so you can already take notes while and right after watching." The T refers to the WB, which lists the key terms and questions and provides the lesson's title. T: "Let's read the terms first. You don't have to write down the answers while watching, but you can already take notes. Just pay attention to the terms and questions, and then we'll find the answers in class. Some of them might not even be mentioned explicitly, but by listening attentively, you'll find out the answer." The T plays the **short video clip** which provides a definition of plastics and introduces the main ideas of current global issues. If the video on the PPT does not work, the grey box in the right corner links to the YouTube-video (1:00-4:42 min). The T should consider watching it a second time. After the clip, the T introduces a **memory activity**: T: "Each student receives a card. About half of the cards hold a term or question; the rest provides their definition or answer on either one or split on more cards. Once every student has a card, move around the classroom and find the person holding the card that matches yours; then, fix it on the board. Don't forget that some terms were not mentioned explicitly; but I'm sure you'll be able to match those, too."	The S read out the terms and questions. The S watch the clip and pay attention to the terms and questions highlighted. They can take notes. The S look for the classmate holding the card that matches theirs and fix it on the board.	Plenum IS Plenum	PPT (slides 2-3), computer, projector, board, WB (p. 1), video clip (https://www.youtube.com/watch?v=RS7IzU2VJIQ), memory cards	Change of methods (video clip, memory activity): Motivation, scaffolding to focus attention (terminology and facts), learning basic terminology appealing to different learning types (visual, auditory, hands-on), activation: Cognitive and physical, participation of all S, scaffolding: Basic terms remain on the board during part the lesson and can be used in further lessons,

Lesson Plans – Plastic Pollution

T = Teacher			S = Students			
PPT = PowerPoint® presentation			WB = Workbook			
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		Once all cards are fixed, they are briefly talked through, and, if necessary, corrected in plenary. By fixing them on the board, they are present throughout the lesson. *Alternative: The T provides sets of memories for small groups of two up to four S and lets the S know they have to present their results in class.* *Note: There are 28 cards. If the class size is smaller, spared cards can be matched by those S who finished first. If the number of S exceeds the number of cards, long definitions (e.g., about special traits of plastics), which are already split on two cards, could be split even further.*	The S go through all matches. When correcting, they should provide explanations. *The S match the cards and present their results.*	*Group work*		communicative skills, cooperative skills
8/ **10/** **5**	Securing I	The T refers to the WB and asks the S to complete the table. If the cards on the board are too small, the PPT can be used instead. *Alternative: If the memory was carried out in groups, the information is presented by the S. They could use the PPT or a document imaging camera.* *Alternative: Depending on S performance, age group, or to save time, the T could provide already printed definitions/ answers, which the S have to cut and glue (or already pre-cut shreds).*	The S copy the definitions or answers. *Some S present their matches using complete sentences and proper explanations.* *The S cut, assign, and stick, the paper shreds in their WB.*	IS	PPT (slides 4-5), computer, projector, WB (p. 1), memory cards	Securing the same level of knowledge as it sets the basis for the whole learning unit, internal differentiation: Shreds vs. copying
5-10	Deepening I (1)	The T introduces a **game** with **dices**. Every S receives a dice, and every number represents a new term. The memory cards on the board should be covered or removed only for this game. In pairs, the S throw the dice and give definitions of the terms the number represents. *Alternative: Instead of pairs, groups could compete.*	The S clear away the lesson materials, pair up, throw the "dice", and give a definition of the term the color represents.	Partner work *Group work*	PPT (slides 6), computer, projector, dices	Activation (all), internal differentiation (temporal, personal), communicative skills

Lesson Plans – Plastic Pollution

T = Teacher			S = Students			
PPT = PowerPoint® presentation			WB = Workbook			
IS = Independent work in silence						

	Deepening I (2)	**Sources of plastics** The T hands out the **voting cards** (one green and red card per S) and points out that they will be repeatedly used throughout the following activities. The T presents **everyday objects** (e.g., synthetic clothes, and cosmetics) and refers to some memory cards (Elaboration I) for scaffolding. T: "Now that we know more about plastics, which of those products contains plastics? Use your green card if you think they are free of plastic and the red one if you think they might be at least partially made of it. The terms on the board might help you." Alternative: The T introduces a **quiz** using the **voting cards**: T: "I'll present different items. If you think the item contains plastic, raise your red card. If you think it's without plastic, raise your green card." "Sometimes it's difficult to know whether a product contains plastic by just looking at it. How can we know that a product is (partially) made of plastics?"	The S vote which products might contain plastics. The S answer the questions and elaborate a feeling for the distribution of plastics in products. The S realize that all plastics have to be listed in the table of ingredients on each product. In case there is no packaging available, they could contact the producer.	Plenum	PPT (slide 8), computer, projector, test items, voting cards, memory cards: Plastic, Microplastic, Microbeads	Activation, participation of all S, reference to everyday life (authenticity), hypotheses as the lesson's contextual framework and provoke engagement, voting cards as a further guide throughout the lessons
		End of lesson or short break				
5	Repetition	To revise the terms already learnt, the S play the same **game of dice** the prior lesson ended with. This time, each S should work with another classmate.	The S pair up or form small groups and throw the dice to revise the definitions without using their WB.	Partner or group work	PPT (slide 6), computer, projector, dices, board	Warm-up, activation, revising key terms, differentiation

Lesson Plans – Plastic Pollution

T	=	Teacher	S	=	Students	
PPT	=	PowerPoint® presentation	WB	=	Workbook	
IS	=	Independent work in silence				

5	Intro II	**<u>Environmental impact of plastics</u>** The T elaborates on microplastics by heading to their environmental impact (**Think-pair-share**): T: "Last lesson, we learnt about microplastics. Why are microplastics harmful although we can hardly see them? Think about the question for half a minute, then talk about it with your partner for another minute, and, right after, prepare to share your results in class." The T creates a **mind map** on the board by taking in the S' suggestions. The T says that he/ she would not, for now, comment on the ideas since they serve as hypotheses, which need to be evaluated later. The T shows the lesson's title and lets the S know it is written in the WB. *Alternative: If the S are reluctant to share their ideas, the T could use the **flashlight method** (see Intro I).*	The S share their ideas to answer the question. The S participate in creating a mind map and, this way, formulate hypotheses.	Plenum IS Partner work Plenum	PPT (slide 9), computer, projector, board *ball*	Activation, communicative skills, incentive for reluctant S to participate, hypotheses constitute the lesson's framework and provoke engagement, reference to everyday items (authenticity)
5	Elaborating II	The T introduces a **text**-based work to answer the question already introduced (see Intro II). T: "I will hand out a short text about microplastics, its interactions with other chemicals, and a few questions to answer while you are reading or after you read the text. You will have 4 min. Place your green card on your table once you have answered all questions. Use your red card if you have any questions; then, I will come and help."	The S read the text, answer the questions, and use their voting cards.	IS	PPT (slide 9), computer, projector, WB (p. 2), voting cards	Differentiation: Learning style, work speed, change of methods, knowledge transfer
5	Securing II	The T prompts the S to answer the questions in plenary. The PPT can be used to present or adapt the answers so they are visible to all S.	The S answer the questions in plenary and correct them in their WB if necessary.	Plenum	PPT (slide 10), computer, projector, WB (p. 2)	Securing the same level of knowledge

Lesson Plans – Plastic Pollution

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9	Deepening II (1)	To elaborate on the topic, the T introduces a **cube model**. In groups of about six, the S use their dices again. T: "Put all dices together to form one large object. The dice(s) represent(s) marine debris. The model helps to demonstrate what happens when plastic fragments. How does the surface area change when you put the large object apart? Discuss in your group for 1 min." "What do both large and small objects represent? Discuss again for 1 min." "Do large plastic items hold more toxins than microplastics? Hold up your green or red card! Why? Again, discuss with your group." "The toxins attached can be dangerous once they interact with organisms. Explain why!" *Alternative: To save time, the T could demonstrate the model in plenary.* *Alternative: The model could be used for calculations. Instead of speculating, the S could calculate the exact surface area.*	The S build more cubes and form groups. The S notice that the total surface area of the separate dices (fragments) is much larger. The S note that the large object represents large plastic items, small cubes microplastics. The S raise one card. The S note that the higher the surface area, the more space there is for toxins and microorganisms to attach.	Group work (collaborative) Plenum	PPT (slide 11), computer, projector, dices, voting cards, WB (p. 3)	Activation, change of methods, visualization, cooperation, communicative skills, ***Note: A model must be presented as such, namely as a copy of reality; parallels and differences must be discussed!*** *approach to scientific work,* *link to math*

Lesson Plans – Plastic Pollution

T = Teacher			S = Students			
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12	Deepening II (2)	A **BBC article** shows a supposedly eco-friendly bag that remained unchanged in the soil for three years; the students should comment on it (**Think-pair-share**). The T relates the issue to an **experiment**: T: "Let's find out how everyday items respond to soil exposure. An experiment will mimic the process." The T points to the WB and prompts the S to formulate hypotheses what visible impacts the students anticipate. T: "We'll analyze our jars in 2 or 3 weeks. On which item do you think we will see most changes?" The T notes the predictions on the table (or in the PPT) to fall back on them in a few weeks. T: "Now, we'll set the jars near the window, keep watering them regularly, and analyze them in a few weeks." *Ideally: The T or S make biodegradable "plastic" films. The T could prepare a few samples for the soil experiment. The S can take their "plastic" home the next day to use it.*	The S link the new information to the BBC article. The S can choose materials they want to test and set up the experiment. The S voice their predictions.	Plenum Group or partner work	PPT (slides 12-15), computer, projector, WB (p. 4-6), experimental set-up (*degradation in the Soil*), *Experimental set-up (bio-degradable "plastic")*	Activation, communicative skills, everyday objects: Authenticity exemplarity, differentiation: Temporal, personal, based on interests (test items), hypotheses help to activate students and to fall back on the topic a few weeks later
		End of lesson or short break				
4	Intro III	**Hook**: The T presents recently published **data** and allows the S to reflect on them for a while before asking questions (*Alternative: Think-pair-share*): T: "What strikes you?", "What do you wonder about?" If the S do not notice the discrepancy between the amount of recycled coffee cups and peoples' lack of awareness, the following slide illustrates it. The main idea is to get the S to reflect on recycling and question its efficiency. The T introduces the lesson's topic: T: "Today, we'll learn about recycling, why so many people do it wrong, and how to get it right."	The S read the data, comment on it, and answer the questions.	Plenum	PPT (slides 16-17), computer, projector, board	Creating a conflict, motivation, reference to everyday life (authenticity), scaffolding (lesson outline)

Lesson Plans – Plastic Pollution

T	=	Teacher	S	=	Students	
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20	Elaboration III	Each S should name one item that can be recycled. The T can either use the **flashlight** method (see Intro I) or let the S write it down on a piece of paper. T: "The table (PPT no. 18) shows the most common plastic types and their abbreviations. Find your item in the table and tell me which type of plastic it mainly consists of. If you can't find it, have a guess where it could belong!" To share the answers, the T could either use the flashlight method or just pick a few S. Then, the T refers to the first lesson and reviews that all types are made of the same resources (revision of terms such as *polymers* while reusing the memory cards of Elaboration I). Depending on the manufacturing process, however, they must be recycled differently. T: "What could be meant by the terms you see on the left of the slide?" (**Think-pair-share**) *Add-on (slide no. 19): "If we differentiate between up- and downcycling, some plastics must be worth more than others. Look at the diagrams and, with your partner, make a list of the most precious to the least precious plastics and name some examples of common plastic items; be prepared to present your results in class!"* The T points to the recycling symbol (chasing arrows) and asks the S what it meant. Since the S had already talked about the economic value of different plastics, the following question should be deductible: T: "What do the different numbers in the chasing arrows imply?" The following questions are rather unlikely for the S to be answered, so the T is prepared to give the answers; nevertheless, asking prompts thinking.	The S name or take notes on items which can be recycled. The S name the main type of plastic their item is predominantly made of. The S explain the terms up- and downcycling. *The S create lists of the most to the least precious plastics.* *A few S present their list. The other S pay attention to correct the information if necessary.* The S understand that it means a product can be recycled. The S answer that it implied how well a product is recyclable. They use the terms *up-* and *downcycling*.	Plenum *Group work (collaborative)* Plenum	PPT (slides 18-19), computer, projector, cards (see Elaboration I) (, ball/ paper)	Activation, participation, informative, time saving, triggering thinking, reference to daily life: Authenticity, contextual learning, communicative skills

Lesson Plans – Plastic Pollution

T = Teacher PPT = PowerPoint® presentation IS = Independent work in silence				S = Students WB = Workbook		
		T: "Can any item holding such a symbol be recycled in your area?" Answer: "No, not necessarily. The symbols were invented to create a uniform global system. Yes, it can be recycled at some places in the world but not everywhere." T: "Why might some plastics be so difficult to recycle? Remember the coffee cups!"	The S understand that products made of a mixture of materials/ plastics or that are contaminated with things like food scraps are more difficult to recycle.			
15	Securing III	The T hands out a **memory cards**. T: "You will receive paper shreds that have either a type of plastic, its abbreviation, an item made of plastic, or a recycling symbol on it. Match the four cards that belong together and be prepared to present your results in class. Place your green card on your table once you have answered all questions; use the red card in case you need help. You will have 5 minutes!" *Extension: The T can introduce the* ***App "Beat the Microbead".***	The S match the cards. Some S present their results in class. The S compare their matches with those presented and, if necessary, correct and then stick them into their WB.	IS Plenum *Plenum/ IS*	PPT (slide 20), computer, projector, WB (p. 7), memory cards, voting cards	Internal differentiation: Learning style and work speed, securing knowledge, *change of methods, authenticity*
6	Deepening III	The T asks the S to use the **dices** again and forms small groups. The S are supposed to throw the dice; numbers are assigned to a term of a common type of plastic. Without using their WB, the S are supposed to name as much additional information as possible.	The S throw the dice and, thereby, revise the information. The larger the group the easier it is to revise the facts collaboratively.	Group work (collaborative)	PPT (slide 21), computer, projector, dices	Activation, communicative skills, revision, motivation
5	Intro IV	The T turns to the next slide and allows the S to think about the question for half a minute. T: "What suggestions do you have?" The T encourages the S to share their thoughts and notes some on the board which serve as hypotheses. If the S do not come up with the three *Rs*, the T presents them via the PPT (*refuse*, *reduce*, and *recycle*).	The S share their thoughts.	Plenum	PPT (slide 22), computer, projector	Activation, authenticity

Lesson Plans – Plastic Pollution

T	=	Teacher	S	=	Students	
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5	Elaboration IV	The T plays a **short clip** ("Microplastics are Everywhere", TEDx Talk), which introduces three additional *Rs*. If the video on the PPT does not work, the grey box in the right corner provides a link to the YouTube-video (8:31- 10:51 min). Watch a second time. The S are supposed to take notes on the *Rs* and present the information. *Add-on: If the S are not familiar with TED, provide a short explanation or prompt some S to introduce the platform.*	The S focus on the additional *Rs*. The S define the *Rs* and take notes.	IS Plenum	PPT (slide 23), computer, projector, WB (p. 8), video clip (https://www.youtube.com/watch?v=jjsrmFUmyh4)	Change of methods, differentiation: Learning type, authenticity, link to media
5	Securing IV	The T points to the WB in which the *Rs* are illustrated and walks the S through it. The T explains the **homework** (*3-Day-Challenge*): The S should list throwaway plastic items and think about which of the *Rs* would be best to apply. The T makes the requirements obvious as how to present their results (e.g., discussion or presentation).	The S carry out the task at home.	Plenum	PPT (slides 24-25), computer, projector, WB (p. 9)	Internal differentiation: Temporal and personal, authenticity, motivation
10	Deepening IV	The T introduces an **activity** to sort throwaway articles into one of the six categories illustrated on the board: T: "Now, we will practice what you have to do at home. You will receive one card, which shows an item that is often thrown away. Decide which category of "The Six Rs" would be best for it and fix it on the board!" A follow-up discussion allows alternative suggestions. *Add-on: Creative suggestions, e.g., using milk cartons to build lanterns, could build a cooperation with ,e.g., arts.*[1]	The S reflect upon their everyday objects and sort them into one of the given categories. The S consider alternatives.	IS Plenum	PPT (slide 26), computer, projector, cards, board	Activation of all students, participation of all, motivation, reference to everyday life (authenticity)
15	Deepening VII	The T leads to the **soil experiment**: T: "Let's get back to the soil experiment. Get together in your groups, take your jar, empty it, and analyze your samples according to the instructions in your WB!" The results of all groups are compared in plenary. *Extension: As a homework, the S create a circular model for a certain product to present in class.* *Extension: A discussion serves as a sum-up.*	The S fill in the table in their WB, while discussing with their partners. The S present their results in class and learn about other results. The S add relevant information to their protocols.	Group work (collaborative) Plenum	PPT (slides 27-29), computer, projector, WB (p. 5-6, 10)	Activation, authenticity, motivation, summary

Lesson Plans – Plastic Pollution

T	=	Teacher	S	=	Students
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[1] Ideas to build a lantern or houses out of a paper milk carton:

PPT - References

Slide	Media	Source
1	Picture, caption: "Microplastics are now in the air"	*BBC News*. (2019). Can microplastics now travel in the air? Retrieved from https://www.bbc.co.uk/newsround/47946210
1	Picture, caption: "Whale starved to death with record amount of plastic in stomach"	Dalton, J. (2019). Whale that straved to death had record 40kg of plastic waste in its stomach. *Independent*. Retrieved from https://www.independent.co.uk/news/world/asia/whale-plastic-waste-stomach-philippines-dead-starved-a8828626.html
1	Picture, caption "Early ocean plastic traced to 1960s"; Picture, caption "Can you spot plastic from the space?"	Gill, V. (2019). Can you spot ocean plastic from space? *BBC News*. Retrieved from https://www.bbc.com/news/science-environment-47914580
1	Picture, caption "We made plastic. We depend on it. Now we're drowning it."	Parker, L. (2018). Planet or plastic? Retrieved from https://www.nationalgeographic.com/magazine/2018/06/plastic-planet-waste-pollution-trash-crisis/
1	Picture, caption: "New York agrees to ban single-use	McKinley, J. (2019). New York agrees to ban single-use plastic bags in bid to tackle pollution. *Independet*. Retrieved from https://www.independent.co.uk/news/world/americas/new-york-single-use-plastic-bags-ban-cuomo-environment-a8846686.html

Lesson Plans – Plastic Pollution

T	= Teacher	S = Students
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	plastic bags in bid to tackle pollution"	
1	Picture, caption: "What's the beef with McDonald's paper straws?"	*BBC News*. (2019). What's the beef with McDonald's paper straws? Retrieved from https://www.bbc.com/news/av/disability-48063553/what-s-the-beef-with-mcdonald-s-paper-straws
1	Picture, caption "Tests on major brands of bottled water have found that nearly all of them contained tiny particles of plastic"	Shukman, D. (2018). Plastic particles found in bottled water. *BBC News*. Retrieved from https://www.bbc.com/news/science-environment-43388870
2	YouTube-Video (Kurzgesagt – In a Nutshell)	*In a Nutshell* (2018). Plastic pollution: how humans are turning the world into plastic. Retrieved from https://www.youtube.com/watch?v=RS7IzU2VJIQ
12	Picture, caption: "'Eco-friendly' bags survive three years in soil"	*BBC News*. (2019). "Biodegradable" plastic bags survive three years in soil. Retrieved from https://www.bbc.com/news/newsbeat-48095482
17	Picture, data "The coffee cup waste problem [...]"	*BBC News*. (2019). Coffee cup ban: Boston Tea Party's sales fall by £250k. Retrieved from https://www.bbc.com/news/uk-england-bristol-47629820
17	Picture, data "Bottle waste [...]"	Herd, G. (2019). Pollution: "Plastic-free"award UK first for Anglesey. *BBC News*. Retrieved from https://www.bbc.com/news/uk-wales-47787793?intlink_from_url=https://www.bbc.com/news/topics/c6lpgw300llt/plastic-pollution&link_location=live-reporting-storyhttps://www.bbc.com/news/uk-wales-47787793?intlink_from_url=https://www.bbc.com/news/topics/c6lpgw
18	Picture, graphics and recycling data	Gilles, M. *The Recycle Guys*. Retrieved from http://www.recycleguys.org/Documents/plastics_info_11-17.pdf
19, 20	Picture, graphics and recycling data	Stephenson, W. (2018). Why plastic recycling is so confusing. *BBC News*. Retrieved from https://www.bbc.com/news/science-environment-45496884
23	YouTube-Video (TEDx Talks)	Dudas, S. at TEDx Talks (2018). Microplastics are everywhere | Sarah Dudas | TEDx Binghamton University. Retrieved from https://www.youtube.com/watch?v=jjsrmFUmyh4
29	Picture, caption: "What's the beef with McDonald's paper straws?"	*BBC News*. (2019). What's the beef with McDonald's paper straws? Retrieved from https://www.bbc.com/news/av/disability-48063553/what-s-the-beef-with-mcdonald-s-paper-straws

Zusätzliche Lernmaterialien – Deckblatt und Abstimmkarten

PLASTIC

POLLUTION

Further Learning Materials

MATERIALS

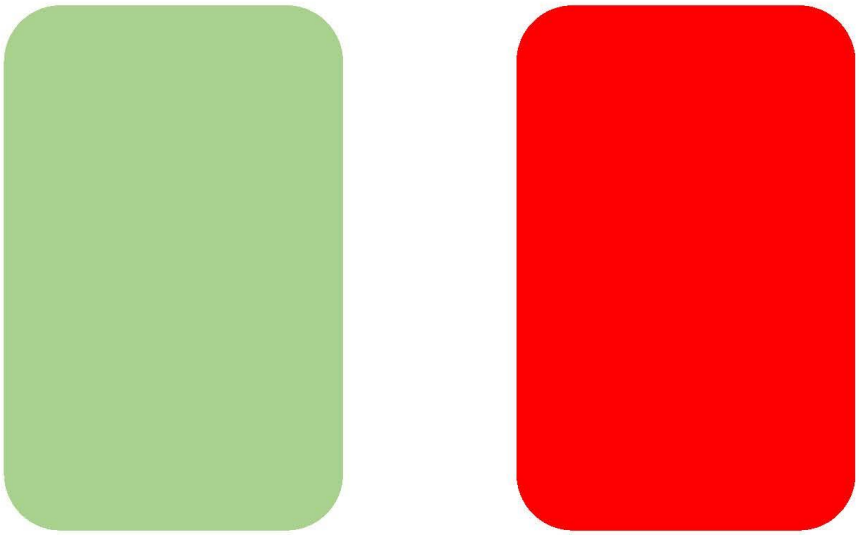
(1) Voting **cards**

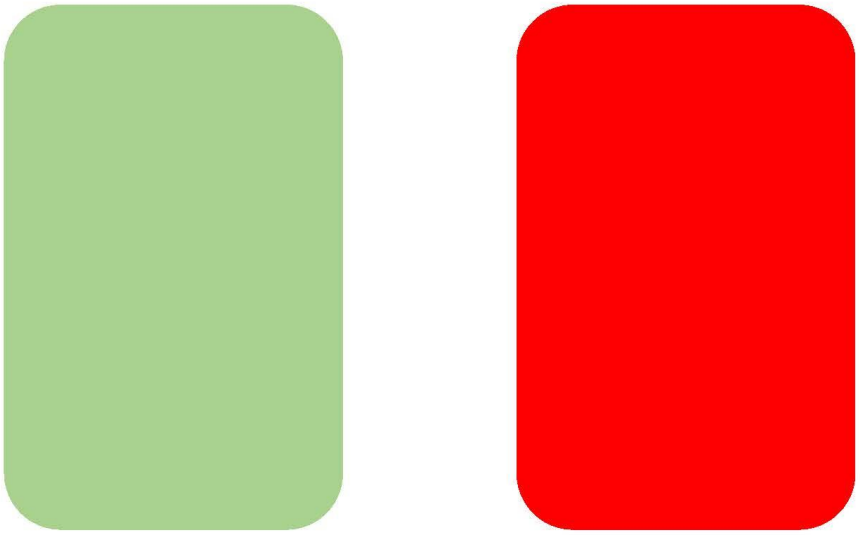
(2) **Memory activity**: Key information (landscape)

(3) **Sorting activity**: Six Rs

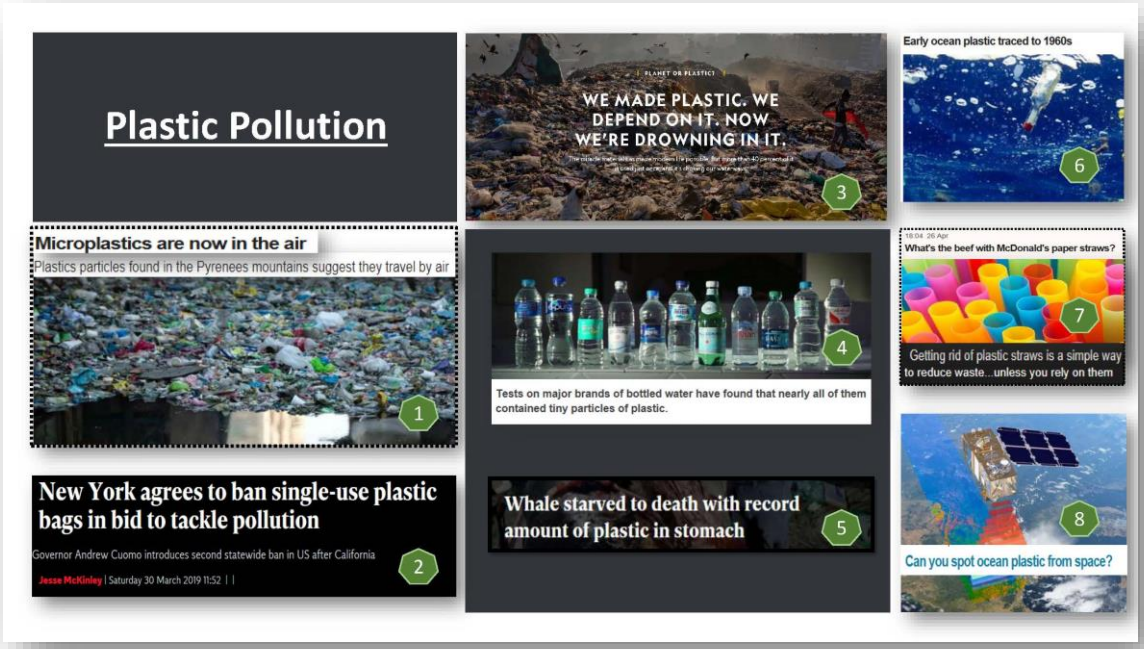
Voting Cards to Use for Quizzes or to Signal if a Task is Completed or Help Needed

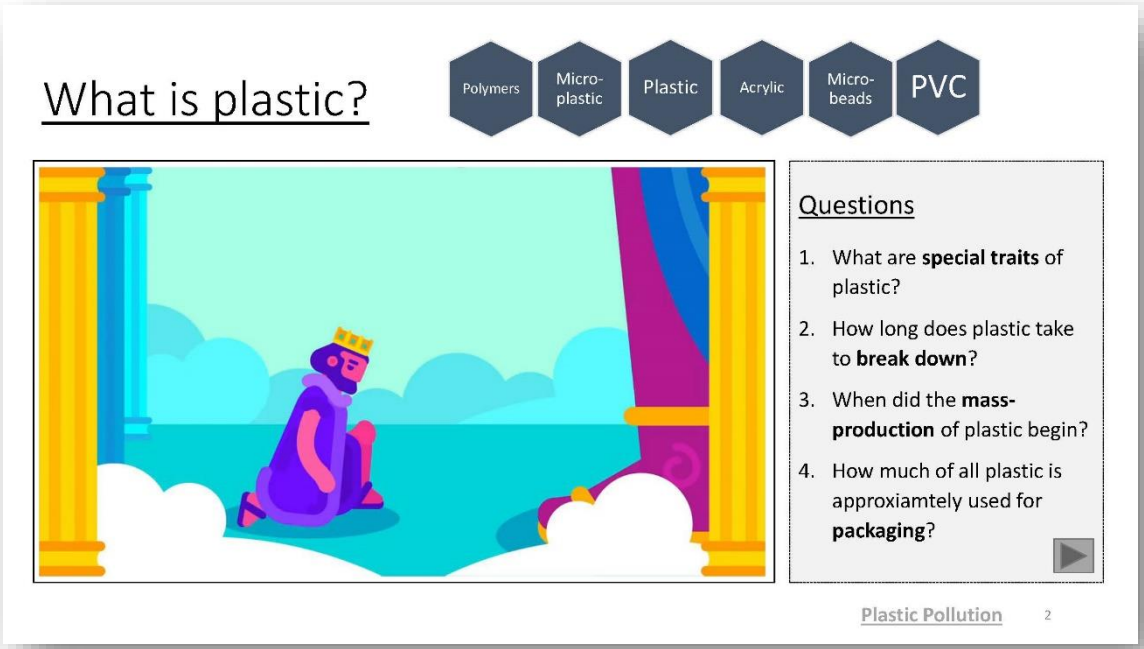
Voting Cards





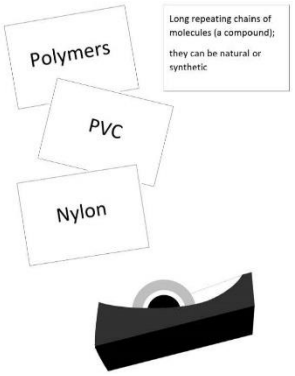
PowerPoint®-Präsentation





Activity: Memory

1. You will receive one card that can be one of the following:
   - An important term
   - A question
   - A definition
   - An answer
2. Find your partner with the card that matches yours!
3. Fix it on the board!
4. Once you are done, check if you agree with the other matches!



Plastic Pollution 3

Important Terms and Questions

Term	Definition
Polymers	Long repeating chains of molecules (a compound); they can be natural or synthetic
Plastic	Made from polymers by breaking down, e.g., crude oil into its components and rearranging them so new synthetic polymers can be formed; manufactured chains of hydrocarbons
Microplastics	Pieces of plastic which are 5 mm in diameter or smaller
Nurdles	Small, pre-manufactured pellets which are used as a raw material to make plastic products
Microbeads	Small plastic beads used in personal care products, for instance, as exfoliators
Marine debris	Anything man-made that ends up in the ocean but does not belong there; marine litter
PVC	A type of plastic that is used for plumbing, electric gears, and cases etc.
Acrylic	A type of plastic that is used as a shatter resistant alternative to glass
Nylon	A type of plastic that is used in fabric, for cooking utensils, or as a component of food packaging

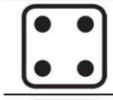
4

Important Terms and Questions

Question	Answer
What are some **special traits** of plastic?	Lightweight, durable, moldable into any shape, easily manufacturable, cheaply producible, raw materials yet available in vast amounts
How long does plastic take to **break down**?	Roughly 500 up to 1000 years
When did the **mass-production** of plastic begin?	About 1950
How much of all the plastic produced is roughly used for **packaging**?	About 40%

5

Game: Throw the dice and define the term!

	Plastic		Microbeads
	Polymer		Nurdles
	Microplastics		Marine debris

6

* Folie 8 zeigt übereinandergelegte Abbildungen von Alltagsgegenständen, bei denen Schüler:innen im Rahmen eines aktivierenden Spiels mithilfe der *Voting Cards* angeben müssen, ob sie in dem angezeigten Gegenstand Plastik als Bestandteil vermuten. Die Bilder haben die *Creative Commons*-Lizenz, deren Referenzen im *Teacher Guide* angegeben sind, und sind exemplarische Beispiele, die durch Lerkräfte ersetzt werden können, weshalb hier von der Darstellung sämtlicher Bilder abgesehen wurde.

Environmental Impact of Plastics 9

How are microplastics harmful if we can hardly see them?

→Brainstorming

→ Text work

- Read the text!
- Answer the questions!
- Place the green card on your table once you are ready, and the red card in case you need help!

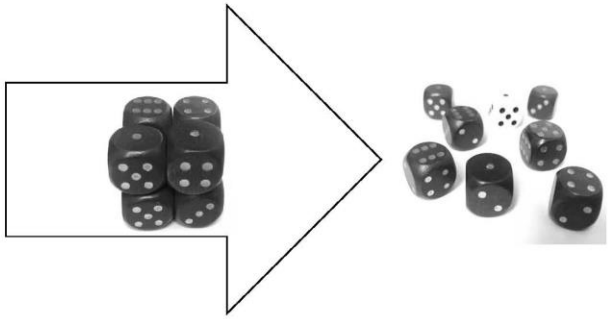
Question	Answer
How can **microplastics** end up in the **oceans**?	
Which **parameters** help to **break down** plastics?	
What can **attach** to the **surface** of plastics?	
Which **impact** can microplastics have on the **environment**?	

Environmental Impact of Plastics 10

How are microplastics harmful if we can hardly see them?

Environmental Impact of Plastics

Model:
Fragmentation



11

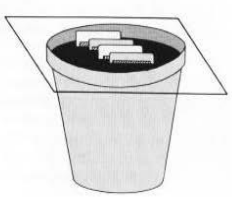
'Eco-friendly' bags survive three years in soil

Bags labelled biodegradable could carry a full bag of shopping after three years in soil and sea.

12

Experiment:
Everyday materials exposed to the soil

- Pair up!
- Read the instructions!
- Conduct the experiment!
- Should you have difficulties or questions, place the red card on your table!
- Once you are ready, place the green card on your table!

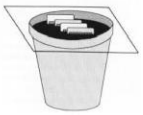


13

Experiment:
Everyday materials exposed to the soil

- Pair up!
- Read the instructions!
- Conduct the experiment!
- Should you have difficulties or questions, place the red card on your table!
- Once you are ready, place the green card on your table!

Item	How durable might the item be? *(Hypotheses)*



14

Experiment: Produce your own biodegradable "plastic"

- Pair up!
- Read the instructions!
- Conduct the experiment!
- Should you have difficulties or questions, place the red card on your table!
- Once you are ready, place the green card on your table!

15

BOTTLE WASTE

7.7 billion plastic water bottles used every year

2.5 billion end up in landfill

700,000 bottles littered every day

Source: Turning Back the Plastic Tide report, UK Parliament

The coffee cup waste problem

Many people think they are widely recycled

2.5 billion coffee cups are thrown away every year

0.25% are recycled

500,000 are littered every day

25,000 tonnes of waste a year in landfill

8 in 10 people asked by Which? in 2011 believed they were recycled

1 in 5 people visit a coffee shop daily

Throwaway society?

Plastic pollution

16

BOTTLE WASTE
7.7 billion
plastic water bottles used every year
2.5 billion end up in landfill
700,000 bottles littered every day
Source: Turning Back the Plastic Tide report, UK Parliament
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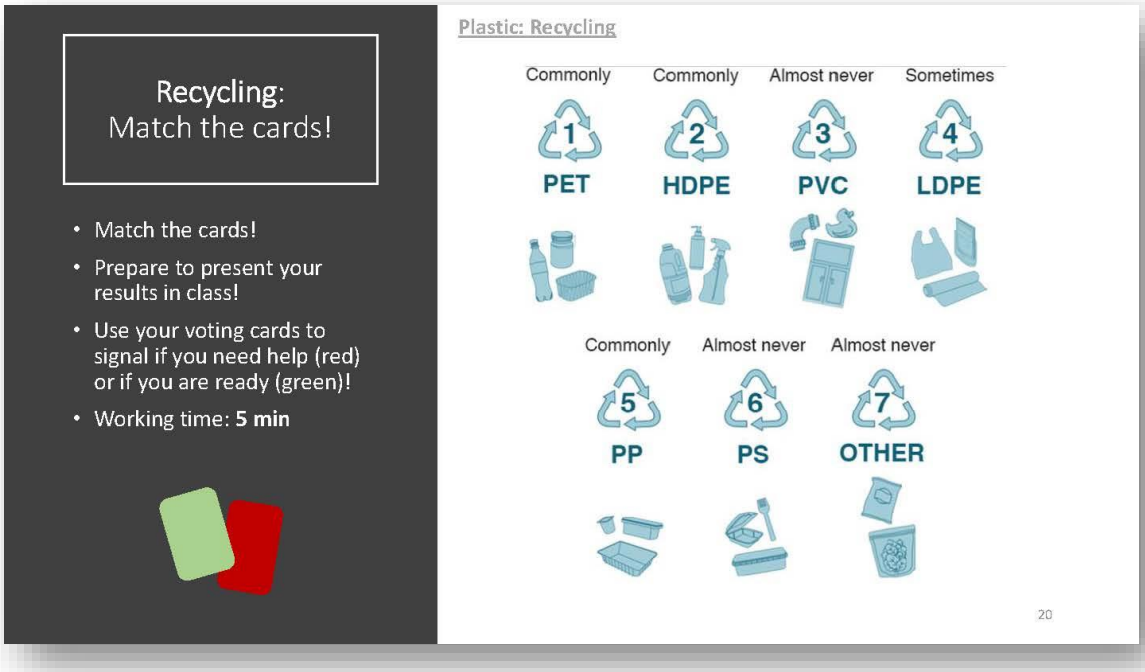
25,000 tonnes of waste a year in landfill
8 in 10 people asked by Which? in 2011 believed they were recycled
1 in 5 people visit a coffee shop daily
Throwaway society?
Plastic pollution: Recycling
17

Plastic: Recycling
Recycling: What can be recycled?
Upcycling
Downcycling
1 PET
Polyethylene terepthalate
soda, water and juice bottles; some takeout containers
fiberfill for winter coats, sleeping and bean bags; rope, carpet, parking stops and other plastic bottles.
2 HDPE
High Density Polyethylene
milk and water jugs, some margarine tubs, detergent bottles, grocery sacks
toys, piping, plastic lumber, nursery containers and other plastic bottles
3 PV
Polyvinyl Choloride
some detergent bottles, shrink wrap, siding and pipes, product packaging, shower curtains
plastic pipes, shower curtains, medical tubing and vinyl dashboards
4 LDPE
Low Density Polyethylene
garbage, sandwich, and dry cleaning bags; six-pack rings, lids from tubs, plastic wrap
plastic lumber, wrapping films, grocery/sandwich bags and recycling carts
5 PP
Polypropylene
yogurt cups, margarine tubs, screw-on lids/ caps from bottles, straws, souvenir cups
clothes hangers, car bumpers
6 PS
Polystyrene
expanded styrofoam, egg cartons, cups, and packing pellets; cutlery and picnic cups
baseboards, CD cases, lightweight concrete and packaging
7 Mixed Plastics
squeezable bottles, biodegradable plastics
nothing at this time.
18

Plastic: Recycling
Recycling: Can all plastics be recycled?
Can any item with a recycling symbol be recycled in your community?
Some types of used plastic are worth more than others
Maximum price per tonne, November 2018
£375
£145
£110
£30
£30
Natural HDPE
Clear and light blue PET
Coloured HDPE
Coloured PET
Mixed plastic
Commonly
Commonly
Almost never
Sometimes
1
PET
2
HDPE
3
PVC
4
LDPE
Commonly
Almost never
Almost never
5
PP
6
PS
7
OTHER
19


Recycling: Match the cards!
Match the cards!
Prepare to present your results in class!
Use your voting cards to signal if you need help (red) or if you are ready (green)!
Working time: 5 min
Plastic: Recycling
Commonly
Commonly
Almost never
Sometimes
1
PET
2
HDPE
3
PVC
4
LDPE
Commonly
Almost never
Almost never
5
PP
6
PS
7
OTHER
20

Plastic: Recycling

Game: Throw the dice and define the term!

●	Polyvinyl chloride
● ●	Polyethylene therephthalate
● ● ●	High density polyethylene
● ● ● ●	Polystyrene
● ● ● ● ●	Polypropylene
● ● ● ● ● ●	Low density polyethylene

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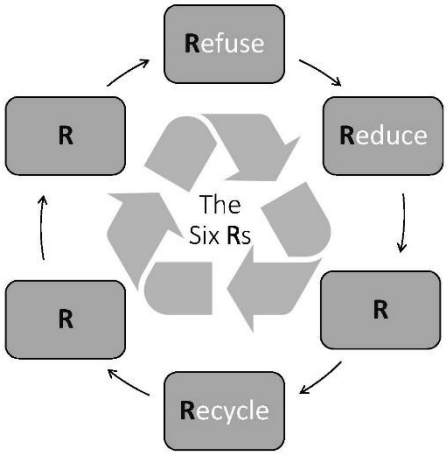
Plastic: Recycling

If not all products can be recycled properly,
what else can we do?



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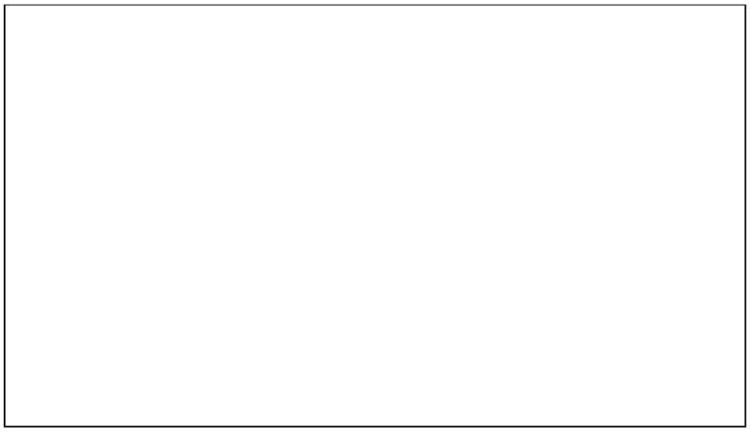
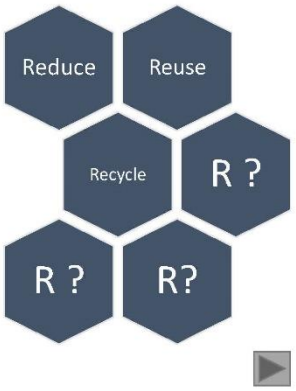
Plastic: Recycling

UA SCIENCE Biosphere 2

Video Clip: "Plastic is Everywhere!" – A **TEDx** Talks

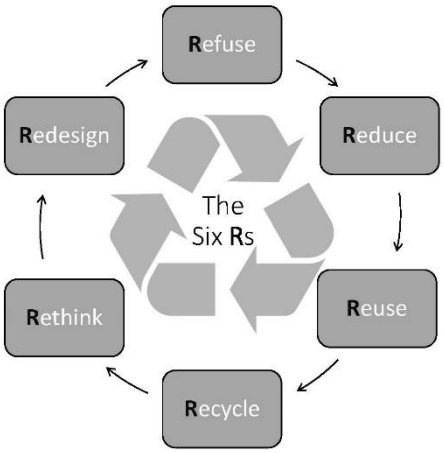




23

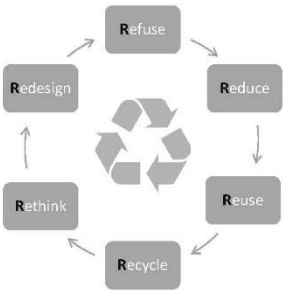
Plastic: Recycling

If not all products can be recycled properly,
what else can we do?



24

Plastic: Recycling



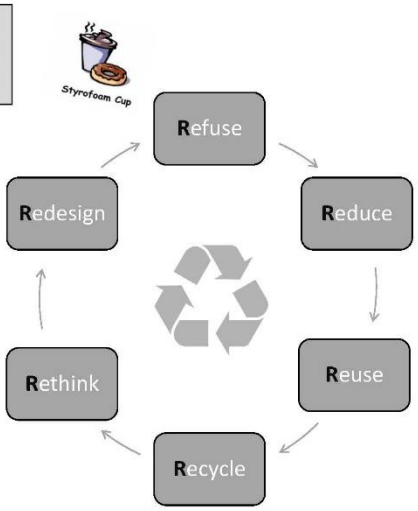
Homework: 3-Day-Challenge at Home

Day	Product	Which "R" would you suggest?
Monday	Water bottle	
	...	
Tuesday		

25

Activity: *The Six Rs*

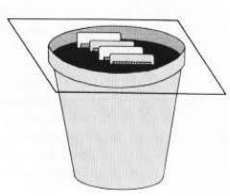
1. You will receive **one card** with an **item** that is **often thrown away**.
2. Decide which **category** would be best for it, then fix it on the **board**!
3. Once you are done, look at the other students' choices and try to come up with **alternative ideas**!



26

If plastics are hardly **biodegradable**, what happened to the materials in your **jars**?

Plastic: Recycling



27

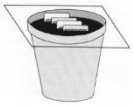
Experiment: Everyday materials exposed to the soil

- Compare your samples!
- Take notes!
- Prepare to present your results in class!
- Use your voting cards to signal if you need help (red) or if you are ready (green)!
- Working time: **5 min**

Plastic: Recycling

UA SCIENCE Biosphere2

Item	How durable might the item be? *(Hypotheses)*



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Plastic: Recycling

Discussion: Plastic – Curse, Blessing, or Both?

- Compare the **biodegradable** and **conventional plastic film** of your jar:

  What changes can you detect?

- Take this comparison as the basis of finding as many **advantages** and **downsides** of plastics as possible!
  1. Think – Pair – Share
  2. Open up to a class discussion

Plastic	Advantages	Downsides
Production	...	...
Resources	...	...
...		

29

Teilarbeit C: Fragebogen

TEQ/ECQ - Earthkeepers - Student

Name: _____

Date: _____ Grade: _____

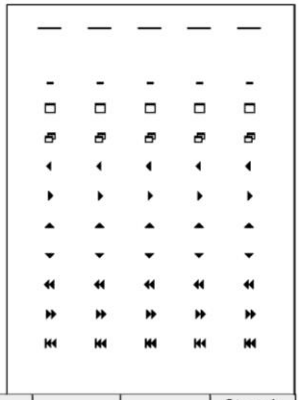
School: _____

Teacher: _____

Age: O 8 O 9 O 10 O 11 O 12

Gender: O Boy O Girl

For each statement, please fill in a circle to show what you think.
There are no right or wrong answers.



Do you agree that:		Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
1.	If I ever have extra money, I will give some to help protect nature.	O	O	O	O	O
2.	To save energy in the winter, I make sure the heat in my room is not on too high.	O	O	O	O	O
3.	I would like to sit by a pond and watch dragonflies.	O	O	O	O	O
4.	People have the right to change the environment (nature).	O	O	O	O	O
5.	Building new roads is so important that trees should be cut down.	O	O	O	O	O
6.	Plants and animals have as much right as people to live.	O	O	O	O	O
7.	There are too many (or almost too many) people on Earth.	O	O	O	O	O
8.	I would help raise money to protect nature.	O	O	O	O	O
9.	I always turn off the light when I do not need it any more.	O	O	O	O	O
10.	I like to go on trips to places like forests away from cities.	O	O	O	O	O
11.	I like a grass lawn more than a place where flowers grow on their own.	O	O	O	O	O
12.	Because mosquitoes live in swamps, we should drain the swamps and use the land for farming.	O	O	O	O	O
13.	People must still obey the laws of nature.	O	O	O	O	O
14.	When people mess with nature it has bad results.	O	O	O	O	O
15.	I try to tell others that nature is important.	O	O	O	O	O
16.	I try to save water by taking shorter showers or by turning off the water when I brush my teeth.	O	O	O	O	O
17.	I like the quiet of nature.	O	O	O	O	O
18.	To feed people, nature must be cleared to grow food.	O	O	O	O	O
19.	People are supposed to rule over the rest of nature.	O	O	O	O	O
20.	People are treating nature badly.	O	O	O	O	O
21.	Weeds should be killed because they take up space from plants we need.	O	O	O	O	O
22.	People are clever enough to keep from ruining the earth.	O	O	O	O	O
23.	If things don't change, we will have a big disaster in the environment soon.	O	O	O	O	O
24.	Nature is strong enough to handle the bad effects of our modern lifestyle.	O	O	O	O	O
25.	People will someday know enough about how nature works to be able to control it.	O	O	O	O	O

Please choose the best answer for each and fill in the circle.

1. Only _____ can turn sunlight energy into food.

O animals O plants O water O air

2. Which of the following shows a food chain (munchline) in proper order?

O Sun ⇒ Animals ⇒ Plants O Plants ⇒ Sun ⇒ Animals

O Animals ⇒ Sun ⇒ Plants O Sun ⇒ Plants ⇒ Animals

3. Which of the following would there be the most of in a food chain (munchline)?

O Plants O Animals that eat plants O Animals that eat animals

4. Which of the following is most true?

O I am made of new materials that have never been a part of anything else before. O I am made of recycled materials that have been part of other things in the past.

5. The materials that everything is made of:

O Stay in one place forever. O Move in a line, never returning to where they started. O Move in circles, often returning to where they started.

6. "I can do just one thing without affecting anything else." This statement is:

O True O False O Sometimes true and sometimes false

7. Which of the following is most true?

O Everything is constantly changing. O Nothing is changing. O Some things change, but some never do.

8. If a place is now a desert,

O it could **never** be an ocean. O it **may** someday be an ocean. O it will **for sure** someday be an ocean.

9. Where do plants get the energy they need to live and grow?

O Sun O Water O Soil O Sun and water

O Water and soil O Soil and sun O Sun and water and soil

10. Take a look at your pencil. Were the materials that make your pencil ever a part of something else?

O Yes, the materials were once part of something else. O No, they were never a part of something else.

11. **Animals** use energy that helps their bodies to live and grow. They get that energy from:

O Sun and water O Plants and sun O Plants and animals O Water and plants

12. **People** use energy that helps their bodies to live and grow. They get that energy from:

O Sun and water O Plants and sun O Plants and animals O Water and plants

13. Imagine a ship has wrecked at sea spilling toxic chemicals into the ocean. Could those chemicals end up inside your body?

O Yes O No O Not sure

Supplementary Material

Table 1S: The 15 Environmental Knowledge Items Ordered by Item Difficulties

Environmental knowledge items	Multiple choice answers	δ	MS_w	MS_u	t_w	t_u
'Woodfree' exercise books are environmentally friendly.	○ Correct ○ Incorrect ○ I don't know	2.08 (.11)	**1.26**	**1.89**	**3.1**	**5.3**
The so-called 'green electricity' is made of fossil fuels such as coal and crude oil.	○ Correct ○ Incorrect ○ I don't know	1.51 (.09)	1.20	1.21	**3.3**	**2.0**
During ozone alarms in summer, you should leave your car because:	○ Summer smog occurs. ○ The hole in the ozone layer expands. ○ The air temperature increases. ○ The engine releases more pollutants.	1.24 (.08)	.84	.86	-4.4	-2.0
How much CO_2 is released when shipping five apples from South America to Germany	○ 1 kg ○ 2 kg ○ 3 kg ○ 4 kg	.92 (.07)	1.10	1.17	**2.9**	**2.6**
Ozone harms forests because it...	○ ...destroys leaf cells. ○ ...acidifies the forest soil. ○ ...deprives plants of oxygen. ○ ...decomposes the roots of plants.	.83 (.07)	1.09	1.14	**2.7**	**2.3**
To reduce the greenhouse effect it makes sense to...	○ ...buy local products. ○ ...save drinking water. ○ ...separate waste. ○ ...avoid using paper.	.45 (.07)	.98	.96	-.8	-.7
An annual ring of a tree is composed of:	○ Periderm and phloem ○ Earlywood and latewood ○ Springwood and winterwood ○ Primary and secondary medullary rays	-.05 (.06)	.87	.83	-5.9	-3.9

continued

Environmental knowledge items	Multiple choice answers	δ	MS_w	MS_u	t_w	t_u
Low-sulfur fuel oil is expensive but contains only half as much sulfur as normal fuel oil does.	○ Correct ○ Incorrect ○ I don't know	-.13 (.06)	.91	.89	-4.1	-2.6
Which of those labels indicates recycled paper?		-.26 (.06)	.91	.89	-3.9	-2.4
The good thing about saving energy is that you also reduce carbon dioxide emissions.	○ Correct ○ Incorrect ○ I don't know	-.34 (.06)	1.02	1.00	.8	.1
How often can we reuse paper through recycling?	○ Once ○ 3-4 times ○ 6-7 times ○ 10-12 times	-.53 (.07)	1.06	1.09	**2.4**	1.7
Pulp is made of:	○ Bark ○ Straw ○ Wood ○ Paper	-.88 (.07)	.92	.85	-2.9	-2.6
Contrary to normal paper, producing recycled paper does need...	○ ...no pulp. ○ ...no wood. ○ ...more water. ○ ...more energy.	-.93 (.07)	1.16	1.29	**5.3**	**4.4**
'Acid rain' harms forest soils.	○ Correct ○ Incorrect ○ I don't know	-1.45 (.08)	.88	.72	-3.2	-3.9
Used paper needs to go into the residual waste bin.	○ Correct ○ Incorrect ○ I don't know	-2.46 (.10)	.94	.85	-.7	-1.1
M (*SD*)		.00 (1.20)	1.01 (.13)	1.04 (.29)	-.4 (3.5)	.0 (2.9)

Note: Item difficulties (δ) are expressed in logits along with their corresponding standard errors of measurement (*SEM*). Mean square (*MS*) and *t* values—unweighted ($_u$) and weighted ($_w$) by the item variance—reflect the relative discrepancy between the model-predicted and actual responses and were used to assess item fit (see, e.g., Wright & Masters, 1982). **Bold figures** highlight either statistically significant *t* values ($p < .05$) or MS_w values that did not fall within an acceptable range of fit even for test items ($0.80 \leq MS \leq 1.20$) and MS_u values that did not fall within the acceptable range for typical survey items ($0.60 \leq MS \leq 1.40$; see Wright et al., 1994). A value of $MS > 1.20$ corresponds to an excess of more than 20% variation in the data than what was predicted by the Rasch model.

Teilarbeit E: Fragebogen

COOPER: Earthkeepers TEQECQ-Student 2018-2019

Name: _____ **Date:** _____

School: _____

Teacher: _____

Age: 9 ○ 10 ○ 11 ○ 12 ○ **Gender:** Girl ○ Boy ○ **Grade:** 4 ○ 5 ○ 6 ○

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Do you agree that:		Strongly Agree	Agree	Not Sure/ Neutral	Disagree	Strongly Disagree
1.	If I ever have extra money, I will give some to help protect nature.	○	○	○	○	○
2.	To save energy in the winter, I make sure the heat in my room is not on too high.	○	○	○	○	○
3.	People have the right to change the environment (nature).	○	○	○	○	○
4.	Building new roads is so important that trees should be cut down.	○	○	○	○	○
5.	I would help raise money to protect nature.	○	○	○	○	○
6.	I always turn off the light when I do not need it any more.	○	○	○	○	○
7.	I like to go on trips to places like forests away from cities.	○	○	○	○	○
8.	Because mosquitoes live in swamps, we should drain the swamps and use the land for farming.	○	○	○	○	○
9.	I try to save water by taking shorter showers or by turning off the water when I brush my teeth.	○	○	○	○	○
10.	I like the quiet of nature.	○	○	○	○	○
11.	To feed people, nature must be cleared to grow food.	○	○	○	○	○
12.	People are supposed to rule over the rest of nature.	○	○	○	○	○
13.	Weeds should be killed because they take up space from plants we need.	○	○	○	○	○
14.	I try to tell others that nature is important.	○	○	○	○	○
15.	I like a grass lawn more than a place where flowers grow on their own.	○	○	○	○	○
16.	I would like to sit by a pond and watch dragonflies.	○	○	○	○	○
17.	I enjoy looking at stars at night.	○	○	○	○	○
18.	I enjoy watching or listening to birds.	○	○	○	○	○
19.	I like to watch the clouds pass by.	○	○	○	○	○
20.	I enjoy smelling the flowers.	○	○	○	○	○

Please choose the best answer and fill in ONE circle

1. Importing fruits from South America is bad for the environment because…

○ The climate is not good for growing fruit in South America. ○ A lot of packaging material is used. ○ Transporting them to Arizona requires a lot of energy.

2. What lunch item uses the most energy and materials?

O Lunchable with ham, cheese, and crackers.
O Ham, cheese, and crackers in a reusable container.
O Ham, cheese, and crackers in a plastic bag.

3. To lessen our impact on the environment, it makes sense to…

O Drive a new car instead of driving an old car.
O Eat organic produce
O Light a fireplace instead of turning on the heater.

4. Cotton clothing takes _____ energy to make when compared to synthetic (polyester) clothing.

O The same amount of
O More
O Less

5. Why is it better to collect and recycle aluminum cans than to throw it away?

O Because we are running out of materials to make aluminum from
O Because discarded aluminum gives off poisons when burned
O Because producing new aluminum creates a lot of pollution.

6. Which bag for groceries is the best choice for the environment?

O Plastic bag
O Reusable bag
O Paper bag

7. Carpooling is better for the environment than driving by yourself because…

O You get to hang out with friends.
O It reduces pollution
O It is easier to find parking.

8. Which yard is the most environmentally friendly in Arizona?

O Desert landscape
O Tropical landscape
O Grass lawn

9. It is better for the environment to hang your clothes up outside to dry because…

O It uses less energy
O You don't need to spend money on buying a dryer.
O It makes you go outside to enjoy nature.

10. Taking a five minute shower uses _____ water than taking a bath.

O The same amount of
O More
O Less

11. Which item is less harmful for the environment to consume?

O Farm-raised meat
O Home grown fruits
O Farm-raised veggies

12. What is the most important reason to save energy?

O To save money
O There is no important reason
O To save fossil fuel energy for the next generation
O To protect the environment

13. Which activity uses the most fossil fuel energy?

O Driving a car
O Using a cell phone
O Lighting a room
O Using a computer

14. Which way is the most environmentally harmful way to go somewhere?

O By car with my mother or father
O Using public transportation
O Riding a bicyce or walking
O Carpooling with friends

Please choose the best answer and fill in ONE circle.

1. Only _____ can turn sunlight energy into food.

O Animals O Plants O Water O Air

2. Which of the following shows a food chain in proper order?

O Sun ⇒ Animals ⇒ Plants O Plants ⇒ Sun ⇒ Animals

O Animals ⇒ Sun ⇒ Plants O Sun ⇒ Plants ⇒ Animals

3. Which of the following would there be the greatest number of in a food chain (munchline)?

O Plants O Animals that eat plants O Animals that eat animals O They are all equal

4. Which of the following is most true?

O I am made of new materials that have never been part of anything else before. O I am made of recycled materials that have been part of other things in the past.

5. The materials that everything is made of:

O Stay in one place forever. O Move in a line, never returning to where they started. O Move in circles, often returning to where they started.

6. "I can do just one thing without affecting anything else." This statement is:

O True. O False. O Sometimes true, sometimes false.

7. Which of the following is most true?

O Everything is constantly changing. O Nothing is changing. O Some things change, but some never do.

8. If a place is now a desert,

O It could never be an ocean. O It may someday be an ocean. O It will for sure someday be an ocean.

9. Where do plants get the energy they need to live and grow?

O Sun O Water O Soil O Sun, water and soil

10. Take a look at your pencil. Were the materials that make your pencil ever a part of something else?

O Yes, the materials were once part of something else. O No, they were never part of something else.

11. Animals use energy that helps their bodies to live and grow. They get that energy directly from:

O Sun and water O Plants and sun O Plants and animals O Water and plants

12. People use energy that helps their bodies to live and grow. They get that energy directly from:

O Sun and water O Plants and sun O Plants and animals O Water and plants

13. Imagine a ship has wrecked at sea spilling toxic chemicals into the ocean. Could those chemicals end up inside your body?

O Yes O No O Not sure

Please indicate how often you do the following:		Never	Seldom (not often)	Occasionally (once in a while)	Often (a lot)	Always
1.	I ride a bicycle, take the bus, or walk to school.	O	O	O	O	O
2.	I collect and recycle used paper.	O	O	O	O	O
3.	If I am the last person to leave a room, I switch off the lights.	O	O	O	O	O
4.	I drink water and other beverages in re-usable bottles.	O	O	O	O	O
5.	I bring empty cans and bottles to a recycling bin.	O	O	O	O	O
6.	I try to persuade my parents to buy an energy-efficient car.	O	O	O	O	O
7.	For short distances (within 15 minutes) I walk or ride a bike.	O	O	O	O	O
8.	I reuse shopping bags.	O	O	O	O	O
9.	I have pointed out behavior that is not environmentally friendly to someone else.	O	O	O	O	O
10.	For making notes, I take paper that has already been used on one side.	O	O	O	O	O
11.	I learn about environmental issues through the media (Internet, newspapers, TV).	O	O	O	O	O

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(§ 8 Satz 2 Nr. 3 PromO Fakultät)
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