UNIVERSITÄT BAYREUTH

Fakultät für Biologie, Chemie und Geowissenschaften

Lehrstuhl Didaktik der Biologie

Bildung zu Mikroplastik

Eine empirische Studie zu Einflussfaktoren auf das Lernen im Kontext der Umweltbildung

Dissertation

zur Erlangung des akademischen Grades

Doctor rerum naturalium
(Dr. rer. nat.)

der Fakultät für Biologie, Chemie und Geowissenschaften
der Universität Bayreuth

vorgelegt von

Patricia Raab
geboren in Sulzbach-Rosenberg

Bayreuth, April 2021

Die vorliegende Arbeit wurde in der Zeit von April 2018 bis April 2021 am Lehrstuhl der Didaktik der Biologie der Universität Bayreuth unter Betreuung von Herrn Prof. Dr. Franz X. Bogner angefertigt.

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

Dissertation eingereicht am: 28.04.2021

Zulassung durch die Promotionskommission: 05.05.2021

Wissenschaftliches Kolloquium: 10.08.2021

Amtierender Dekan: Prof. Dr. Matthias Breuning

Prüfungsausschuss:

Prof. Dr. Franz X. Bogner	(Gutachter)
Prof. Dr. Volker Ulm	(Gutachter)
Prof. Dr. Christian Laforsch	(Vorsitz)
Prof. Dr. Stefan Peiffer	

Inhalt

Hinweis auf diversitätsgerechten Sprachgebrauch:

Ein sensibler Sprachgebrauch ist das Grundfundament für eine Gleichberechtigung und wertschätzende, diskriminierungsfreie Ansprache. Aus Gründen der Übersichtlichkeit und besseren Lesbarkeit wird jedoch in der vorliegenden Arbeit das generische Maskulinum verwendet. Es wird ausdrücklich darauf hingewiesen, dass die Verwendung der männlichen Form geschlechtsunabhängig unter Einbeziehung aller Geschlechteridentitäten erfolgt. Entsprechend der Inhaltserfordernisse wird die geschlechterübergreifende Pluralform verwendet. Wenn es der inhaltliche Kontext erforderlich macht, wird speziell auf die Geschlechterunterschiede eingegangen und die geschlechterspezifische Benennung vorgenommen.

1 SUMMARY

Protecting the planet from the contamination with plastics and microplastics is an immediate environmental challenge. Stakeholders in both government and industry are encouraged to take instant action. Yet, consumers need to reflect on the consequences of their buying behavior and act more responsibly. Such reflection and environmentally-friendly action require specific knowledge. Imparting this knowledge and creating pro-environmental awareness should, thus, be the objective of future educational policy since neither the effect of plastics nor microplastics is, as yet, part of the curriculum.

The present thesis considered this initial situation. On the one hand, it conceptualized, evaluated, and advanced an environmental educational measure on microplastics; on the other hand, it investigated factors potentially influencing ecological content learning.

Study A provides insights into the relationship between environmental values and circadian preference. Scrutinizing the individual personality trait of circadian preference showed that - irrespective of gender - younger students preferred morning hours while older students favored evening hours. Analyses of environmental values and circadian preference produced positive correlations between environmental values and morning preference: \`early birds\` seem to have increased preservative and appreciative attitudes towards nature. Understanding personality-specific relations like these can provide important impulses for future teaching.

In **study B**, a curriculum compliant learning module on microplastics was designed, implemented, and evaluated in primary schools. To better comprehend an effective and sustainable knowledge enhancement, the identical learning module was performed at two different learning locations (in-school and out-of-school). The module followed a student-centered approach. Students used the material provided at learning stations to independently acquire knowledge relevant to their everyday life on microplastic sources, sinks, pathways, environmental consequences as well as on strategies to take action. The students recorded a short- and long-term acquisition of environmentally relevant knowledge about microplastics at both learning sites. Regardless of the student's environmental value's intensity, the module affected all students in similar strength. Students, both with strong or weak environmental values, increased their knowledge and retained this level over six weeks. A regression model proved utilization of nature to be the strongest predictor of knowledge at T1 (directly after participation), followed by preservation of nature. The model also indicated that utilization of nature negatively influences personal knowledge, while preservation of nature has a positive effect. The learning site proved to be a relatively weak predictor of knowledge at T1. The in-school location postulated higher knowledge at T1 compared to the out-

of-school site. However, the superiority of the in-school learning site was statistically significant at T2 only (6 weeks after the intervention).

The learning module designed for and implemented in the intervention study (study B) was refined in **study C**. Based on experience and feedback from practice, adjustments were made to intensify the students' learning autonomy. This entailed organizational, methodological, and content-related adaptations, including, for instance, the integration of tasks that increase the relevance to everyday life. In addition to the former learning stations, a new one was included to explore the sustainable use of plastics. Subsequently, the adapted learning module was disseminated to teachers for independent use.

Study D analyzed students' conceptions of microplastics. Its results provide well-founded, topic-specific starting points for developing teaching units in secondary education or outreach activities led by experts. The majority of the students defined microplastics as small plastic particles. The students' understanding of the term revealed a strong association between microplastics and its negative consequences. Plastic packaging, followed by personal care products, were the best-known sources of microplastics in the household, while only a few mentioned plastic objects or textiles, and no one pointed out hygiene products. Compared to oceans, lakes, and rivers, few students recognized the microplastic contamination of groundwater. The risk evaluation unveiled students' high threat awareness. The addressed reasons were diverse, ranging from environmental consequences to the ingestion of microplastics by animals and humans. Students indicated to have obtained their information primarily from the media.

This thesis meets particularly two objectives: Firstly, it provides a practice-approved, curriculum compliant, and knowledge-generating learning module on the topic of microplastics. Secondly, it shows effects of student-related and infrastructural factors, which provide implications for effective learning.

2 ZUSAMMENFASSUNG

Der Umgang mit Kunststoffen und Mikroplastik ist aufgrund der globalen Kontamination eine enorme umweltpolitische Herausforderung. Für Akteure aus Politik und Industrie besteht akuter Handlungsbedarf. Gleichzeitig ist es die Pflicht des Konsumenten, die Konsequenzen seines Kaufverhaltens zu hinterfragen und seiner Verantwortung gerecht zu werden. Gesamtgesellschaftliches Ziel muss es sein, ein ökologisches Bewusstsein zu schaffen, indem man umweltschutzspezifisches Wissen etabliert, um letztlich umweltfreundliches Handeln zu fördern. Der stärkste bildungspolitische Ansatzpunkt hierfür ist eine, bis dato nicht im Lehrplan verankerte, schulische Auseinandersetzung mit Kunststoffen und Mikroplastik im Kontext des Umweltschutzes.

Die vorliegende Arbeit nahm diese Ausgangssituation auf und befasste sich zum einen mit der Konzeptionierung, Evaluierung und Weiterentwicklung einer schulischen Umweltbildungsmaßnahme zum Thema Mikroplastik, zum anderen untersuchte sie Faktoren, die potenziell Einfluss auf das Lernen von Umweltinhalten haben.

Teilarbeit A gibt Einblicke in den Zusammenhang zwischen der Tageszeitpräferenz und den Umwelteinstellungen. Mit Fokus auf das individuelle Persönlichkeitsmerkmal der Tageszeitpräferenz zeigte sich geschlechtsunabhängig, dass jüngere Schüler eine Präferenz für Morgenstunden besitzen, während ältere Schüler stärker zu den Abendstunden tendieren. Bei Betrachtung der Beziehungen der beiden Konstrukte zueinander erkannte man folgenden positiven Zusammenhang: Schüler mit einer ausgeprägten Präferenz für die Morgenstunden scheinen stärker umweltschützende und wertschätzende Einstellungen gegenüber der Natur zu besitzen. Das Verständnis für persönlichkeitsspezifische Zusammenhänge dieser Art kann wichtige Impulse für ein verbessertes Lehrangebot geben.

In **Teilarbeit B** wurde ein lehrplankonformes Unterrichtsmodul zum Thema Mikroplastik in der Primarstufe entwickelt, durchgeführt und evaluiert. Mit dem Ziel, eine effektive und nachhaltige Wissensvermittlung besser zu verstehen, wurde das identische Unterrichtsmodul an zwei Lernorten (inner- und außerschulisch) durchgeführt. In einem lernerzentrierten Ansatz erarbeiteten Schüler eigenständig alltagsrelevante Inhalte zu Quellen, Senken, Eintragspfaden und Umweltauswirkungen von Mikroplastik sowie Handlungsoptionen mit entsprechenden Materialien an Lernstationen. Die Schüler verzeichneten an beiden Lernorten einen kurz- und langfristigen Erwerb umweltrelevanten Wissens über Mikroplastik. Unabhängig von der Intensität ihrer individuellen Umwelteinstellungen erreichte das Unterrichtsmodul alle Schüler ähnlich effektiv. Sowohl Schüler mit einer hohen als auch mit einer niedrigen Ausprägung ihrer Umwelteinstellungen lernten signifikant dazu und konnten den Wissensstand auch noch nach sechs Wochen abrufen. In einem Regressionsmodell zeigte sich die Naturausnutzungspräferenz noch vor der Naturschutzpräferenz als stärkster Prädiktor des Wissens zum Testzeitpunkt T1 (direkt nach der Teilnahme). Dabei beschreibt das Modell einen plausibel nachvollziehbaren negativen Einfluss der Naturausnutzungspräferenz auf individuelles Wissen, während die Naturschutzpräferenz positive Effekte bedingt. Der Lernort erwies sich als relativ schwacher Prädiktor des Wissens zu T1, wobei der innerschulische Lernort im Vergleich zum außerschulischen Lernort ein höheres Wissen postulierte. Statistisch signifikant war die Überlegenheit des innerschulischen Lernorts lediglich zum dritten Testzeitpunkt T2 (sechs Wochen nach der Intervention).

Das für die Interventionsstudie (Teilarbeit B) konzipierte, und darin durchgeführte Unterrichtsmodul, wurde in **Teilarbeit C** weiterentwickelt. Auf Grundlage von Erfahrungen und Rückmeldungen aus der Praxis wurden organisatorische, methodische und inhaltliche Anpassungen vorgenommen, um im Sinne des schülerzentrierten Ansatzes die eigenständige Arbeit der Schüler weiter zu stärken. Hierzu zählten die Erweiterungen vorhandener Lernstationen mit Aufgaben, die den Alltagsbezug erhöhen sowie die Integration einer neuen Lernstation, in der die Schüler nachhaltige Handlungsoptionen im Umgang mit Kunststoffen kennenlernen. Das angepasste Unterrichtsmodul wurde anschließend für einen losgelösten Einsatz Lehrpersonen zur Verfügung gestellt.

Teilarbeit D analysierte Vorstellungen von Studierenden zum Thema Mikroplastik. Die Ergebnisse liefern fundierte, themenspezifische Ansatzpunkte zur Entwicklung von Bildungsmaßnahmen in der Sekundarstufe sowie von Outreach-Aktivitäten, geleitet durch außerschulische Experten. Ein Großteil der Studierenden definierte Mikroplastik als kleine Kunststoffpartikel. Bereits im Begriffsverständnis zeigte sich eine starke Assoziation zu den negativen Konsequenzen von Mikroplastik. Kunststoffverpackungen zählten gefolgt von Körperpflegeprodukten zu den bekanntesten Quellen im Haushalt. Weitaus weniger Studierende nannten beispielsweise Kunststoffgegenstände oder Textilien. Weitere Mikroplastikquellen, wie Hygieneartikel, waren den Studierenden völlig unbekannt. Verglichen mit den Meeren, den Seen und Flüssen, vermuteten relativ wenige Studierende eine Mikroplastikkontamination des Grundwassers. Die abgefragte Gefahreneinschätzung deutete auf eine hohe Sensibilität der Studierenden hin. Die genannten Gründe hierfür waren vielfältig. Sie reichten von Folgen für die Umwelt bis hin zur Aufnahme von Mikroplastik als bzw. mit Nahrung durch Tiere und Menschen. Die Hauptinformationsquelle der Studierenden waren die Medien.

Zusammenfassend leistet diese Arbeit vor allem zweierlei: Zum einen liefert sie ein praxiserprobtes, lehrplankonformes und wissensbildendes Unterrichtsmodul zum Thema Mikroplastik, zum anderen zeigt sie Effekte von schülerindividuellen sowie lerninfrastrukturellen Einflussfaktoren und daraus resultierende Implikationen für ein zielführendes Lernen.

3 SYNOPSIS

3.1. Einleitung

„Humans are the cause and solution."

Pahl et al., 2007

Der Siegeszug der Kunststoffe hat das Leben des Menschen und gleichzeitig die Erde dauerhaft und unwiderruflich verändert. Ihre Eigenschaften, wie das geringe Gewicht, die Stabilität, die Langlebigkeit und die unerschöpflichen Einsatzgebiete bei geringem finanziellen Aufwand, machten sie in vielen Lebensbereichen unersetzlich (Andrady, 2011; Thompson et al., 2009). Die globale Produktion an Kunststoffen steigt stetig und betrug im Jahr 2020 mit 368 Millionen Tonnen beinahe das 250-fache, verglichen mit dem Beginn der Massenproduktion im Jahr 1950 (PlasticsEurope, 2020). Was dem Menschen in fast allen Lebenslagen von großem Nutzen ist, wird jedoch nach seiner Verwendung zu einem Problem für die Umwelt. Die Verschmutzung der Erde durch Kunststoffe gilt folglich als eine der größten ökologischen Herausforderungen unserer Generation (Allen et al., 2019). Die Kunststoffbelastung ist untrennbar mit der Mikroplastikbelastung der Umwelt verbunden, da Kunststoffe zwangsläufig zu Mikroplastik defragmentieren. Mikroplastik ist definiert als Kunststoffpartikel mit einer Größe von weniger als 5 mm (GESAMP, 2016). Über atmosphärischen (Bergmann et al., 2019) oder aquatischen Transport (Auta et al., 2017) erreicht Mikroplastik selbst entlegene Bergregionen (Allen et al., 2019), die Arktis (Bergmann et al., 2019) oder die Tiefsee (van Cauwenberghe et al., 2013). Folglich stellt auch die Mikroplastikbelastung ein globales Phänomen dar. Zu den potenziellen Auswirkungen von Mikroplastik gehören beispielsweise dessen Aufnahme mit bzw. als Nahrung (Cole et al., 2013), dessen Akkumulation im Nahrungsnetz (Setälä et al., 2014) oder dessen Veränderung von Bodeneigenschaften (de Souza Machado et al., 2019). Forschungsarbeiten zur Toxizität ergaben bisher kein einheitliches Bild, weshalb diesbezüglich noch kein Konsens in wissenschaftlichen Kreisen besteht (Bucci et al., 2020). Die Komplexität dieses Themas wird wesentlich durch die Vielfältigkeit von Mikroplastik erhöht. Unter anderem können Form, Größe oder auch Polymertyp maßgeblich die Verbreitung und die Auswirkungen in der Umwelt beeinflussen (Hidalgo-Ruz et al., 2012).

Die potenziell von der Kunststoff- und Mikroplastikbelastung ausgehenden Gefahren haben die internationale und deutsche Politik in den letzten Jahren dazu veranlasst, verschiedene Konzepte, Handlungsrichtlinien, Beschlüsse und sogar Verbote zu entwickeln, um die Auswirkungen des Kunststoffeintrags in die Umwelt zu reduzieren. Im November 2018 wurde vom BMU (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit) der sogenannte „5-Punkte-Plan für weniger Plastik und mehr Recycling" verabschiedet (BMU, 2018). Mit dem klar definierten Ziel der

Verringerung des Kunststoffmülls bei gleichzeitiger Stärkung der Recyclingquote, nimmt die Politik auf diesem Weg Hersteller, Händler und Verbraucher in die Pflicht. Konkret fallen unter diesen Maßnahmenkatalog beispielsweise das Verbot von Wegwerfprodukten aus Kunststoff (wie Einmalbesteck und -teller oder Trinkhalme) von 2020 oder die, 2019 im Dialog mit der Industrie erarbeitete, Selbstverpflichtung der Hersteller zum Verzicht auf Mikroplastik in kosmetischen Produkten (BMU, 2018).

Weitestgehend unabhängig vom politischen Druck treibt die Industrie einen Wandel in ihrem Umgang mit dem Thema Kunststoffverwendung voran. Insbesondere Hersteller von sogenannten Fast Moving Consumer Goods, also schnelllebigen Konsumgütern (u. a. Nahrungsmittel, Körperpflegeprodukte, Reinigungsmittel), scheinen bemüht, sich hinsichtlich ihrer unternehmerischen Nachhaltigkeit im Allgemeinen und der Kunststoffvermeidung im Speziellen, positiver zu positionieren (Feber et al., 2020; Ma et al., 2020). Dabei spielen in der Regel überarbeitete Verpackungs-Designs aus aufbereitetem Kunststoffmüll und vollständig wiederverwendbare Verpackungen die zentrale Rolle (Feber et al., 2020). Zusätzlich findet der Endverbraucher vermehrt neu ins Leben gerufene, aufmerksamkeitswirksam präsentierte, Siegel oder Prädikate, die auf nachhaltige Produktion, beispielsweise durch Mikroplastikfreiheit, hinweisen.

Im Kontrast zu anderen Umweltproblemen, wie dem Klimawandel oder dem Biodiversitätsverlust, ist das Thema rund um Kunststoffe greif- und sichtbar für jedes einzelne Mitglied der Gesellschaft. Der individuelle und gemeinschaftliche Handlungsbedarf kann, aufgrund der immensen Flut an Kunststoffverschmutzung, jeder Person mit einfachen Erfahrungen im direkten Lebensumfeld deutlich gemacht werden. Solch ein Bewusstsein des Einzelnen ist ein Eckpfeiler für nachhaltigeres Handeln und damit ein Schlüssel zur Reduktion der Kunststoff- und Mikroplastikbelastung (Rees & Pond, 1995). Ein weiterer Eckpfeiler ist das Wissen über Zusammenhänge und Handlungsalternativen.

Die Schullaufbahn bildet die Plattform, in welcher der Grundstein für eine nachhaltige, umweltbewusste Lebensweise gelegt werden kann. Übergeordnetes Ziel von schulischer Umweltbildung ist die Vermittlung eines verantwortungsbewussten Umgangs mit der Natur und ihren Ressourcen (Potter, 2009). Im Zentrum dieser Arbeit steht deswegen das umweltrelevante Thema Mikroplastik gemeinsam mit der Frage, wie man mittels Umweltbildungsmaßnahmen Verständnis, Bewusstsein, und folglich einen nachhaltigen Umgang mit Kunststoffen und Mikroplastik bestmöglich und langfristig fördern kann. Hierfür wurden ein Umweltbildungsmodul konzipiert, evaluiert und weiterentwickelt, Faktoren untersucht, die potenziell Einfluss auf das Lernen nehmen sowie Vorstellungen identifiziert, die Studierende zum Thema Mikroplastik besitzen.

3.2. Theoretischer Hintergrund

Der schulische Biologieunterricht verfolgt eine Vielzahl unterschiedlicher fachspezifischer wie allgemein anwendbarer Bildungsziele. Hierzu zählen beispielhaft der Aufbau eines biologischen Grundwissens, die Entwicklung einer verantwortungsvollen Einstellung gegenüber Flora und Fauna oder die Befähigung des Individuums, umweltspezifische Zusammenhänge und Fragestellungen zu analysieren, zu reflektieren und diesen nachhaltig zu begegnen (Killermann, 1996). Ein zentraler Aspekt der genannten Zielsetzungen ist die Umweltbildung. Um diesen Ansprüchen effektiv und nachhaltig gerecht zu werden, ist es entscheidend, ein Verständnis darüber zu haben, was Lernen beeinflusst. Es existieren zahlreiche Faktoren, die das Potenzial besitzen auf das Lernen der Schüler einzuwirken. Sie können unter anderem von kognitiver (Novak, 1988), affektiver (Pekrun et al., 2002), motivationaler (Bandura, 1993), methodischer (Killermann, 1998) oder räumlicher Art sein (Orion & Hofstein, 1994; Sturm & Bogner, 2010). Die vorliegende Arbeit behandelt, diversen Fragestellungen folgend, in Summe vier verschiedene Einflussfaktoren. Die erste Studie beleuchtet den Zusammenhang der *Umwelteinstellungen* und der *Tageszeitpräferenz*. Die Interventionsstudie behandelt den Einfluss des *Lernorts* und der *Umwelteinstellungen* auf das Wissen nach der Teilnahme an einem Umweltbildungsmodul. Die abschließende Studie untersucht die *Vorstellungen* von Studierenden zum Thema Mikroplastik.

3.2.1. Umweltwissen und Umwelteinstellungen

Das zentrale Ziel der Umweltbildung ist die Entwicklung von Verhaltensweisen, die der Bewahrung der Umwelt dienen. Die Bedingungen für umweltbewusstes Verhalten sind weitreichend erforscht, aufgrund der Vielzahl an einflussnehmenden Faktoren (Kollmuss & Agyeman, 2002) jedoch komplex und deshalb noch immer Gegenstand zahlreicher wissenschaftlicher Arbeiten. Wissen gilt allgemein als eine Voraussetzung für Verhalten (Frick et al., 2004). Somit ist es wenig verwunderlich, dass viele Studien Hinweise auf die Bedeutung von fundiertem Wissen für die Entwicklung von umweltfreundlichen Handlungen geben (Bord et al., 2000; Frick et al., 2004; Kaiser & Fuhrer, 2003). Mangelndes Wissen gilt als Hindernis für umweltbewusste Verhaltensweisen (Gifford, 2011). Umweltbildungsstudien bauen auf die Vermittlung umweltrelevanten Wissens und zeigten, dass sich umweltspezifisches Wissen sowohl kurz- als auch langfristig durch die Teilnahme an Lernprogrammen verbessert (Schönfelder & Bogner, 2017; Stöckert & Bogner, 2020).

Studien der Umweltbildung beschäftigen sich häufig neben dem Umweltwissen auch mit den Umwelteinstellungen (Liefländer & Bogner, 2016; Schneiderhan-Opel & Bogner, 2020). Im Kompetenzmodell von Roczen et al. (2014) zeigten sich sowohl das Wissen (unterteilt in verschiedene Wissensarten) als auch die Umwelteinstellungen für umweltfreundliches Verhalten verantwortlich. Ebenfalls empirisch belegt ist ein Zusammenhang zwischen Umweltwissen und Umwelteinstellungen (Boeve-de Pauw & van Petegem, 2011; Thorn & Bogner, 2018). Das damit zweidimensionale Ziel von Umweltbildungsprogrammen, sowohl das Wissen als auch die Umwelteinstellungen positiv verändern zu können, fand ebenfalls wissenschaftliche Bestätigung (Sellmann & Bogner, 2013). Auch wenn der genaue Zusammenhang mit einem umweltfreundlichen Verhalten komplex und noch nicht ganzheitlich aufgeklärt ist, ist die Betrachtung der Beziehung zwischen Umwelteinstellungen und Umweltwissen sowie das Potenzial beider Faktoren für die Evaluierung von Umweltbildungsmaßnahmen von entscheidender Relevanz.

Die Messung eines Konstrukts wie der Umwelteinstellungen bedarf eines sorgsam ausgewählten Instruments. Ein valides Messinstrument zur Erhebung der Umwelteinstellungen bietet das 2-MEV Modell (2-**M**ajor **E**nvironmental **V**alues-Modell; Bogner & Wiseman, 1999, 2006). Dieses dichotome Modell basiert auf den beiden orthogonalen Dimensionen Preservation of Nature (Naturschutzpräferenz) und Utilization of Nature (Naturausnutzungspräferenz). Die Naturschutzpräferenz umfasst die ökozentrische Perspektive, in welcher der Natur ein Eigenwert zugeschrieben wird und diese daher als schützens- und erhaltenswert gilt (Wiseman & Bogner, 2003). Die Naturausnutzungspräferenz spiegelt die anthropozentrische Perspektive wider, in welcher der Wert der Natur in ihrer Nutzung durch den Menschen begründet liegt und folglich natürliche Ressourcen zum Vorteil des Menschen genutzt bzw. ausgenutzt werden (Wiseman & Bogner, 2003). Interne (Wiseman et al., 2012) sowie unabhängige Studien verschiedener Arbeitsgruppen bestätigten das Konstrukt (Borchers et al., 2014; Braun et al., 2017; Johnson & Manoli, 2011; Milfont & Duckitt, 2004). Ein zusätzlicher Faktor, der von Bogner (2018) kürzlich mit dem 2-MEV Modell in Verbindung gebracht wurde, ist die Wertschätzung der Natur, die sogenannte Appreciation of Nature (wertschätzende Naturnutzungspräferenz; Brügger et al., 2011). Die wertschätzende Naturnutzungspräferenz bildet das Gegenstück zur Naturausnutzungspräferenz. Sie reflektiert die Wertschätzung und Freude an der Natur anhand ihrer bewussten Nutzung beispielsweise für Erholungszwecke (Bogner, 2018; Kibbe et al., 2014).

3.2.2. Tageszeitpräferenz

Auch individuelle Eigenschaften der Schüler können potenziell beeinflussend auf die Effektivität wissensbildender Maßnahmen im Umweltbildungsbereich wirken. Ein Einflussfaktor, der bislang nicht bei der Umsetzung von Umweltbildungsprogrammen berücksichtigt wurde, ist die Tageszeitpräferenz, der individuelle Chronotyp, der Schüler. Die Präferenz für unterschiedliche Tageszeiten wird von der inneren Körperuhr, dem sogenannten zirkadianen Rhythmus, vorgegeben. Der zirkadiane Rhythmus ist individuell unterschiedlich und beeinflusst neben der Vorliebe für bestimmte Tageszeiten auch das Verhalten im Tagesverlauf (Adan et al., 2012). Jede Person besitzt demzufolge eine tageszeitabhängige individuelle, intellektuelle und physische Leistungsfähigkeit mit entsprechenden Spitzen und Tiefen (Adan et al., 2012). Im Regelfall steht der Morgenmensch (auch Lerche genannt) morgens früher auf, geht abends früher ins Bett und erreicht seine Höchstleistung in den Morgenstunden (Horne & Östberg, 1977). Der Abendmensch (auch Eule genannt) steht hingegen morgens später auf, geht abends später zu Bett und hat seine Höchstleistung nachmittags oder in der Nacht (Adan et al., 2012). Die Präferenzen können sich im Laufe des Lebens verändern (Roenneberg et al., 2004). Während Kinder stärker morgenorientiert sind, dominiert bei Jugendlichen tendenziell die Abendorientierung. Diese individuelle Präferenz oszilliert zum Ende der Adoleszenz in der Regel wieder langsam zum Morgen hin (Randler et al., 2017). Neben altersspezifischen werden auch geschlechtsabhängige Tageszeitpräferenzen angenommen. Demnach geben Studien Hinweise darauf, dass Frauen im Vergleich zu Männern stärker morgenorientiert sind (Randler, 2007). Die Tageszeitpräferenz wurde zudem mit verschiedenen Persönlichkeitsmerkmalen sowie Denk- und Verhaltensweisen in Beziehung gebracht. So zeigte sich ein Zusammenhang zwischen der Morgenorientierung mit Gewissenhaftigkeit (Tsaousis, 2010), Proaktivität (Randler, 2009) oder einem rationalen Denkstil und Pflichtbewusstsein (Díaz-Morales, 2007). Abendorientierung wurde hingegen mit einer hohen Risikobereitschaft (Díaz-Morales, 2007; Ponzi et al., 2014), Sensation Seeking (Russo et al., 2012) oder unkonventionellem bzw. auffälligem Verhalten (Díaz-Morales, 2007) assoziiert. Im Bildungskontext zeigten diverse Studien einen positiven Zusammenhang der Morgenorientierung mit der schulischen Leistung (Díaz-Morales & Escribano, 2013) oder auch der Aufmerksamkeit (Vollmer et al., 2013).

3.2.3. Lernort

Jeder Ort kann ein Lernort sein, sofern er Lernprozesse ermöglicht (Somrei, 1997). Eine Klassifikation von Lernen auf Grundlage der Örtlichkeit an sich, und der traditionell dort vorherrschenden Lernbedingungen, ist die Unterscheidung in formales und informelles Lernen. Formales Lernen findet klassischerweise an einem gut strukturierten Lernort innerhalb von originären Bildungseinrichtungen mit dem spezifischen Ziel, den Wissenszuwachs anhand von lehrerzentriertem Unterricht zu fördern, statt (Gerber et al., 2001; Werquin, 2010). Dagegen versteht man unter informellem Lernen zunächst unstrukturierte, problem- und ergebnisorientierte, lernerzentrierte Lerngelegenheiten außerhalb von Bildungseinrichtungen (Bell et al., 2009). Aufgrund der allzu starken Vereinfachung (Eshach, 2007) und der Vielfältigkeit der Lernangebote an unterschiedlichen Lernorten verwischen die Grenzen dieser strikten Trennung (Fallik et al., 2013). Schlussendlich kann jeder Ort formal oder informell sein, abhängig von den gebotenen Lerngelegenheiten. Dieser definitorischen Unklarheit entgegenwirkend gab es Vorschläge, Lernanlässe entlang eines Kontinuums (Hofstein & Rosenfeld, 1996) oder nach Formalitätsgraden zu positionieren (Werquin, 2010).

Die Überwindung der trennscharfen Unterteilung von formalem und informellem Lernen eröffnet den unterschiedlichen Lernorten verschiedene Gestaltungsmöglichkeiten, die sich (im besten Fall) gegenseitig bereichern können. Eine Brücke können sogenannte Outreach-Aktivitäten schlagen. Outreach-Aktivitäten sind Lernangebote unter Einbezug von externen Experten (Vennix et al., 2018). Sie können sowohl an klassischen Bildungseinrichtungen, wie es die Schule ist, als auch an außerschulischen Lernorten (z.B. Botanischer Garten, Nationalpark, Schullandheim) stattfinden (Vennix et al., 2017). Die Einbindung von Outreach-Aktivitäten in eine per se formale Lernumgebung in einem Klassenzimmer bietet viele Mehrwerte, wie beispielsweise die Integration von Elementen aus dem realen Leben, die additive Ermöglichung kooperativer Arbeit in Gruppen oder die stärkere Nutzung von Aufgabenstellungen, die Problemlösefähigkeiten und wissenschaftliche Kompetenz erfordern (Laursen et al., 2007). In außerschulischen Lernumgebungen verleihen Outreach-Aktivitäten der ursprünglich informellen Lernumgebung Struktur, ohne ihre Neuartigkeit und Authentizität zu mindern. Dadurch können beide Lernumgebungen ihr jeweiliges Potenzial zur Steigerung des Interesses, der Motivation oder des Wissens erweitern (DeWitt & Storksdieck, 2008). Ein konkretes Beispiel für eine Outreach-Aktivität ist eine Umweltbildungsmaßnahme, die von Experten entsprechender Fachgebiete angeboten und durchgeführt wird, um bei den Teilnehmern umweltrelevantes Wissen und Bewusstsein zu generieren.

3.2.4. Vorstellungen

Jeder Mensch besitzt theoretische, individuelle Vorstellungen, die dazu dienen, sich in der Welt zu orientieren und natürliche Phänomene zu erklären (Gropengießer & Marohn, 2018). Aus den lebensweltlichen Erfahrungen stammend, können sie sich von denen der Mitmenschen und den wissenschaftlichen Erklärungen unterscheiden (Duit & Treagust, 2003). Vom fachlichen Verständnis divergierende Vorstellungen finden sich auch in den naturwissenschaftlichen Disziplinen (Treagust & Duit, 2008). Für diese Vorstellungen mit Lebensweltbezug hat sich der Terminus der alternativen Vorstellungen etabliert, um sie von den fachlichen Vorstellungen abzugrenzen (Wandersee et al., 1994). Andere, in der Fachliteratur verwendete, Begriffe für Vorstellungen sind Alltagsvorstellungen, Präkonzepte oder Schülervorstellungen (Kattmann, 2007).

Der konstruktivistischen Sichtweise des Lernens folgend, wird neues Wissen konstruiert indem man auf die vorhandene kognitive Basis zurückgreift und diese aktiv durch Erfahrungen umgestaltet (Pope & Gilbert, 1983; Smith et al., 1994). Das Lernen selbst kann dabei ein sehr individueller Prozess sein (Zabel & Gropengiesser, 2011) und findet stets im Kontext der persönlichen Vorstellungen statt. Dabei sind Vorstellungen oftmals fest im Individuum verankert und gegenüber Veränderungen relativ stabil (Gropengießer & Marohn, 2018). Der Grund hierfür liegt häufig darin, dass wissenschaftliche Erklärungen nicht immer ausreichend plausibel und greifbar zur Erläuterung alltäglicher Phänomene sind (Schrenk et al., 2019). Im Unterricht sollen die Schüler deshalb darin gefördert werden, ihre vorhandenen Vorstellungen mit neuen Informationen zu konfrontieren und zu kombinieren (Novak, 2002) und sie dadurch mit fachlichen Vorstellungen in Beziehung zu setzen. Dementsprechend bedarf es geeigneter Analysen sowie unterrichtlicher Ansätze, um die Vorstellungen lernförderlich zu nutzen und zu formen.

Erfolgreicher Unterricht beruht u. a. auf der Berücksichtigung und Einbeziehung individueller Kenntnisse in den Lernprozess (Maskiewicz & Lineback, 2013; Pope & Gilbert, 1983). Daran anknüpfend kann man anschlussfähige Ideen erkennen und möglicherweise alternative Vorstellungen überwinden (Asshoff et al., 2020). Mithilfe der Vorstellungsforschung deckt man die Vorkenntnisse bzw. Lernvoraussetzungen der Schüler auf und identifiziert auf diese Weise Verständnisprobleme und -lücken. Sie dienen der Diagnose der Lernausgangslage, des fachlichen Niveaus und der fachlichen Tiefe der Vorkenntnisse. Daher stellen Vorstellungen gute Ausgangspunkte zur Entwicklung eines wissenschaftlichen Verständnisses dar (Maskiewicz & Lineback, 2013).

In den Naturwissenschaften haben sich bereits viele Forschungsarbeiten mit den Vorstellungen von Schülern befasst (Duit & Treagust, 2003; Schneiderhan-Opel & Bogner, 2019; Shaw et al., 2008). Empirische Studien geben Hinweise auf positive Effekte durch die Integration von Vorstellungen bei der Wissensvermittlung. Es zeigte sich, dass Schüler, die im Unterricht mit gängigen, alternativen Vorstellungen zum behandelten Thema konfrontiert wurden, ein höheres Interesse und Wohlbefinden sowie eine bessere kognitive Leistung aufwiesen (Franke & Bogner, 2013). Zusätzlich zu den direkten Effekten durch die Berücksichtigung von Vorstellungen im Unterrichtsalltag, weisen Schülervorstellungen indirekt auch auf vernachlässigte Aspekte im Lehrplan hin und geben Anregungen für zukünftige Adaptionen (Fröhlich et al., 2013).

3.3. Ziele und Fragestellungen der Teilarbeiten

Im Zentrum dieser Arbeit befinden sich die Untersuchung diverser Einflussfaktoren auf das Lernen sowie die Entwicklung einer Bildungsmaßnahme zum Thema Mikroplastik. Die in den Teilarbeiten betrachteten Faktoren sind die Umwelteinstellungen, die Tageszeitpräferenz, die Vorstellungen sowie die bildungskonzeptionelle Variable Lernort. Besonderer bildungsthematischer Fokus liegt auf dem höchst umweltrelevanten Thema Mikroplastik. Teilarbeit A untersucht das Zusammenspiel zwischen den individuellen Umwelteinstellungen und der Tageszeitpräferenz. Teilarbeit B evaluiert ein konzipiertes Unterrichtsmodul im Rahmen der Umweltbildung zum Thema Mikroplastik in der Primarstufe anhand des kurz- und langfristigen Wissenserwerbs unter Berücksichtigung der individuellen Umwelteinstellungen und des Lernorts. Das in Teilarbeit B durchgeführte Unterrichtsmodul wird in Teilarbeit C auf der Grundlage von Praxiserfahrungen weiterentwickelt. Vorstellungen von Studierenden zum Thema Mikroplastik liefern in Teilarbeit D Ansatzpunkte für eine zukünftige Umsetzung von Bildungsmaßnahmen in der Sekundarstufe. Abbildung 1 gibt einen Überblick über die vier Teilarbeiten.

Abbildung 1: Übersicht über die vier Teilarbeiten der Gesamtstudie.

Teilarbeit A: Umwelteinstellungen im Zusammenhang mit Tageszeitpräferenz

In der ersten Teilarbeit stehen die Umwelteinstellungen sowie die Tageszeitpräferenz und deren Beziehung zueinander im Mittelpunkt. Da sowohl die Umwelteinstellungen als auch die Tageszeitpräferenz bereits mit verschiedenen Persönlichkeitsmerkmalen in Verbindung gebracht wurden, kann man davon ausgehen, dass auch die individuellen Ausprägungen der beiden Parameter zueinander in einem Zusammenhang stehen. Es wird vermutet, dass positive Umwelteinstellungen mit einer Präferenz für die Morgenstunden in Beziehung stehen.

Die konkreten Forschungsfragen lauten:

1. Inwiefern eignet sich die Morningness-Eveningness Scale for Children (MESC) zur Erhebung der Tageszeitpräferenz bei Jugendlichen aus Irland?
2. Bilden die drei Faktoren Preservation of Nature, Utilization of Nature und Appreciation of Nature die Faktorenstruktur des 2-MEV Modells und der Appreciation of Nature Skala ab?
3. Inwiefern stehen die Umwelteinstellungen der Schüler im Zusammenhang mit ihrer Tageszeitpräferenz?

Teilarbeit B: Wissen im Zusammenhang mit Lernort und Umwelteinstellungen

Die zweite Teilarbeit richtet ihren Fokus auf den potenziellen Wissenszuwachs durch die Teilnahme an einem Unterrichtsmodul zum Thema Mikroplastik. Die Effektivität eines, speziell für diese Teilarbeit konzipierten, Unterrichtsmoduls für die Primarstufe wird anhand des hinzugewonnenen Wissens beurteilt. Die analoge Durchführung desselben Unterrichtsmoduls an zwei unterschiedlichen Lernorten (innerschulisch und außerschulisch) ermöglicht eine Evaluation des Einflusses des Lernorts auf das erworbene Wissen. Weiterhin soll der Zusammenhang zwischen dem erworbenen Wissen und den Umwelteinstellungen der Schüler ermittelt werden. Es wird erwartet, dass das Unterrichtsmodul bei allen Schülern, unabhängig vom besuchten Lernort, zu einem kurz- und langfristigen Wissensanstieg führt. Anzunehmen ist, dass die Schüler vom außerschulischen Lernort zusätzlich profitieren und sie sich deshalb mit ihrer Teilnahme mehr Wissen angeeignet haben, als innerschulisch unterrichtete. Bezüglich der Umwelteinstellungen wird erwartet, dass eine positive Umwelteinstellung lernförderlich ist, während sich eine negative Umwelteinstellung abträglich auf den Wissenszuwachs auswirkt.

Die daraus abgeleiteten Fragestellungen lauten wie folgt:

1. Inwiefern beeinflusst das Unterrichtsmodul das kurz- und langfristige Wissen der Grundschüler zum Thema Mikroplastik?
2. Wie unterscheiden sich inner- und außerschulisch unterrichtete Schüler hinsichtlich ihres Wissenserwerbs und ihrer Umwelteinstellungen?
3. Inwiefern gibt es einen Zusammenhang zwischen den Umwelteinstellungen und dem Wissen?

Teilarbeit C: Weiterentwicklung des Unterrichtsmoduls zu Mikroplastik

Mit dem übergeordneten Ziel, bereits zu einem frühen Zeitpunkt der schulischen Bildung ein Bewusstsein für das Thema Mikroplastik zu schaffen, wurde für die Interventionsstudie (Teilarbeit B) ein Unterrichtsmodul für Grundschüler entwickelt. Die frühe Etablierung eines grundlegenden Verständnisses der Begrifflichkeiten, Auswirkungen und Handlungsstrategien zur Reduktion des eigenen Kunststoffaufkommens kann ein langfristiges, wachsendes Bewusstsein für die Thematik fördern. Unter Berücksichtigung des Lehrplans, der theoretischen Konstrukte zur effektiven Wissensvermittlung und der Zielsetzung dieser Arbeit, wurde der inhaltliche und methodische Rahmen des Unterrichtsmoduls gesteckt, das den Schüler stets in das Zentrum des Lernprozesses rückt. Kapitel 3.4.3 gibt eine Erläuterung zu den Abläufen und Inhalten des Unterrichtskonzepts. Basierend auf der Durchführung des Unterrichtsmoduls mit 470 Schülern in Teilarbeit B, ist die erfahrungsbasierte Weiterentwicklung des Lernprogramms das Ziel von Teilarbeit C. Anschließend an die Interventionsstudie soll das Unterrichtsmaterial für einen eigenständigen, unabhängigen Einsatz einer breiten Zielgruppe zur Verfügung gestellt werden. Das durchgeführte Modul wird folglich in einer überarbeiteten, erweiterten Form veröffentlicht.

Teilarbeit D: Studierendenvorstellungen zu Mikroplastik

Die Kontamination der Umwelt mit Mikroplastik hat sich zu einer globalen Herausforderung entwickelt, die Aufklärung, Bewusstsein und Handeln eines jeden Einzelnen erfordert. Angesichts der hohen Relevanz sowie Dringlichkeit dieses Themas, ist eine adäquate Integration in die schulische Laufbahn erforderlich. Studierende, die eine ausgiebige schulische Bildung erfahren haben, können Implikationen für Optimierungsansätze im Bildungssystem liefern. Das Wissen um die themenspezifischen Vorstellungen von Studierenden gibt einen Einblick in deren Verständnis für Mikroplastik und ermöglicht die systematische Entwicklung von Bildungsmaßnahmen mit zielgerichteten, angepassten Unterrichtsinhalten sowie die zweckgerichtete Planung von Outreach-Aktivitäten durch Experten.

Vor diesem Hintergrund leiten sich folgende Forschungsfragen ab:

1. Was verstehen Studierende unter dem Begriff Mikroplastik?
2. Woher beziehen Studierende ihre Informationen zum Thema Mikroplastik?
3. Welche Mikroplastikquellen im Haushalt kennen Studierende?
4. Welche Senken in aquatischen Ökosystemen kennen Studierende?
5. Für wie gefährlich halten Studierende Mikroplastik und wie begründen sie ihre Einschätzung?

3.4. Methoden

3.4.1. Stichprobe und Studiendesign

Die Daten für **Teilarbeit A** wurden im Mai 2018 an 429 irischen Schülern (M_{Alter}±SD = 14,7±1,9; 32,9 % weiblich) der Primar- und Sekundarstufe erhoben. Die teilnehmenden Schüler besuchten fünf verschiedene Schulen. Die einmalige Erhebung erfolgte während der regulären Schulzeit mittels einer schriftlichen Befragung mit Papierfragebögen. Die Teilnahme war freiwillig. Eine Zuordnung der Fragebögen zu einzelnen Schülern ist aufgrund der pseudo-anonymen Datenerhebung nicht möglich.

Für die **Teilarbeit B** nahmen im Zeitraum von Juni 2018 bis Januar 2019 insgesamt 470 Schüler der 3. und 4. Jahrgangsstufe aus 26 Schulklassen an 13 bayerischen Grundschulen am Unterrichtsmodul „Plastik-Detektive - dem Plastik auf der Spur" teil. In der Auswertung wurden nur jene Schüler berücksichtigt, bei denen die Vollständigkeit der Datensätze gegeben war, d.h. bei denen zu jedem der drei Testzeitpunkte ein ausgefüllter Fragebogen vorlag. Dementsprechend reduzierte sich die in die Studie einfließende Schülerzahl von 470 auf 444. Das Unterrichtsmodul wurde von zwei Mitarbeiterinnen der Universität Bayreuth an zwei unterschiedlichen Lernorten durchgeführt, wobei sich je eine Person für einen Lernort verantwortlich zeigte. Für 333 Schüler, wovon 312 (M_{Alter}±SD = 9,3±0,6; 47,8 % weiblich) in die Analyse eingingen, fand das Unterrichtsmodul innerhalb ihrer Schule in ihrem eigenen Klassenzimmer oder einem ihnen bekannten Mehrzweckraum statt. 137 Schüler, wovon 132 (M_{Alter}±SD = 9,6±0,7; 55,3 % weiblich) in die Analyse aufgenommen wurden, besuchten das Unterrichtsmodul außerschulisch während ihres mehrtägigen Aufenthalts im Schullandheim in einem Mehrzweckraum. Weitere 50 Schüler, von denen 44 (M_{Alter}±SD = 8,8±0,6; 52,3 % weiblich) in die Analyse eingingen, fungierten als Kontrollgruppe. Sie erhielten im Laufe der Studie keinen Unterricht zum Thema Mikroplastik, sondern füllten lediglich die Wissensfragebögen aus, um Lerneffekte aufgrund der wiederholten Beantwortung der Wissensfragen ausschließen zu können. Voraussetzung für die Teilnahme an der Studie war die schriftliche Einverständniserklärung der Eltern. Zudem wurden die Schüler über die Freiwilligkeit ihrer Teilnahme informiert. Die Regierung von Oberfranken genehmigte die Studie mit dem Schreiben unter Aktenzeichen 40.1-5038-1-26 vom 13.04.2018.

Zu insgesamt drei Testzeitpunkten füllten die teilnehmenden Schüler Papierfragebögen aus. Die erste Datenerhebung erfolgte ein bis zwei Wochen vor dem Besuch des Unterrichtsmoduls (Vortest - T0), die zweite direkt nach Beendigung des Unterrichtsmoduls (Nachtest - T1) und die dritte etwa sechs Wochen nach der Teilnahme am Unterrichtsmodul (Behaltenstest - T2). Die Kontrollgruppe beantwortete den Vor- und Nachtest ebenfalls in den angegebenen Zeitabständen. Die

Schüler benötigten etwa 25 Minuten für die Beantwortung eines Fragebogens, eine maximale Ausfülldauer existierte nicht. Ein pseudonymisierter Code wahrte die Anonymität und ermöglichte die korrekte Zuordnung der drei Fragebögen eines Schülers.

In **Teilarbeit D** nahmen 267 in Deutschland Studierende (M_{Alter}±*SD* = 20,3±2,6; 56,6 % weiblich) zu Beginn des Wintersemesters (2017/2018) an einer einmaligen, 15-minütigen Befragung mittels Papierfragebogen teil. Die Studierenden gehörten folgenden wissenschaftlichen Disziplinen an: Naturwissenschaften, Geisteswissenschaften, Ingenieurwissenschaften, Wirtschaftswissenschaften und Kulturwissenschaften. Vor der Teilnahme wurden sie über die Freiwilligkeit ihrer Studienteilnahme aufgeklärt. Aufgrund der pseudo-anonymen Datenerhebung ist es nicht möglich, die Fragebögen einzelnen Studierenden zuzuordnen.

3.4.2. Erhebungsinstrumente und Datenauswertung

Zur statistischen Auswertung wurde das Programm *IBM SPSS Statistics Version 24* verwendet (IBM Corp., 2016). Sofern die Werte von Variablen von der Normalverteilung abwichen, wurden die Hypothesen mit nicht-parametrischen Tests überprüft.

Die Skalen des 2-MEV Modells und der Appreciation of Nature wurden vor ihrem Einsatz entsprechend der Stichprobe angepasst. In den Teilarbeiten wurden Instrumente und Items untersucht, die in längere Fragebögen eingebettet waren. Bei wiederholter Abfrage (Teilarbeit B) wurde die Itemreihenfolge innerhalb der Instrumente zu jedem Testzeitpunkt verändert, um Antwortverzerrungen aufgrund der Itemreihenfolge auszuschließen (Schnell et al., 2018).

Der Schwerpunkt von **Teilarbeit A** lag auf der Beziehung zwischen Umwelteinstellungen und der Tageszeitpräferenz. Die in Summe drei Faktoren der Umwelteinstellung wurden mit Hilfe zweier Instrumente erhoben. Das 2-MEV Modell untersucht die Preservation of Nature und Utilization of Nature (Bogner & Wiseman, 1999, 2006). Die Appreciation of Nature resultiert aus der gleichnamigen Skala nach Brügger et al. (2011). Den überarbeiteten und verkürzten Skalen von Bogner (2018) folgend, wurden die drei Faktoren Preservation of Nature (sechs Items), Utilization of Nature (sieben Items) sowie Appreciation of Nature (sieben Items) mit insgesamt 20 Items abgefragt. Entlang einer 5-Punkt-Likert-Skala gaben die Schüler ihren Grad der Zustimmung bzw. Ablehnung an. Zur Messung der Tageszeitpräferenz wurde das Instrument Morningness-Eveningness Scale for Children (MESC) nach Carskadon et al. (1993) verwendet. Die Skala besteht aus zehn Items, deren Antwortformat einer Likert-Skala folgt: drei Items sind von 1-5 und sieben Items von 1-4 skaliert. Die Schülerantworten addierten sich zu einem Gesamtwert von maximal 43 auf. Die Werte wurden entlang eines Kontinuums bewertet: Ein niedriger Wert stand für eine minimale Morgenpräferenz, ein hoher Wert spiegelte eine starke Morgenpräferenz wider. Nach Prüfung der Normalverteilung mittels Shapiro-Wilk und Q-Q-Plots, wurden für die MESC Cronbach's Alpha, Alter- und Geschlechtereffekte untersucht. Der Zusammenhang zwischen der Tageszeitpräferenz und dem Alter wurde mittels einer bivariaten Pearson-Korrelation (zweiseitig) ermittelt. Die Analyse der Geschlechterunterschiede erfolgte für die Tageszeitpräferenz und die Umwelteinstellungen mittels ungepaarter t-Tests. Für das 2-MEV Modell und die Appreciation of Nature Skala wurde Cronbach's Alpha ermittelt und zur Überprüfung der Faktorenstruktur eine Hauptkomponentenanalyse (schiefes Rotationsverfahren: Oblimin, direkt) durchgeführt. Die Analyse der Beziehungen zwischen den Umwelteinstellungen und der Tageszeitpräferenz geschah unter Verwendung einer bivariaten Pearson-Korrelation (zweiseitig). Hierfür korrelierte man die Mittelwerte der drei Umwelteinstellungsvariablen mit den Summenwerten der Tageszeitpräferenz.

Teilarbeit B untersuchte zum einen den Wissenserwerb zum Thema Mikroplastik, zum anderen den Einfluss der Umwelteinstellungen und des Lernorts im, für diesen Zweck konzipierten, Unterrichtsmodul. Die speziell zur Überprüfung des Gelernten entwickelten sieben Wissensfragen umfassten den Inhalt des Unterrichtsmoduls und wurden zu allen drei Testzeitpunkten erhoben. In der Form von Single Choice Fragen mit je vier Antwortmöglichkeiten sollten die Schüler die korrekte Antwort markieren. Zur statistischen Auswertung wurden alle richtigen Antworten mit „1" und alle falschen Antworten mit „0" kodiert. Der daraus berechnete Summenwert für das abgerufene Wissen konnte zum jeweiligen Testzeitpunkt maximal sieben betragen. Die Qualität der für diesen Zweck kreierten Wissensfragen wurde mittels Cronbach's Alpha (als Maß für die Reliabilität) und der Schwierigkeitsindizes (p_i), die den Anteil der Teilnehmer mit richtiger Antwort angeben, ermittelt. Vor dem Hintergrund, dass es sich um eine ad hoc Skala handelte und die Anzahl der Items zur Reduktion der kognitiven Belastung junger Schüler gering war, wurde die Skala mit einem Cronbach's-Alpha-Wert von $\alpha_{T1} = 0{,}56$ akzeptiert (Tavakol & Dennick, 2011). Die Schwierigkeitsindizes zum Zeitpunkt T0 lagen zwischen $p_i = 0{,}34$ und $p_i = 0{,}79$, was eine angemessene Bandbreite darstellt. Die Ergebnisse direkt nach der Teilnahme am Unterrichtsmodul weisen darauf hin, dass die Itemschwierigkeit zu diesem Zeitpunkt als leicht (Minimum: $p_i = 0{,}72$; Maximum $p_i = 0{,}95$) einzuschätzen ist.

Aufgrund einer nicht gegebenen Normalverteilung, die mittels Shapiro-Wilk und Q-Q-Plots identifiziert werden konnte, wurden nicht-parametrische Tests für alle weiteren Analysen verwendet. Für *p*-Werte wurde die Bonferroni-Korrektur angewandt und bei signifikanten Ergebnissen die Effektstärke *r* berechnet (Field, 2018).

Zur Auswertung der Wissensunterschiede zwischen den Testzeitpunkten T0, T1 und T2 wurde die Friedman's ANOVA herangezogen. Die Analyse der Wissensunterschiede zwischen den inner- und außerschulisch unterrichteten Schülern und der Kontrollgruppe geschah unter Verwendung des Kruskal-Wallis-Tests. Die Wissensunterschiede zwischen inner- und außerschulisch unterrichteten Schülern ergaben sich aus dem Mann-Whitney-*U*-Test.

Die Umwelteinstellungen wurden mit den bereits beschriebenen Instrumenten 2-MEV Modell (Bogner & Wiseman, 1999, 2006) und Appreciation of Nature Skala (Brügger et al., 2011) erhoben. Entsprechend der verkürzten Skalen von Bogner (2018) wurden insgesamt 20 Items (Preservation of Nature: sechs Items; Utilization of Nature: sieben Items; Appreciation of Nature: sieben Items) abgefragt. In einer Hauptkomponentenanalyse (schiefes Rotationsverfahren: Oblimin, direkt) zeigten sich Preservation of Nature, Utilization of Nature und Appreciation of Nature als drei getrennte Faktoren. Für eine noch detailliertere Untersuchung der Einflüsse auf das Wissen wurde eine multiple lineare Regressionsanalyse aufgestellt. Dabei diente das Wissen direkt nach der Teilnahme an der Intervention (T1) als abhängige Variable, die unabhängigen Variablen waren durch die drei Umwelteinstellungen sowie den Lernort gegeben. Um die Ausprägungen der Umwelteinstellungen der Schüler genauer zu beleuchten, wurden Quartile ermittelt. Mittels Friedman's A-NOVA und Mann-Whitney-*U*-Test konnten folgend die Zusammenhänge zwischen dem Wissen zu den drei Testzeitpunkten und den unteren sowie den oberen 25 % der jeweiligen Umwelteinstellung näher untersucht werden. Die unteren 25 % vereinten Schüler mit einer niedrigen Ausprägung der jeweiligen Umwelteinstellung, während sich die oberen 25 % aus Schülern mit einer hohen Ausprägung der jeweiligen Umwelteinstellung zusammensetzten.

Teilarbeit D erforschte die Vorstellungen von Studierenden zum Thema Mikroplastik unter Verwendung von drei offenen Fragen (Fragen 1-3), einer geschlossenen Frage (Frage 4) sowie einer Kombination aus einer geschlossenen und einer offenen Frage (Fragen 5a und 5b). Die Fragen wurden speziell für diese Studie erstellt, der Wortlaut war der Folgende:

1. Was verstehen Sie unter dem Begriff Mikroplastik?
2. Woher haben Sie Ihr Wissen über Mikroplastik?
3. Nennen Sie Quellen von Mikroplastik im Haushalt.
4. In welchen Ökosystemen befindet sich Mikroplastik in Deutschland? Kreuzen Sie an (mehrere Kreuze sind möglich).
    a) Meere b) Flüsse c) Seen d) Grundwasser
5. a) Schätzen Sie die potenzielle Gefahr ein, die von Mikroplastik ausgeht.
    a) sehr gefährlich b) gefährlich c) kaum gefährlich d) nicht gefährlich

   b) Begründen Sie Ihre Entscheidung, die Sie unter 5a) getroffen haben.

Die offenen Fragen gaben den Studierenden die Möglichkeit, ihre persönlichen Ideen und Gedanken zu beschreiben, ohne durch vorgegebene Antwortmöglichkeiten gelenkt zu werden. Die beiden geschlossenen Fragen wurden bewusst eingesetzt. Die Einordnung von Grundwasser als ein Ökosystem ist dem Fachfremden eventuell nicht geläufig. Dieser Aspekt zur Belastung von Gewässern würde ohne eine Vornennung vermutlich unberücksichtigt bleiben. Um dies zu verhindern, wurde der Begriff Grundwasser als eine Antwortmöglichkeit aufgelistet. Hinsichtlich Frage 5a, der Gefahreneinschätzung, war eine möglichst präzise Einordnung entlang einer Abstufung förderlich für die Aussagekraft. Das freie Antwortformat hätte nicht zu einem vertieften Verständnis der Vorstellungen der Studierenden beigetragen. Die zusätzliche Abfrage einer Begründung zur Gefahreneinschätzung über 5b wirkte der sogenannten Ja-Sage-Tendenz bzw. einer sozial erwünschten Antwort entgegen (Schnell et al., 2018).

Die Analyse der Studierendenantworten erfolgte anhand einer qualitativen Inhaltsanalyse nach Mayring (2000), der eine Quantifizierung der Ergebnisse folgte. Die individuellen Studierendenantworten waren der Ausgangspunkt der Auswertung. Die genannten Begrifflichkeiten bzw. Erläuterungen bildeten die Grundlage eines kategorialen Gerüsts, das für jede Fragestellung unabhängig konstruiert wurde. Diese induktive Vorgehensweise, die sogenannte induktive Kategorienbildung bzw. Kodierung, ermöglichte eine detaillierte und akkurate Erfassung sowie inhaltlich homogene Bündelung der mannigfaltigen Vorstellungen der Studierenden. Das Kategoriensystem wurde schrittweise verfeinert, sodass die Einführung kaskadierender Unterkategorien eine noch detailliertere Analyse der Antworten ermöglichte. Entwickelte Kodierrichtlinien enthielten zu jeder Frage, neben einer eindeutigen Kategorien-Definition, ein Ankerbeispiel aus den Studierendenantworten, um eine transparente Kategorisierung zu gewährleisten. Aufgrund der Tatsache, dass die Vorstellungen der Studierenden zu einem Thema durchaus mehrdimensional, und zum Teil konzeptionell inkonsistent waren, konnte die Antwort eines Studierenden gleichzeitig mehreren Kategorien zugeordnet werden. Antworten, die Unwissenheit oder inadäquate Inhalte ausdrückten, wurden als \`keine Antwort\` zusammengefasst. Vereinzelte Auffassungen, die von weniger als 3 % der Studierenden vertreten wurden, wurden unter \`Sonstiges\` gesammelt. Die Ergebnisse des Kategoriensystems wurden anschließend quantifiziert. Hierfür wurde die Anzahl der Nennungen ermittelt, die einer gewissen Kategorie zugeordnet werden konnte, und erhielt in einem nächsten Schritt prozentuale Antworthäufigkeiten über alle Studierenden hinweg.

Der Erstautor der Studie kategorisierte alle Daten. Die Objektivität des vom Erstautor entworfenen Kategoriensystems wurde anhand der Inter- und Intrarater-Reliabilität bestimmt. Sie gilt als Maß für die Übereinstimmung unterschiedlicher Personen, auch Rater genannt, zu identischen Bewertungssystemen. Zur Validierung der Kategorien wurde eine zufällig ausgewählte 20 %ige Teilstichprobe der Daten nach einem Jahr zum einen vom Erstautor (Intrarater), zum anderen von einer unbeteiligten Person (Interrater), erneut kategorisiert. Für die vier offenen Fragen (Fragen 1-3 sowie 5b) wurden die Cohens-Kappa-Koeffizienten der Intra- und Interreliabilität berechnet (Cohen, 1960). Die Cohens-Kappa-Werte lagen zwischen 0,86 und 0,97, was auf eine fast perfekte Übereinstimmung zwischen den Ratern und demzufolge auf ein objektives Kategoriensystem hindeutet (Landis & Koch, 1977).

3.4.3. Ausführliche Beschreibung des Unterrichtsmoduls

Gemäß des bayerischen Lehrplans für Grundschulen (3. und 4. Jahrgangsstufe) kann das Thema Mikroplastik im Heimat- und Sachunterricht den folgenden drei Themenbereichen zugeordnet werden: „1.2 Leben in einer Medien- und Konsumgesellschaft", „3.1 Tiere, Pflanzen, Lebensräume" und „3.3 Luft, Wasser, Wetter" (Bayerisches Staatsministerium für Bildung und Kultus, Wissenschaft und Kunst, 2014). Die schulische Auseinandersetzung mit Kunststoffen vereint Inhalte der einzelnen Themenbereiche unter dem Schirm einer nachhaltigen, verantwortungsbewussten und den Umweltschutz fördernden, Wissensvermittlung. Sie zeigt die Zusammenhänge zwischen bewussten Kaufentscheidungen der Konsumenten (Endverbraucher), den Auswirkungen menschlicher Handlungen auf Gewässer und der Relevanz von Schutzmaßnahmen.

Das lehrplankonforme, 160-minütige Unterrichtsmodul „Plastik-Detektive - dem Plastik auf der Spur", wurde speziell für den Einsatz in der 3. und 4. Jahrgangsstufe in Grundschulen konzipiert. Die Dauer des Unterrichtsmoduls erlaubte die Durchführung während regulärer Schulstunden, zu denen stets eine Mitarbeiterin der Universität Bayreuth und die betreuende Lehrkraft anwesend waren. Zu Beginn des Unterrichtsmoduls besaßen die Schüler keine schulische Vorbildung zum Thema Mikroplastik. Die Lehrkräfte wurden instruiert, von einer etwaigen Nachbereitung der Inhalte vor dem Ausfüllen der Behaltenstests, und der damit einhergehenden Beendigung der Studie, abzusehen.

Inhaltlicher Schwerpunkt des Unterrichtsmoduls war die Kontamination aquatischer Ökosysteme mit Mikroplastik. Mit Fokus auf die individuelle Verantwortlichkeit sowie den eigenen Wirkungskreis der Schüler behandelte das Unterrichtsmodul mögliche Mikroplastikquellen im Haushalt, den Weg des Mikroplastiks in die Umwelt, Senken in aquatischen Ökosystemen, potenzielle ökologische Folgen auf marine Organismen sowie einfache und effektive Vermeidungsstrategien, um den individuellen Eintrag von Kunststoffen und Mikroplastik zu reduzieren. Auf diese Weise gelang es, den Schülern eine umfassende Betrachtung der Thematik aus einer ökologischen Perspektive zu ermöglichen.

Zur Vermittlung der Inhalte wurde der schülerzentrierte Ansatz „Lernen an Stationen“ gewählt. Bei dieser kooperativen Methode bearbeiteten die Schüler in Kleingruppen (3-4 Schüler) die gestellten Arbeitsaufträge eigenständig an Lernstationen. An den einzelnen Stationen, die - mit Ausnahme der letzten Station - zweifach im Klassenzimmer aufgebaut waren, setzten sich die Schüler in Eigenregie und in ihrem persönlichen Lerntempo mit den Inhalten des Unterrichtsmoduls auseinander. Die gezielte Auswahl von Objekten aus der Lebenswelt der Schüler erhöhte den Alltagsbezug für das, den Grundschülern noch unbekannte, Themenfeld Mikroplastik. Die Untersuchung der Alltagsgegenstände mithilfe wissenschaftlichen Equipments in Hands-On Versuchen, befähigte die Schüler zu eigenverantwortlicher und selbstbestimmter „Detektivarbeit“ entlang konkreter Fragestellungen. Alle Arbeitsaufträge, Materialien und zusätzlichen Informationsblätter waren an den jeweiligen Stationen zu finden.

Die konkreten Aufgabenstellungen und Erklärungen zur Durchführung der einzelnen Stationen konnten die Schüler einem Arbeitsheft entnehmen, welches jeder zu Beginn erhielt und das durch das Unterrichtsmodul leitete. Mit den Informationen aus dem Arbeitsheft konnten die Schüler die Stationen selbstverantwortlich durchlaufen. Die Kleingruppen begannen an von ihnen gewählten Stationen und wechselten die Arbeitsplätze einem vorgegebenen Muster folgend. Dieser Ablauf war durch die umfassende Aufbereitung der Materialien möglich, wonach jede Station auch ohne Vorwissen aus anderen Stationen erarbeitet werden konnte. Alle Materialien waren selbsterklärend. Dadurch fungierten die Lehrkraft und die Mitarbeiterin der Universität Bayreuth lediglich als Aufsichtspersonen und intervenierten nur auf Anfrage oder Gefahr. Im Sinne der Differenzierung stand für leistungsstarke Gruppen eine Zusatzstation (1C) zur Verfügung, in der sie Gelerntes aus der Station 1A anwenden konnten. Station 4 wurde am Ende des Unterrichtsmoduls zeitgleich von allen Schülergruppen bearbeitet. Musterlösungen zur selbstständigen Überprüfung der eigenen Lösungen lagen am Lehrerpult bereit.

Das Unterrichtsmodul begann mit einer gemeinsamen, lehrerzentrierten **Einführungsphase**, deren Ziel die Gewährleistung eines kollektiven Wissensstands aller teilnehmender Schüler war. Geführt über eine PowerPoint Präsentation lernten sie die Bedeutung des Begriffs Mikroplastik kennen, erfuhren von der Mikroplastikbelastung an Stränden und stießen letztlich auf die zentrale Frage des Unterrichtsmoduls: „Wie gelangt Mikroplastik an den Strand?“ Darüber hinaus erhielten die Schüler alle notwendigen Informationen über den Ablauf des Stationenlernens und die Verwendung des wissenschaftlichen Arbeitsmaterials, beispielsweise dem Binokular. Von diesem Zeitpunkt an waren die Schüler selbst für die folgenden Arbeitsschritte verantwortlich.

Die **Lernstation 1** „Die Suche nach Mikroplastik in Alltagsprodukten“ war in drei unabhängige Lernstationen untergliedert: 1A, 1B und 1C. Die drei Stationen verfolgten das übergeordnete Ziel, die Schüler für Mikroplastik in täglich genutzten Gegenständen in ihrem Alltag zu sensibilisieren. Hierfür wurden zum einen Kosmetikprodukte gewählt, die primäres Mikroplastik veranschaulichen und zum anderen synthetische Textilien verwendet, die die Entstehung von sekundärem Mikroplastik verdeutlichen. Lernstation **1A** „Untersuchung von Peeling“ beschäftigte sich mit dem primären Mikroplastik in Kosmetikprodukten. Die Schüler filtrierten in einem Versuch in Wasser gelöstes Peeling, das Polyethylen als Schleifmittel enthält. Das Mikroplastik verblieb als Rückstand im Filterpapier, das die Schüler mithilfe eines Binokulars genauer untersuchten und ihre Beobachtungen im Arbeitsheft notierten. Unter Verwendung einer Liste der häufigsten Kunststoffe in Kosmetikprodukten identifizierten die Schüler auf der Produktverpackung die enthaltene Kunststoffsorte. Bei Lernstation **1B** „Die Suche nach Mikroplastik in der Kleidung“ lag der Fokus auf synthetischen Textilien, die während des Waschens Mikroplastik in Form von Fasern freisetzen. In einem Versuch stellten die Schüler den Waschvorgang einer Waschmaschine nach, indem sie ein Stück einer Fleecedecke in Seifenlauge wuschen. Aus der, zu 100 % aus Polyester bestehenden, Fleecedecke lösten sich Fasern, die nach Filtration der Waschlauge im Filter als Rückstand zurückblieben. Nach Betrachtung unter dem Binokular hielten die Schüler ihre Beobachtungen wiederum im Arbeitsheft fest und identifizierten mithilfe des Etiketts die Fasern als Polyester. Eine Informationskarte half den Schülern beim Ausfüllen eines Lückentexts zum Weg von Mikroplastikfasern aus der Waschmaschine über die Kläranlage in Gewässer. Lernstation **1C** „Herr Experto auf Spurensuche im Drogeriemarkt“ diente als optionale Zusatzstation für leistungsstarke Schülergruppen, die noch vor Ablauf der zur Verfügung stehenden Zeit die anderen Stationen (1A, 1B, 2 und 3) erledigt hatten. An dieser Lernstation konnten die Schüler Gelerntes aus der Lernstation 1A anwenden und auf Spurensuche im Drogeriemarkt gehen. Mithilfe der bereits bekannten Liste zu Kunststoffquellen untersuchten sie die Inhaltsangaben verschiedener Kosmetika, Pflegeprodukte und Reinigungsmittel nach enthaltenen Kunststoffen und konnten somit, bezogen auf dieses Kriterium, über die Umweltfreundlichkeit der Produkte urteilen.

An **Lernstation 2** „Wie kommt das Mikroplastik an den Strand?“ vermittelte ein kurzes Informationsvideo den Schülern den Weg des Mikroplastiks aus dem Haushalt in die Umwelt. Mit Bildkarten sortierten die Schüler anschließend ein Fließschema, welches neben dem potenziellen Eintragspfad des Mikroplastiks über Kläranlagen die Fragmentierung von Kunststoffen zu Mikroplastik veranschaulichte. Das Fließschema erklärte, wie Umwelteinflüsse die Fragmentierung von Plastiktüten zu Mikroplastik bedingen. Damit konnten sich die Schüler den Unterschied zwischen primärem und sekundärem Mikroplastik erarbeiten. Anhand einer weiteren Informationskarte erfuhren sie, dass die unzureichende Aufreinigungsleistung von Kläranlagen die Einleitung von Mikroplastik in den Vorfluter und in anschließende Gewässer zur Folge hat.

An **Lernstation 3** „Mikroplastik in der Umwelt- na und?!" lasen die Schüler den Text „Konferenz der Tiere im Meer", in welchem sie von den Auswirkungen der Mikroplastikverschmutzung auf verschiedene Meereslebewesen erfuhren. Indem sie selbst die Rollen der Meeresbewohner einnahmen, wurde ihnen die Tragweite der beabsichtigten oder unbeabsichtigten Aufnahme von Mikroplastik für das gesamte Nahrungsnetz nähergebracht. Neben den potenziellen Folgen für die im Meer lebenden Organismen wurde auch die Verantwortlichkeit der Menschen angesprochen. Begleitend beantworteten die Schüler Fragen und erstellten eine Nahrungskette, vor deren Hintergrund sie abschließend die Belastung des Menschen mit Mikroplastik diskutierten.

Die **Lernstation 4** „Mikroplastik in der Umwelt - was kannst du tun?!" wurde am Ende des Unterrichtsmoduls gemeinsam behandelt nachdem alle Schülergruppen die Stationen 1A, 1B, 2 und 3 abgeschlossen hatten. Diese Station erforderte keinen separaten Aufbau im Klassenzimmer. Die Schüler erhielten in ihren Gruppen lediglich Notizzettel. An dieser letzten Station hatten die Schüler die Möglichkeit, sich den Inhalt der anderen Stationen erneut ins Gedächtnis zu rufen und auf Grundlage ihres neu erlangten Wissens Handlungsstrategien zu überlegen, die den Eintrag von Kunststoffen im Generellen und Mikroplastik im Speziellen reduzieren können. Die Schüler sammelten ihre Lösungsvorschläge in der Gruppe, wodurch alle Schüler ihre persönlichen Ideen einbringen konnten. Zusammenfassend wurden die gesammelten Vorschläge im Plenum besprochen und über die besten Strategien diskutiert. Anschließend fixierten die Schüler ihre Handlungsempfehlungen auf einem Poster und hängten dieses im Klassenzimmer auf.

Die **Abschlussphase** diente der Rekapitulation des gesamten Unterrichtsmoduls. In einem Klassengespräch wurden die Inhalte der einzelnen Stationen gemeinschaftlich resümiert. Die Schüler erörterten die Ergebnisse ihrer Detektivarbeit und hatten die Gelegenheit, offene Fragen zu klären. Auf diese Weise wurde das selbstständig erarbeitete Wissen der Schüler überprüft, gegebenenfalls verbessert oder ergänzt. Die kollektive Besprechung in der Abschlussphase gewährleistete somit einen gemeinsamen Wissensstand der Schüler und eine Gesamtsicherung der Lerninhalte zum Ende des Lernmoduls.

3.5. Ergebnisse und Diskussion

3.5.1. Teilarbeit A - Umwelteinstellungen im Zusammenhang mit Tageszeitpräferenz

Teilarbeit A beschäftigte sich mit der grundlegenden Faktorenstruktur der Umwelteinstellungen, der Tageszeitpräferenz irischer Schüler sowie deren Beziehung zueinander. Der Cronbach's-Alpha-Wert von α = 0,78 der Morningness-Eveningness Scale for Children (MESC) sprach für eine akzeptable interne Konsistenz (Blanz, 2021; Tonetti et al., 2015). Darüber hinaus zeigte sich eine signifikant negative Korrelation zwischen dem Alter der Befragten und der Tageszeitpräferenz. Jüngere Schüler tendierten mehr zu einer Morgenpräferenz, während ältere Schüler stärker zum Abend tendierten. Ein Ergebnis, das sich bereits in einer deutschen Stichprobe zeigte (Randler et al., 2017). Entgegen bisheriger Studien wiesen die Schülerinnen keine höhere Morgenpräferenz auf als ihre männlichen Mitschüler (Randler, 2007). Dieses, von der Literatur abweichende, Ergebnis ist vermutlich auf die Altersgruppe zurückführbar. Es ist davon auszugehen, dass die Pubertät anderweitig erforschte Geschlechterunterschiede wohlmöglich überlagerte.

Für die Umwelteinstellungen ergab sich ein Cronbach's-Alpha-Wert von α = 0,76, der für eine akzeptable interne Konsistenz steht (Blanz, 2021; Tonetti et al., 2015). Die Kürzung des 2-MEV Modells sowie dessen Verbindung mit der Appreciation of Nature Skala ergab eine klare dreidimensionale Struktur. Die ergänzende Abfrage der Appreciation of Nature Skala ermöglichte ein präziseres Verständnis der Präferenzen für Naturnutzung (Kibbe et al., 2014). Neben der Utilization of Nature, welche Präferenzen, die Natur zu dominieren und auszunutzen erhebt (Bogner, 2018), berücksichtigt die Appreciation of Nature Skala die Präferenzen, die Natur für Erholung und Ruhe zu nutzen (Kibbe et al., 2014). Ein gemeinsamer Einsatz des 2-MEV Modells mit der Appreciation of Nature Skala erweitert somit das Verständnis der Umwelteinstellungen.

Im Einklang mit bisherigen Studien wiesen Schülerinnen eine höhere Naturschutzpräferenz und Wertschätzung der Natur auf (Schneiderhan-Opel & Bogner, 2020). Eine ausgeprägtere Naturausnutzungspräferenz der männlichen Schüler, wie in anderen Untersuchungen zu finden, wurde wiederum nicht bestätigt (Fremerey & Bogner, 2015; Schneiderhan-Opel & Bogner, 2020; Schumm & Bogner, 2016). Die Naturschutzpräferenz korrelierte signifikant positiv mit der wertschätzenden Naturnutzungspräferenz. Es scheint damit ein Zusammenhang zwischen einer wertschätzenden Einstellung gegenüber der Natur und einer naturschützenden Haltung zu existieren (Nord et al., 1998; Roczen et al., 2014). Die jeweiligen Beziehungen zwischen der Naturschutzpräferenz, der Wertschätzung der Natur und der Tageszeitpräferenz zeigten sich in signifikant positiven Korrelationen. Jugendliche mit einer ausgeprägten Präferenz für die Morgenstunden, scheinen auch eine allgemein naturschützende und wertschätzende Einstellung gegenüber der Natur zu besitzen.

3.5.2. Teilarbeit B - Wissen im Zusammenhang mit Lernort und Umwelteinstellungen

Teilarbeit B hatte zwei thematische Schwerpunkte. Zum einen untersuchte sie den Zuwachs umweltrelevanten Wissens nach der Teilnahme an einem Unterrichtsmodul zu Mikroplastik, zum anderen erforschte sie den Einfluss von zwei unterschiedlichen Lernorten und der Umwelteinstellungen der Schüler auf das erworbene Wissen.

An beiden Lernorten - innerschulisch und außerschulisch - verzeichneten die Schüler einen signifikanten Wissenserwerb. Nach dem Unterrichtsmodul besaßen alle Schüler mehr Wissen zum Thema Mikroplastik als zuvor und konnten diesen Zugewinn auch über einen Zeitraum von sechs Wochen (ohne signifikanten Verlust) bewahren. Bei der Kontrollgruppe, die während der Studienteilnahme keinen Unterricht zum Thema Mikroplastik erhalten hatte, war keine Wissensänderung nachweisbar. Ein Lerneffekt aufgrund des wiederholten Ausfüllens der Fragebögen kann damit ausgeschlossen werden.

In der Literatur findet man einige Arbeiten mit einem vergleichbaren Studiendesign, die ebenfalls die Effektivität von Unterrichtseinheiten zu umweltrelevanten Themen untersucht haben. Allen gemein ist, analog zu den vorliegenden Ergebnissen, ein Wissenserwerb direkt nach der Teilnahme (Schneiderhan-Opel & Bogner, 2020; Schumm & Bogner, 2016). Der in dieser Studie festgestellte langfristige Erhalt des Wissens zum Zeitpunkt des Nachtests ist ein bemerkenswerter Unterschied zu bisherigen Studien, in denen sich das Wissen sechs Wochen nach der Teilnahme reduzierte, dabei jedoch stets über dem Niveau des Vorwissens blieb (Schneiderhan-Opel & Bogner, 2020; Schumm & Bogner, 2016). Die Wissensabnahme zeigte sich in den genannten Studien unabhängig vom Lernort in innerschulisch (Schneiderhan-Opel & Bogner, 2020; Schumm & Bogner, 2016) und auch in außerschulisch (Fremerey & Bogner, 2015; Sattler & Bogner, 2017) durchgeführten Interventionen. Lediglich in einer Studie zum Thema Abfallmanagement mit Schülern einer vergleichbaren Altersklasse (5. Jahrgangsstufe) konnte analog zu dieser Arbeit ein langfristiger Erhalt des Wissens nach sechs Wochen nachgewiesen werden (Stöckert & Bogner, 2020).

Eine entscheidende Voraussetzung, um die Effektivität unterschiedlicher Lernorte beurteilen zu können, ist ein vergleichbares Vorwissen der Schüler. Diese war in der vorliegenden Studie gegeben. Es bestand kein statistisch signifikanter Unterschied zwischen den Schülern (innerschulisch, außerschulisch, Kontrollgruppe) bezüglich deren Wissen vor Beginn der Intervention. Überraschenderweise war der außerschulische Lernort nicht effektiver als der innerschulische (Seybold et al., 2014; Sturm & Bogner, 2010). Das Wissen der inner- wie außerschulisch unterrichteten Schüler unterschied sich im Nachtest, direkt nach dem Unterrichtsmodul, nicht signifikant voneinander. Im Behaltenstest, sechs Wochen nach der Intervention, hingegen zeigten die Teilnehmer des innerschulischen Programms einen Wissensvorsprung mit geringer Effektstärke gegenüber den außerschulisch unterrichteten (Cohen, 1988). Die Untersuchung weist damit zwar sechs Wochen nach der Teilnahme auf eine potenzielle Überlegenheit des innerschulischen Lernorts hin, eine abschließende Beurteilung des Faktors Lernort lässt dieses Ergebnis allerdings nicht zu. Insgesamt scheint im untersuchten Studienaufbau, in dem sich Lerninhalte und -methoden nicht unterschieden, der Lernort selbst eine untergeordnete Rolle zu spielen. Unabhängig von diesem Ergebnis ist anzumerken, dass auch vergleichbare Studien kein einheitliches Bild ergaben (Geier & Bogner, 2010; Sturm & Bogner, 2010). Ein Grund für den mangelnden wissenschaftlichen Konsens bei der Beurteilung von Lernorten mag die Vielzahl an beeinflussenden Faktoren sein, die den Effekt eines Lernorts entscheidend mitbestimmen, bis dato aber noch nicht ausreichend erforscht wurden (z.B. Art des außerschulischen Lernorts, Neuheit der Lernortbedingungen; DeWitt & Storksdieck, 2008; Orion & Hofstein, 1994).

Im Rahmen der durchgeführten Regressionsanalyse (abhängige Variable: Wissen des Nachtests (T1); unabhängige Variablen: drei Umwelteinstellungen und Lernort) ergab sich ein Modell moderater Güte. Drei der vier Prädiktoren wiesen Signifikanzen aus; lediglich bei der wertschätzenden Naturnutzungspräferenz musste man aufgrund fehlender Signifikanz von einer limitierten Aussagekraft ausgehen. Die unabhängige Variable Lernort trug im erstellten Modell zur Vorhersage des Wissens bei: Die Teilnahme an einem innerschulischen Unterrichtsmodul prognostizierte ein höheres Wissen zum Zeitpunkt T1. Die dabei vorliegende Koeffizientenstärke der Variable Lernort in der Regressionsgleichung war jedoch verhältnismäßig gering. Nachdem bereits in den vorangegangenen Analysen kein signifikanter Unterschied zwischen dem außerschulisch und innerschulisch erarbeiteten Wissen zu T1 festgestellt wurde, scheint die relativ schwache Koeffizientenstärke durchaus plausibel.

Als bessere Prädiktoren des Wissens haben sich die Naturschutzpräferenz und insbesondere die Naturausnutzungspräferenz herausgestellt. Während die Naturschutzpräferenz das Wissen zum Zeitpunkt T1 positiv beeinflusste, zeigte die Naturausnutzungspräferenz eine entgegengesetzte, negative Wirkung. Vergleichbare Studien zeigten ebenfalls einen positiven Zusammenhang zwischen der Naturschutzpräferenz und dem Wissen sowie einen negativen Zusammenhang zwischen der Naturausnutzungspräferenz und dem Wissen (Dieser & Bogner, 2017; Thorn & Bogner, 2018). Dementsprechend kann die Vermutung aufgestellt werden, dass jene Schüler, bei denen die Naturschutzpräferenz stärker ausgeprägt ist, mehr von einem Umweltbildungsmodul profitieren als Schüler, bei denen die Naturausnutzungspräferenz präsenter ist. Im Gegensatz zu diesen zwei Einstellungsvariablen konnte die wertschätzende Einstellung gegenüber der Natur das Wissen nach dem Unterrichtsmodul nicht vorhersagen. Ein Ergebnis, das in ähnlicher Weise auch von Schneiderhan & Bogner (2020) gefunden wurde. Auch hier wurde keine Korrelation zwischen der

Wertschätzung der Natur und dem Wissen zum Zeitpunkt unmittelbar nach der Unterrichtseinheit festgestellt.

Inner- und außerschulisch unterrichtete Schüler unterschieden sich zum Zeitpunkt der Erhebung nicht bezüglich ihrer Umwelteinstellungen. Mit dem Ziel, vertiefende Erkenntnisse zu der Rolle der Umwelteinstellungen im Prozess der Wissensgenerierung zu erlangen, wurden sogenannte Extremgruppen gebildet und untersucht. Als Extremgruppe bezeichnete man eine Teilmenge der Gesamtstichprobe mit sehr starker bzw. sehr schwacher Ausprägung (unterhalb des ersten bzw. oberhalb des dritten Quartils) hinsichtlich jeder der drei Umwelteinstellungen.

Ein zentrales Ergebnis: Jede der insgesamt sechs Extremgruppen konnte ein signifikantes Wachstum des Wissens zu T1, unabhängig vom jeweiligen Lernort, nachweisen. Am Beispiel der Naturausnutzungstendenz bedeutet das, dass sowohl Schüler mit einer schwachen als auch Schüler mit einer starken Naturausnutzungspräferenz von der Unterrichtseinheit profitierten. Analog zu den Ergebnissen der Gesamtstichprobe zeigte der Wissensstand aller Extremgruppen zum Zeitpunkt T2 keinen signifikanten Unterschied zu T1, das Erlernte konnte auch nach sechs Wochen noch umfassend abgerufen werden.

Weitere Einblicke in die Wirkung der Intervention ermöglichte die intrakonzeptionelle Extremgruppenbetrachtung der drei Umwelteinstellungen vor dem Hintergrund des Lernorts. Die deutlichsten Differenzen zwischen den Extremgruppen fand man bei der Naturausnutzungspräferenz. Zwar lernten, wie oben beschrieben, sowohl Schüler mit einer niedrigen als auch mit einer hohen Naturausnutzungspräferenz signifikant hinzu, das Wissen der beiden Extremgruppen unterschied sich jedoch zu jedem Messzeitpunkt und innerhalb beider Lernsettings signifikant voneinander. Die Gruppe mit einer schwächer ausgeprägten Tendenz zur Naturausnutzung besaß stets ein höheres Wissen als ihr Pendant mit stark ausgeprägter Naturausnutzungstendenz. Das bedeutet, dass das Lernmodul den Wissensstand dieser beiden Extremgruppen zu keinem Zeitpunkt nivellieren konnte. Dies deckt sich mit der Teilstichprobe von Schönfelder & Bogner (2017), welche Unterricht über Bienen am lebenden Objekt auf dem Schulgelände erhielt. Die daraus resultierende Empfehlung ist die spezifische Förderung und individuelle Ansprache von Schülern mit einer Tendenz zur Naturausnutzung. Sie sind empfänglich für Maßnahmen zur Steigerung ihrer Umweltschutzbildung, benötigen jedoch vermutlich einen ausgeprägteren Lernimpuls verglichen mit ihren Mitschülern.

Mit Blick auf die Extremgruppen innerhalb der wertschätzenden Naturnutzungspräferenz zeigte sich ein anderes Bild. Im innerschulischen Setting unterschieden sich die Schüler mit einer hohen Wertschätzung der Natur von denen mit einer niedrigen Ausprägung sowohl vor der Intervention, als auch sechs Wochen nach der Intervention, in ihrem Wissen signifikant voneinander. Beim Wissenstest direkt nach der Intervention schnitten beide Gruppen vergleichbar ab. Offensichtlich war die Unterrichtseinheit in der Lage, den ursprünglichen Wissensrückstand der Schüler mit einer schwach ausgeprägten Wertschätzung auszugleichen. Der Wissenserwerb dieser Gruppe war jedoch, verglichen mit den Schülern mit einer stark ausgeprägten Wertschätzung, weniger nachhaltig, was zu den signifikanten Unterschieden zu T2 führte. In Studie 2, dem außerschulischen Interventionssetting, waren keine signifikanten Unterschiede der Extremgruppen der wertschätzenden Naturnutzungspräferenz zu erkennen.

Bei Betrachtung der, zur Naturschutzpräferenz gebildeten, Extremgruppen fand man ebenfalls messzeitpunktabhängige, signifikante Unterschiede. In Studie 1 wiesen die Schüler mit starker Tendenz zum Umweltschutz im Vergleich zu ihrer niedrig ausgeprägten Äquivalenzgruppe ein signifikant höheres Wissen zu den Zeitpunkten T0 und T1 auf. Sie konnten also ihren zu T0 vorhandenen Wissensvorsprung direkt nach der Intervention aufrechterhalten, indem sie zumindest vergleichbar viel dazulernten wie die Extremgruppe unterhalb des ersten Quartils. Nachhaltig war dieser Wissensvorsprung allerdings nicht. Die Ergebnisse des Behaltenstests wiesen keine signifikanten Unterschiede auf. Beide Extremgruppen bewegten sich zu diesem Zeitpunkt auf einem vergleichbaren, in Relation zu T0 gestiegenem, Wissensniveau. In Studie 2, dem außerschulischen Lernort, hatten die Extremgruppen, analog zur wertschätzenden Naturnutzungspräferenz, zu allen Testzeitpunkten einen vergleichbaren Wissensstand. Ein Befund, der auch von Schönfelder & Bogner (2017) festgestellt wurde. Im außerschulischen Interventions-Setting lernten also alle Extremgruppen der Naturschutz- und wertschätzenden Naturnutzungspräferenz relativ gleichwertig.

Letztlich soll bei der Interpretation der Ergebnisse darauf hingewiesen werden, dass aufgrund des geringen Schwierigkeitsgrads der Testfragen die Abbildung der potenziellen Wissensleistung der Schüler limitiert sein könnte (Ceiling-Effekt; Wirth, 1997).

3.5.3. Teilarbeit C - Weiterentwicklung des Unterrichtsmoduls zu Mikroplastik

Das in der Interventionsstudie (Teilarbeit B) durchgeführte Unterrichtsmodul wurde in Teilarbeit C auf Grundlage von Erfahrungen und Rückmeldungen aus der Praxis weiterentwickelt und für einen losgelösten Einsatz Lehrpersonen zur Verfügung gestellt. Das Unterrichtsmodul blieb in seiner Gesamtheit unverändert und entspricht grundsätzlich dem in Kapitel 3.4.3 erläuterten Konzept für die Primarstufe. Basierend auf Erfahrungen aus der Durchführung mit 470 Schülern wurden einige organisatorische, methodische und inhaltliche Anpassungen vorgenommen, um im Sinne des schülerzentrierten Ansatzes die eigenständige Arbeitsweise der Schüler zu intensivieren. Diese Adaptionen werden im Folgenden kurz erläutert. Die Abfolge der Stationen blieb unverändert, lediglich die Stationstitel wurden modifiziert (Stationen 1A, 1B, 1C, 2, 3 wurden umbenannt in Stationen 1, 2, 3, 4, 5). Die ehemalige Station 4 wird nun unter Station 7 geführt, nachdem eine zusätzliche Station auf Position 6 eingeführt wurde

Die Einführungsphase beinhaltet in der Überarbeitung zusätzliche Fragen zu den persönlichen Erfahrungen der Schüler. Anhand dieser Aufgabenstellungen beschäftigen sich die Schüler aktiv mit Kunststoffen in ihrem Alltag. Darüber hinaus wurde die Einführung um eine Gruppendiskussion zu Eintragspfaden und der Präsenz von Kunststoffen und Mikroplastik am Strand erweitert und schließt mit einer Definitionsfindung zum Begriff Mikroplastik.

Station 5 (ehemalige Station 3) enthält durch die Anpassungen zusätzliche Fragen, um das Verständnis und Bewusstsein zu den Auswirkungen von Mikroplastikeinträgen auf Meeresbewohner weiter zu vertiefen. Station 6 wurde zur Optimierung des Gesamtmoduls gänzlich neu entworfen. Die Dauer des Moduls verlängert sich damit um 20 Minuten auf insgesamt 180 Minuten. An Station 6 spielen die Schüler zusätzlich ein Memory-Spiel, bei dem sie Einweg-, Mehrweg- und Alternativprodukte einander zuordnen. In diesem Kontext gibt man den Schülern die Möglichkeit, über Vor- und Nachteile der Produkte in Bezug auf Preis, Gewicht, Haltbarkeit, Müllmenge oder Langlebigkeit zu sprechen. Damit erarbeiten sich die Schüler hilfreiches Hintergrundwissen für den gemeinsamen Abschluss des Stationenlernens an Station 7.

Im letzten Part des Unterrichtmoduls, an Station 7 (ehemalige Station 4), werden nochmals Ideen zur Kunststoffvermeidung bzw. -reduktion gesammelt. Zusätzlich werden ausgewählte Fragen aus der Einführung erneut aufgegriffen, um den Schülern die Möglichkeit zu geben, über ihre ursprünglichen und neu entwickelten Erfahrungen zu Kunststoffen in ihrem Zuhause und der Umwelt sowie über ihre neuen Erkenntnisse zu Eintragspfaden in die Umwelt zu sprechen. Ein mögliches Ergebnis dieser Diskussion kann die Erkenntnis sein, dass die Verwendung von Kunststoffen allgegenwärtiger und die Umweltbelastung durch Kunststoffe stärker ist als zuvor angenommen.

Auch das Arbeitsmaterial, das an den Lernstationen ausliegt, wurde anhand der Beobachtungen aus der Praxis adaptiert und um Erklärungen zu Begriffen, wie beispielsweise Kosmetika, Peeling und Textilien erweitert. Dies unterstützt die Schüler nochmals in ihrer eigenständigen Erarbeitung der Inhalte.

3.5.4. Teilarbeit D - Studierendenvorstellungen zu Mikroplastik

Die Teilarbeit D beschäftigte sich mit den Vorstellungen von Studierenden zum Thema Mikroplastik. Bislang existieren nur wenige sozialwissenschaftliche Studien, die sich mit der gesellschaftlichen Wahrnehmung von Mikroplastik befassen (Pahl & Wyles, 2017). Die vorliegende Arbeit legte sowohl erwartete als auch überraschende Ergebnisse zu den Vorstellungen junger Erwachsener zu Mikroplastik offen, die jeweils wertvolle Ansätze für die Bildungsarbeit bieten.

Der Themenkomplex Mikroplastik war den Studierenden in seinen groben Zügen bekannt. Der Großteil verstand unter dem Begriff Mikroplastik kleine Kunststoffpartikel. Dieses Ergebnis steht im Gegensatz zu der Untersuchung von Deng et al. (2020), in der die Begrifflichkeit Mikroplastik unter den Teilnehmern weitestgehend unbekannt war. Die weitere Einteilung in primäres und sekundäres Mikroplastik gelang den Studierenden nur implizit, d.h. ohne Nennung der Termini „primär“ und „sekundär“. Dass sie ein grundlegendes Verständnis für die Herkunft des Mikroplastiks besitzen, zeigten sie in der Beantwortung der Frage zu den Mikroplastikquellen im Haushalt. Hierzu gaben die Teilnehmer neben Kosmetika (einzuordnen als primäre Mikroplastikquelle) auch Kunststoffgegenstände verschiedener Art an, die erst nach Fragmentierung als sekundäres Mikroplastik einzuordnen sind. Dies indiziert: Das Konzept des primären und sekundären Mikroplastiks ist den Studierenden durchaus bekannt, ihnen fehlt jedoch die dementsprechende, fachliche Bezeichnung.

Bei der Frage nach Quellen von Mikroplastik im Haushalt waren Kunststoffverpackungen die meistgenannte Antwort. Die Häufigkeit dieser Nennung ist kaum verwunderlich, stellt die Kunststoffverpackung doch mit 39,6 % den Großteil des europäischen Kunststoffbedarfs dar (PlasticsEurope, 2020). Ebenfalls wenig überraschend ist, dass Körperpflegeprodukte (insbesondere Kosmetika) die am zweithäufigsten aufgeführte Mikroplastikquelle im Haushalt waren. In einer Studie aus dem Jahr 2016 war das Thema bei den befragten Studierenden noch unbekannt (Anderson et al., 2016). Der nunmehr verhältnismäßig starke Fokus auf Körperpflegeprodukte ist durch die vermehrte Aufmerksamkeit in wissenschaftlichen Studien (Hann et al., 2018), die große Medienpräsenz (Völker et al., 2019) oder die gezielten Werbemaßnahmen der Kosmetikindustrie zu erklären. Zwar schreibt man Pflegeprodukten an der Gesamtproblematik des Mikroplastiks aktuell eine relativ geringe Relevanz zu (Hann et al., 2018), ein Bewusstsein hinsichtlich dieser Quelle im eigenen Haushalt ist dennoch wertvoll. Das unter den Befragten offenbar vorhandene Verständnis zu Kunststoffverpackungen oder Kosmetika als Mikroplastikquellen im Privathaushalt kann ein Ankerpunkt in einem Prozess der Verhaltensänderung sein. Leire & Thidell (2005) beschreiben in ihrer Studie, dass den Konsumenten aufgrund mangelnden Bewusstseins der Zusammenhang zwischen Kaufentscheidungen und Umweltkonsequenzen fehlt. Zugleich hat in einer Studie von Hartley et al. (2015) die Teilnahme an einem Unterrichtsmodul zu Meeresmüll bei den Schülern zu einer Verbesserung des selbstberichteten umweltfreundlichen Verhaltens geführt, welches auch an Freunde und Familie weitergegeben wurde. Entsprechend dieser Erkenntnisse muss es zukünftig das zentrale Ziel sein, den Lernenden bewusst werden zu lassen, inwiefern ihre Kaufentscheidungen und ihr Kunststoffkonsum direkte Auswirkungen auf die Kunststoff- und Mikroplastikbelastung der Natur haben (Stanton et al., 2020). Die Auswertung der Studierendenantworten zeigte auch, dass einige Mikroplastikquellen den Teilnehmern bislang kaum oder nicht bekannt waren. Nur wenige Studierende nannten Kunststoffgegenstände, Kunststoffmüll, Reinigungsmittel, Textilien oder Lebensmittel. Keiner der Studierenden wies auf Hygieneprodukte (wie Damenhygieneartikel, Wattestäbchen, etc.) oder den Eintrag über den Biomüll als Quelle hin. Zu ähnlichen Ergebnissen kam die Studie von Deng et al. (2020), in der den Probanden herkömmliche Kunststoffprodukte, wie Plastikflaschen durchaus bekannt waren, Farben oder Textilfasern aus Kunststoffen jedoch weniger. Eben solche Erkenntnisse stellen gezielte Ansatzpunkte für Bildungsmaßnahmen dar.

Hinsichtlich der Mikroplastikbelastung deutscher Gewässer indizieren die Antworten der Studierenden ebenfalls konkrete Anknüpfungspunkte für die Bildung. Verglichen mit dem Meer, den Seen und Flüssen, vermuteten relativ wenige Studierende eine Mikroplastikkontamination des Grundwassers. Dieses Ergebnis steht im Einklang mit Re (2019), der argumentierte, dass Mikroplastik im Grundwasser nur wenig wissenschaftliche und politische Beachtung findet.

Der Großteil der Studierenden nahm Mikroplastik als sehr gefährlich oder gefährlich wahr. Der Anteil jener, der Mikroplastik als kaum gefährlich einschätzte, war verschwindend gering und niemand hielt es für nicht gefährlich. Die Begründungen waren vielfältig und reichten von Auswirkungen auf Tiere, Menschen und Ökosysteme bis hin zu den chemischen und physikalischen Eigenschaften von Mikroplastik. In der Studie von Deng et al. (2020) zeigten die Probanden eine stärker ausgeprägte anthropozentrische Sichtweise zur Kunststoffbelastung. Sie fühlten sich (aus einer Auswahl negativer Auswirkungen von Kunststoffen) am stärksten durch die Verschmutzung der Stadt, also ihrem persönlichen, menschengemachten Lebensraum belastet. Neben wissenschaftlich fundierten Gefahren durch Mikroplastik, z.B. der Aufnahme von Mikroplastik durch diverse Organismen (Laist, 1997), beschrieben einige Studierende auch Themen die weiterer Forschung bedürfen, um eine verlässliche Aussage zur potenziellen Gefahr treffen zu können, z.B. die gesundheitlichen Folgen des Konsums (Hämer et al., 2014; Moos et al., 2012). Grundsätzlich schien bei den Studierenden eine starke Sensibilität bezüglich der Auswirkungen von Mikroplastik zu existieren. Fast ein Drittel der Studierenden beschrieb bereits in ihrer Definition von Mikroplastik negative Folgen, obwohl diese in der Fragestellung nicht gefordert waren. Dieses Ergebnis signalisiert eine starke thematische Verknüpfung zwischen Mikroplastik und seinen Konsequenzen.

Eine Begründung der beobachteten hohen Sensibilität für die Gefahren durch Mikroplastik liegt möglicherweise im Informationsverhalten der Befragten. Für die Studierenden waren die Medien die relevanteste Informationsquelle. Für die Gefahrenwahrnehmung innerhalb der Gesellschaft spielt Völker et al. (2019) zufolge das Framing in Medienberichten eine entscheidende Rolle. Unter Framing versteht man die Betonung einzelner, ausgewählter Aspekte der wahrgenommenen Realität innerhalb eines Kommunikationsprozesses, wodurch Sachverhalte mit einer vom Sender bestimmten Note eingefärbt werden (Entman, 1993). Wissenschaftliche Unsicherheiten werden in den Medien zum Teil durch die Vereinfachung wissenschaftlicher Erkenntnisse oder den Einsatz einseitiger Berichterstattung ausgeblendet (Völker et al., 2019). Damit suggerieren sie eine höhere Wahrscheinlichkeit von Risiken durch Mikroplastik als objektiv erhoben wurde (Völker et al., 2019).

Innerhalb der Medienlandschaft war das Fernsehen, noch vor dem Internet, die am häufigsten genannte Informationsquelle. Dieses Ergebnis kann aus wissenschaftlicher Sicht insbesondere deshalb als positiv bewertet werden, da die Studierenden spezifizierend für das Medium Fernsehen tendenziell qualitativ verlässliche Quellen wie Nachrichten oder Dokumentationen anführten. Auch in anderen Studien der Vorstellungsforschung zeigten sich die Medien als relevante Informationsquelle (Schmid & Bogner, 2018; Shaw et al., 2008). Dieser Trend wurde bereits in den 1980er Jahren von Blum (1987) beobachtet und hat sich in den vergangenen Jahrzehnten weiter verstärkt: Weg von den Bildungseinrichtungen hin zu den Medien. Auch Deng et al. (2020) beschrieben diese starke Relevanz der Medien verglichen zu Schulen oder Universitäten. Grundsätzlich hat das Internet eine wachsende Bedeutung bei der Informationsbeschaffung (Brossard, 2013). So lässt sich vermuten, dass sich das Bild mittlerweile wandelt und das Internet im informativen Medienkonsum zunehmend die zentrale Rolle spielt. Dies geht mit neuen Herausforderungen, aber auch Chancen für die Bildungspolitik einher.

Vor dem Hintergrund der starken medialen Präsenz des Themas, und der bislang mangelnden Einbindung in den Lehrplan, war die Dominanz der Medien bei der Informationsgewinnung ein zu erwartendes Ergebnis. Medien haben das Potenzial, wissenschaftliches Verständnis zu formen, zu artikulieren und damit öffentliche Vorstellungen zu prägen (Antilla, 2010). Die Art und Weise, wie Informationen zur Kunststoffbelastung der Umwelt über die Medien dargestellt werden, kann das Verständnis der Gesellschaft beeinflussen (Henderson & Green, 2020). Neben den vielen Vorteilen der Medienlandschaft, wie Geschwindigkeit, Aktualität und Reichweite, birgt die wissenschaftliche Medienberichterstattung auch Nachteile. Diese entstehen beispielsweise dann, wenn, wie bereits angesprochen, die Qualität der Berichterstattung zu wissenschaftlichen Themen unter Übertreibungen, Vereinfachungen oder schlicht inkorrekten Darstellungen leidet (Brownell et al., 2013). Demnach können Medien auch zur Verbreitung von alternativen Vorstellungen beitragen (Dekker et al., 2012) und diese im Bewusstsein der Öffentlichkeit verfestigen. Ein Beispiel für eine sich hartnäckig haltende alternative Vorstellung im Zusammenhang mit Kunststoffverschmutzung ist der sogenannte „Great Pacific Garbage Patch", der fälschlicherweise als geschlossener Müllteppich im Bewusstsein der Öffentlichkeit verankert ist (Hahladakis, 2020; Henderson &

Green, 2020). Entgegen dieser weit verbreiteten Vorstellung eines Teppichs oder einer Insel aus Müll ist er eine Ansammlung einzelner Kunststoffgegenstände im Nordpazifik (Hahladakis, 2020). Nachdem auch Lehrende nicht vor alternativen Vorstellungen gefeit sind, sollen auch sie dazu aufgerufen werden, ihre Vorstellungen regelmäßig und intensiv zu prüfen (Azevedo & Duarte, 2018), da sie andernfalls alternative Vorstellungen der Schüler nicht erkennen oder schlimmstenfalls zu deren Entwicklung beitragen. Zusammenfassend wäre es vor dem Hintergrund der erhobenen Studierendenvorstellungen erstrebenswert, dem Thema Mikroplastik einen fachlich fundierten und konstanten Platz in Lernorten wie Schulen und Universitäten einzuräumen. Dort kann man aktuelle Informationen zur Thematik bereitstellen, Schülern und Studierenden das Angebot machen, sich mit Lehrkräften und Mitschülern bzw. Fachwissenschaftlern und Kommilitonen auszutauschen und allen die Möglichkeit geben, ihre Wahrnehmungen zu hinterfragen und abweichende Ansichten zu diskutieren. Dabei sollte die Bildungsarbeit sich auf fundierte Ergebnisse stützen, Unsicherheiten als solche betiteln und, eine gesamtheitliche Aufarbeitung anstrebend, auch die positiven Eigenschaften von Kunststoffen, z. B. für die Lebensmittelsicherheit oder die Anwendung im medizinischen Bereich (Mitrano & Wohlleben, 2020), thematisieren. Eine derartige Stärkung des Bildungssektors würde es jungen Erwachsenen erleichtern, Verantwortung als gut informierter Teil der Gesellschaft zu übernehmen und weiterzutragen.

3.6. Schlussfolgerungen und Ausblick

Die Umweltbelastung durch Kunststoffe und Mikroplastik ist eine globale Herausforderung, die einer nachhaltigen Lösung bedarf (Thompson, 2015). Die Wissenschaft fordert ein sofortiges Handeln ein, um Kunststoffmüll zu reduzieren und damit zumindest die kontinuierliche Belastung der Natur zu limitieren. Eine Entschärfung hin zu einer Lösung des Problems kann nur mit Maßnahmen der Politik und einem Umdenken in Industrie und Handel geschehen. Ein zentraler und maßgeblicher Akteur in diesem Handlungsfeld ist zugleich die Gesellschaft und damit jede Einzelperson. Individuen beeinflussen den gesamten Lebenszyklus eines Produkts, beginnend mit dem Erwerb über die Verwendung bis hin zur Entsorgung (European Commission, 1998). Die Gesellschaft ist dazu in der Lage mit einem gesteigerten Problembewusstsein und einem, sich daraus ableitenden, umweltfreundlicheren Handeln einen signifikanten Unterschied zu machen (Derraik, 2002). Ein Umdenken der Konsumenten bezüglich ihres Umgangs mit Wertstoffen, und hierunter sind Kunststoffe zwingend zu zählen, ist unerlässlich. Jeder Mensch sollte verstehen und verinnerlichen, dass eine unbewusste Kaufentscheidung oder ein unachtsam entsorgter Gegenstand potenziell jahrzehntelange oder gar jahrhundertelange Folgen für die Natur bedeutet.

Das Thema Mikroplastik ist angesichts der nachhaltigen Aktualität, der irreversiblen Konsequenzen für die Umwelt und der stetig steigenden Produktion von Kunststoffen als hoch relevantes Feld der Umweltbildung einzuordnen. Vor dem Hintergrund der pädagogischen Erkenntnis, dass in der schulischen Ausbildung die Grundlagen naturwissenschaftlichen Wissens gelegt werden (Miller, 1992), sollte Unterricht zu Mikroplastik, über die Primarstufe hinausgehend, fester Bestandteil des Lehrplans sein. Umweltbildungsmaßnahmen haben sich bereits in diversen Themenkomplexen als vielversprechend darin erwiesen, Wissen (Schneiderhan-Opel & Bogner, 2019), positive Umwelteinstellungen (Sellmann & Bogner, 2013) und umweltfreundliches Handeln (Hartley et al., 2015) zu fördern. Auch das, im Rahmen dieser Arbeit konzipierte und durchgeführte, Unterrichtsmodul konnte allen teilnehmenden Grundschülern umweltrelevantes Wissen kurz- sowie langfristig vermitteln. Selbst bei Schülern mit einer stark ausgeprägten Naturausnutzungspräferenz konnte man einen nachhaltigen Wissenszuwachs generieren. Die Erkenntnis, dass durch das schülerzentrierte Unterrichtmodul an unterschiedlichen Lernorten effektiv zu Mikroplastik gelernt werden konnte, lässt Implikationen für den Bildungsalltag ableiten. Die eingesetzten, einfachen Experimente lassen sich mit überschaubarem Aufwand in den naturwissenschaftlichen Unterricht integrieren. Dabei kann die Einbeziehung der Umwelteinstellungen der Schüler sehr lohnend sein. Naturschutzpräferenzen, aber noch stärker Naturausnutzungspräferenzen, haben Einfluss auf die Wissensaufnahme der Schüler. Sofern möglich, sollten Lernende mit einer dominanten Neigung zur Naturausnutzung bereits vor der Bildungsmaßnahme gezielt pädagogisch adressiert werden, um solch lernhemmende Einstellungstendenzen abzubauen. Bei der Gestaltung unterrichtlicher Ansätze zum Umweltschutz können neben den Umwelteinstellungen auch Tageszeitpräferenzen berücksichtigt werden. Die Durchführung von Lernmodulen zu bestimmten Tageszeiten, entsprechend der Tageszeitpräferenzen der Schüler, könnte die Effektivität der Unterrichtseinheit potenziell steigern.

Die identifizierten Vorstellungen von Studierenden zu Mikroplastik sind in vielerlei Hinsicht relevant. Die Antworten der Studienteilnehmer projizieren den Stand einer Bildungsgeneration, die keine spezifische, lehrplanbasierte Auseinandersetzung mit der Thematik hatte und legt dadurch Ansatzpunkte für zukünftige Schulinhalte offen. Das grundlegende Verständnis der Studierenden zum Begriff Mikroplastik, zu Quellen von Mikroplastik oder zu potenziellen Gefahren durch Mikroplastik, ist als positiv zu bewerten. Auch wenn Studierende in ihrer Schullaufbahn nicht zwingend zu Mikroplastik unterrichtet wurden, scheint eine gewisse mediale Präsenz sowie die eigenmotivierte Auseinandersetzung mit der Thematik ein solides Grundverständnis zu schaffen. In einigen Teilgebieten erkennt man aus Perspektive der Umweltbildung dennoch Optimierungsfelder: So sind beispielsweise gewisse Mikroplastikquellen im Haushalt nur wenigen (u. a. Textilien) bzw. keinem (u. a. Hygieneartikel) Studierenden bekannt. Auch ist die Belastung des Grundwassers nicht im Bewusstsein der Befragten. Letztlich deuten die hohe Gefahrenzuschreibung und die stark verknüpften Assoziationen mit negativen Konsequenzen auf einen Aufklärungsbedarf seitens der Wissenschaft hin.

Der Handlungsbedarf wird zudem dadurch verstärkt, dass die Studierenden als Hauptinformationsquelle die Medien nannten. Während es zweifellos ein positives Zeichen ist, dass Medien das Thema Mikroplastik aufgreifen, plädiert man an dieser Stelle für eine fachlich geprüfte und pädagogisch begleitete Wissensvermittlung über die klassische Schulbildung. Zielgerichtete Bildung, beispielsweise in Form von Outreach-Aktivitäten, zum Thema Mikroplastik kann Schülern praxisnahes, ganzheitliches Wissen vermitteln und ihnen damit adäquate Werkzeuge für einen bewussten Umgang mit Kunststoffen und Mikroplastik an die Hand geben. Die Kunststoffmüllbelastung ist auch ein Problem des menschlichen Verhaltens und ist nicht allein durch die Eigenschaften von Kunststoffen begründet. Deshalb muss die Lösung dieser globalen Herausforderung auch an dessen Quelle, der Nutzung von Kunststoffen, angegangen werden. Das Wissen, dass jeder einzelne zum Problem beiträgt und es somit auch verhindern bzw. abmildern kann, muss vermittelt werden. Denn es gilt: „Humans are the cause and solution" (Pahl et al., 2017).

4 LITERATURVERZEICHNIS DER SYNOPSIS

Adan, A., Archer, S. N., Hidalgo, M. P., Di Milia, L., Natale, V. & Randler, C. (2012). Circadian typology: a comprehensive review. *Chronobiology International*, *29*(9), 1153–1175. https://doi.org/10.3109/07420528.2012.719971

Allen, S., Allen, D., Phoenix, V. R., Le Roux, G., Durántez Jiménez, P., Simonneau, A., Binet, S. & Galop, D. (2019). Atmospheric transport and deposition of microplastics in a remote mountain catchment. *Nature Geoscience*, *12*(5), 339–344. https://doi.org/10.1038/s41561-019-0335-5

Anderson, A. G., Grose, J., Pahl, S., Thompson, R. C. & Wyles, K. J. (2016). Microplastics in personal care products: Exploring perceptions of environmentalists, beauticians and students. *Marine Pollution Bulletin*, *113*(1-2), 454–460. https://doi.org/10.1016/j.marpolbul.2016.10.048

Andrady, A. L. (2011). Microplastics in the marine environment. *Marine Pollution Bulletin*, *62*(8), 1596–1605. https://doi.org/10.1016/j.marpolbul.2011.05.030

Antilla, L. (2010). Self-censorship and science: a geographical review of media coverage of climate tipping points. *Public Understanding of Science*, *19*(2), 240–256. https://doi.org/10.1177/0963662508094099

Asshoff, R., Düsing, K., Winkelmann, T. & Hammann, M. (2020). Considering the levels of biological organisation when teaching carbon flows in a terrestrial ecosystem. *Journal of Biological Education*, *54*(3), 287–299. https://doi.org/10.1080/00219266.2019.1575263

Auta, H. S., Emenike, C. U. & Fauziah, S. H. (2017). Distribution and importance of microplastics in the marine environment: A review of the sources, fate, effects, and potential solutions. *Environment International*, *102*, 165–176. https://doi.org/10.1016/j.envint.2017.02.013

Azevedo, M.-M. & Duarte, S. (2018). Continuous Enhancement of Science Teachers' Knowledge and Skills through Scientific Lecturing. *Frontiers in Public Health*, *6*, 41. https://doi.org/10.3389/fpubh.2018.00041

Bandura, A. (1993). Perceived Self-Efficacy in Cognitive Development and Functioning. *Educational Psychologist*, *28*(2), 117–148. https://doi.org/10.1207/s15326985ep2802_3

Bayerisches Staatsministerium für Bildung und Kultus, Wissenschaft und Kunst. (2014). *LehrplanPLUS Grundschule: Lehrplan für die bayerische Grundschule.* Bayerisches Staatsministerium für Bildung und Kultus, Wissenschaft und Kunst.

Bell, P., Lewenstein, B., Shouse, A. W. & Feder, M. A. (2009). *Learning Science in Informal Environments: People, Places, and Pursuits*. National Academies Press. https://doi.org/10.17226/12190

Bergmann, M., Mützel, S., Primpke, S., Tekman, M. B., Trachsel, J. & Gerdts, G. (2019). White and wonderful? Microplastics prevail in snow from the Alps to the Arctic. *Science Advances*, *5*(8), eaax1157. https://doi.org/10.1126/sciadv.aax1157

Blanz, M. (2021). *Forschungsmethoden und Statistik für die Soziale Arbeit: Grundlagen und Anwendungen* (2. Auflage). Kohlhammer.

Blum, A. (1987). Students' Knowledge and Beliefs concerning Environmental Issues in Four Countries. *The Journal of Environmental Education*, *18*(3), 7–13. https://doi.org/10.1080/00958964.1987.9942734

BMU. (26. November 2018). *„Nein zur Wegwerfgesellschaft": 5-Punkte-Plan des Bundesumweltministeriums für weniger Plastik und mehr Recycling*. https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Abfallwirtschaft/5_punkte_plan_plastik_181123_bf.pdf

Boeve-de Pauw, J. & van Petegem, P. (2011). The Effect of Flemish Eco-Schools on Student Environmental Knowledge, Attitudes, and Affect. *International Journal of Science Education*, *33*(11), 1513–1538. https://doi.org/10.1080/09500693.2010.540725

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

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

Bogner, F. X. & Wiseman, M. (2006). Adolescents' attitudes towards nature and environment: Quantifying the 2-MEV model. *The Environmentalist*, *26*(4), 247–254. https://doi.org/10.1007/s10669-006-8660-9

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

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

Braun, T., Cottrell, R. & Dierkes, P. (2017). Fostering changes in attitude, knowledge and behavior: demographic variation in environmental education effects. *Environmental Education Research*, *24*(6), 899–920. https://doi.org/10.1080/13504622.2017.1343279

Brossard, D. (2013). New media landscapes and the science information consumer. *Proceedings of the National Academy of Sciences of the United States of America*, *110*, 14096–14101. https://doi.org/10.1073/pnas.1212744110

Brownell, S. E., Price, J. V. & Steinman, L. (2013). Science Communication to the General Public: Why We Need to Teach Undergraduate and Graduate Students this Skill as Part of Their Formal Scientific Training. *Journal of Undergraduate Neuroscience Education*, *12*(1), E6-E10.

Brügger, A., Kaiser, F. G. & Roczen, N. (2011). One for All? Connectedness to Nature, Inclusion of Nature, Environmental Identity, and Implicit Association with Nature. *European Psychologist*, *16*(4), 324–333. https://doi.org/10.1027/1016-9040/a000032

Bucci, K., Tulio, M. & Rochman, C. M. (2020). What is known and unknown about the effects of plastic pollution: A meta-analysis and systematic review. *Ecological Applications*, *30*(2). https://doi.org/10.1002/eap.2044

Carskadon, M. A., Vieira, C. & Acebo, C. (1993). Association between Puberty and Delayed Phase Preference. *Sleep*, *16*(3), 258–262. https://doi.org/10.1093/sleep/16.3.258

Cohen, J. (1960). A Coefficient of Agreement for Nominal Scales. *Educational and Psychological Measurement*, *20*(1), 37–46. https://doi.org/10.1177/001316446002000104

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2. Auflage). Lawrence Erlbaum Associates.

Cole, M., Lindeque, P., Fileman, E., Halsband, C., Goodhead, R., Moger, J. & Galloway, T. S. (2013). Microplastic ingestion by zooplankton. *Environmental Science & Technology*, *47*(12), 6646–6655. https://doi.org/10.1021/es400663f de Souza Machado, A. A., Lau, C. W., Kloas, W., Bergmann, J., Bachelier, J. B., Faltin, E., Becker, R., Görlich, A. S. & Rillig, M. C. (2019). Microplastics Can Change Soil Properties and Affect Plant Performance. *Environmental Science & Technology*, *53*(10), 6044–6052. https://doi.org/10.1021/acs.est.9b01339

Dekker, S., Lee, N. C., Howard-Jones, P. & Jolles, J. (2012). Neuromyths in Education: Prevalence and Predictors of Misconceptions among Teachers. *Frontiers in Psychology*, *3*, 429. https://doi.org/10.3389/fpsyg.2012.00429

Deng, L., Cai, L., Sun, F., Li, G. & Che, Y. (2020). Public attitudes towards microplastics: Perceptions, behaviors and policy implications. *Resources, Conservation and Recycling*, *163*, 105096. https://doi.org/10.1016/j.resconrec.2020.105096

Derraik, J. G. B. (2002). The pollution of the marine environment by plastic debris: a review. *Marine Pollution Bulletin*, *44*(9), 842–852. https://doi.org/10.1016/S0025-326X(02)00220-5

DeWitt, J. & Storksdieck, M. (2008). A Short Review of School Field Trips: Key Findings from the Past and Implications for the Future. *Visitor Studies*, *11*(2), 181–197. https://doi.org/10.1080/10645570802355562

Díaz-Morales, J. F. (2007). Morning and evening-types: Exploring their personality styles. *Personality and Individual Differences*, *43*(4), 769–778. https://doi.org/10.1016/j.paid.2007.02.002

Díaz-Morales, J. F. & Escribano, C. (2013). Predicting school achievement: The role of inductive reasoning, sleep length and morningness–eveningness. *Personality and Individual Differences*, *55*(2), 106–111. https://doi.org/10.1016/j.paid.2013.02.011

Dieser, O. & Bogner, F. X. (2017). How individual environmental values influence knowledge acquisition of adolescents within a week-long outreach biodiversity module. *Journal of Global Research in Education and Social Science*, *9*(4), 213–224.

Duit, R. & Treagust, D. F. (2003). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education*, *25*(6), 671–688. https://doi.org/10.1080/09500690305016

Entman, R. M. (1993). Framing: Toward Clarification of a Fractured Paradigm. *Journal of Communication*, *43*(4), 51–58. https://doi.org/10.1111/j.1460-2466.1993.tb01304.x

Eshach, H. (2007). Bridging In-school and Out-of-school Learning: Formal, Non-Formal, and Informal Education. *Journal of Science Education and Technology*, *16*(2), 171–190. https://doi.org/10.1007/s10956-006-9027-1

European Commission. (1998). *Integrated product policy: A study analysing national and international developments with regard to integrated product policy in the environment field and providing elements for an EC policy in this area*. Executive summary from the final report. https://ec.europa.eu/environment/ipp/pdf/ippsum.pdf

Fallik, O., Rosenfeld, S. & Eylon, B.-S. (2013). School and out-of-school science: a model for bridging the gap. *Studies in Science Education*, *49*(1), 69–91. https://doi.org/10.1080/03057267.2013.822166

Feber, D., Nordigården, D., Granskog, A., Ponkshe, S. & Berg, P. (2020). *The Drive Toward Sustainability in Packaging - Beyond the Quick Wins.*

Field, A. (2018). *Discovering Statistics Using IBM SPSS Statistics* (5. Auflage). SAGE.

Franke, G. & Bogner, F. X. (2013). How does integrating alternative conceptions into lessons influence pupils' situational emotions and learning achievement? *Journal of Biological Education*, *47*(1), 1–11. https://doi.org/10.1080/00219266.2012.716777

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

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

Fröhlich, G., Goldschmidt, M. & Bogner, F. X. (2013). The effect of age on students' conceptions of agriculture. *Studies in Agricultural Economics*, *115*(2), 61–67.

Geier, C. S. & Bogner, F. X. (2010). Student-centred anti-smoking education: Comparing a classroom-based and an out-of-school setting. *Learning Environments Research*, *13*(2), 147–157. https://doi.org/10.1007/s10984-010-9069-4

Gerber, B. L., Marek, E. A. & Cavallo, A. M. L. (2001). Development of an informal learning opportunities assay. *International Journal of Science Education*, *23*(6), 569–583. https://doi.org/10.1080/09500690116959

GESAMP (2016). *Sources, fate and effects of microplastics in the marine environment: part two of a global assessment*. IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection.

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

Gropengießer, H. & Marohn, A. (2018). Schülervorstellungen und Conceptual Change. In D. Krüger, I. Parchmann & H. Schecker (Hg.), *Lehrbuch. Theorien in der naturwissenschaftsdidaktischen Forschung* (1. Aufl., S. 49–67). Springer. https://doi.org/10.1007/978-3-662-56320-5_4

Hahladakis, J. N. (2020). Delineating the global plastic marine litter challenge: clarifying the misconceptions. *Environmental Monitoring and Assessment*, *192*(5), 267. https://doi.org/10.1007/s10661-020-8202-9

Hämer, J., Gutow, L., Köhler, A. & Saborowski, R. (2014). Fate of Microplastics in the Marine Isopod Idotea emarginata. *Environmental Science & Technology*, *48*(22), 13451–13458. https://doi.org/10.1021/es501385y

Hann, S., Sherrington, C., Jamieson, O., Hickman, M., Kershaw, P., Bapasola, A. & Cole, G. (2018). *Investigating options for reducing releases in the aquatic environment of microplastics emitted by (but not intentionally added in) products. Final Report*. London/Bristol.

Hartley, B. L., Thompson, R. C. & Pahl, S. (2015). Marine litter education boosts children's understanding and self-reported actions. *Marine Pollution Bulletin*, *90*(1-2), 209–217. https://doi.org/10.1016/j.marpolbul.2014.10.049

Henderson, L. & Green, C. (2020). Making sense of microplastics? Public understandings of plastic pollution. *Marine Pollution Bulletin*, *152*, 110908. https://doi.org/10.1016/j.marpolbul.2020.110908

Hidalgo-Ruz, V., Gutow, L., Thompson, R. C. & Thiel, M. (2012). Microplastics in the Marine Environment: A Review of the Methods Used for Identification and Quantification. *Environmental Science & Technology*, *46*(6), 3060–3075. https://doi.org/10.1021/es2031505

Hofstein, A. & Rosenfeld, S. (1996). Bridging the Gap Between Formal and Informal Science Learning. *Studies in Science Education*, *28*(1), 87–112. https://doi.org/10.1080/03057269608560085

Horne, J. A. & Östberg, O. (1977). Individual differences in human circadian rhythms. *Biological Psychology*, *5*(3), 179–190. https://doi.org/10.1016/0301-0511(77)90001-1

IBM Corp. (2016). *IBM SPSS Statistics for Windows (Version 24)*. IBM Corp.

Johnson, B. & Manoli, C. C. (2011). The 2-MEV Scale in the United States: A Measure of Children's Environmental Attitudes Based on the Theory of Ecological Attitude. *The Journal of Environmental Education*, *42*(2), 84–97. https://doi.org/10.1080/00958964.2010.503716

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

Kattmann, U. (2007). Biologie-Lernen mit Alltagsvorstellungen. *Unterricht Biologie*, *31*(329), 2–6.

Kibbe, A., Bogner, F. X. & Kaiser, F. G. (2014). Exploitative vs. appreciative use of nature – Two interpretations of utilization and their relevance for environmental education. *Studies in Educational Evaluation*, *41*, 106–112. https://doi.org/10.1016/j.stueduc.2013.11.007

Killermann, W. (1996). Biology education in Germany: research into the effectiveness of different teaching methods. *International Journal of Science Education*, *18*(3), 333–346. https://doi.org/10.1080/0950069960180306

Killermann, W. (1998). Research into biology teaching methods. *Journal of Biological Education*, *33*(1), 4–9. https://doi.org/10.1080/00219266.1998.9655628

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

Laist, D. W. (1997). Impacts of Marine Debris: Entanglement of Marine Life in Marine Debris Including a Comprehensive List of Species with Entanglement and Ingestion Records. In J. M. Coe & D. B. Rogers (Hg.), *Springer Series on Environmental Management. Marine Debris: Sources, Impacts, and Solutions* (S. 99–139). Springer.

Landis, J. R. & Koch, G. G. (1977). The Measurement of Observer Agreement for Categorical Data. *Biometrics*, *33*(1), 159–174. https://doi.org/10.2307/2529310

Laursen, S., Liston, C., Thiry, H. & Graf, J. (2007). What Good is a Scientist in the Classroom? Participant Outcomes and Program Design Features for a Short-Duration Science Outreach Intervention in K-12 Classrooms. *CBE Life Sciences Education*, *6*(1), 49–64. https://doi.org/10.1187/cbe.06-05-0165

Leire, C. & Thidell, Å. (2005). Product-related environmental information to guide consumer purchases – a review and analysis of research on perceptions, understanding and use among Nordic consumers. *Journal of Cleaner Production*, *13*(10-11), 1061–1070. https://doi.org/10.1016/j.jclepro.2004.12.004

Liefländer, A. K. & Bogner, F. X. (2016). Educational impact on the relationship of environmental knowledge and attitudes. *Environmental Education Research*, *24*(4), 611–624. https://doi.org/10.1080/13504622.2016.1188265

Ma, X., Park, C. & Moultrie, J. (2020). Factors for eliminating plastic in packaging: The European FMCG experts' view. *Journal of Cleaner Production*, *256*(1526), 120492. https://doi.org/10.1016/j.jclepro.2020.120492

Maskiewicz, A. C. & Lineback, J. E. (2013). Misconceptions are "so yesterday!". *CBE Life Sciences Education*, *12*(3), 352–356. https://doi.org/10.1187/cbe.13-01-0014

Mayring, P. (2000). Qualitative Content Analysis. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *1*(2). https://doi.org/10.17169/FQS-1.2.1089

Milfont, T. L. & Duckitt, J. (2004). The structure of environmental attitudes: A first- and second-order confirmatory factor analysis. *Journal of Environmental Psychology*, *24*(3), 289–303. https://doi.org/10.1016/j.jenvp.2004.09.001

Miller, J. D. (1992). Toward a scientific understanding of the public understanding of science and technology. *Public Understanding of Science*, *1*(1), 23–26. https://doi.org/10.1088/0963-6625/1/1/005

Mitrano, D. M. & Wohlleben, W. (2020). Microplastic regulation should be more precise to incentivize both innovation and environmental safety. *Nature Communications*, *11*(1), 5324. https://doi.org/10.1038/s41467-020-19069-1

Nord, M., Luloff, A. E. & Bridger, J. C. (1998). The Association of Forest Recreation with Environmentalism. *Environment and Behavior*, *30*(2), 235–246. https://doi.org/10.1177/0013916598302006

Novak, J. D. (1988). Learning Science and the Science of Learning. *Studies in Science Education*, *15*(1), 77–101. https://doi.org/10.1080/03057268808559949

Novak, J. D. (2002). Meaningful learning: The essential factor for conceptual change in limited or inappropriate propositional hierarchies leading to empowerment of learners. *Science Education*, *86*(4), 548–571. https://doi.org/10.1002/sce.10032

Orion, N. & Hofstein, A. (1994). Factors that influence learning during a scientific field trip in a natural environment. *Journal of Research in Science Teaching*, *31*(10), 1097–1119. https://doi.org/10.1002/tea.3660311005

Pahl, S. & Wyles, K. J. (2017). The human dimension: how social and behavioural research methods can help address microplastics in the environment. *Analytical Methods*, *9*(9), 1404–1411. https://doi.org/10.1039/C6AY02647H

Pahl, S., Wyles, K. J. & Thompson, R. C. (2017). Channelling passion for the ocean towards plastic pollution. *Nature Human Behaviour*, *1*(10), 697–699. https://doi.org/10.1038/s41562-017-0204-4

Pekrun, R., Goetz, T., Titz, W. & Perry, R. P. (2002). Academic Emotions in Students' Self-Regulated Learning and Achievement: A Program of Qualitative and Quantitative Research. *Educational Psychologist*, *37*(2), 91–105. https://doi.org/10.1207/S15326985EP3702_4

PlasticsEurope (2020). *Plastics - the Facts 2020: An analysis of European plastics production, demand and waste data*. Brussels. Plastics Europe: Association of Plastic Manufacturers.

Ponzi, D., Wilson, M. C. & Maestripieri, D. (2014). Eveningness is Associated with Higher Risk-Taking, Independent of Sex and Personality. *Psychological Reports*, *115*(3), 932–947. https://doi.org/10.2466/19.12.PR0.115c28z5

Pope, M. & Gilbert, J. (1983). Personal experience and the construction of knowledge in science. *Science Education*, *67*(2), 193–204. https://doi.org/10.1002/sce.3730670208

Potter, G. (2009). Environmental Education for the 21st Century: Where Do We Go Now? *The Journal of Environmental Education*, *41*(1), 22–33. https://doi.org/10.1080/00958960903209975

Randler, C. (2007). Gender differences in morningness–eveningness assessed by self-report questionnaires: A meta-analysis. *Personality and Individual Differences*, *43*(7), 1667–1675. https://doi.org/10.1016/j.paid.2007.05.004

Randler, C. (2009). Proactive People Are Morning People. *Journal of Applied Social Psychology*, *39*(12), 2787–2797. https://doi.org/10.1111/j.1559-1816.2009.00549.x

Randler, C., Faßl, C. & Kalb, N. (2017). From Lark to Owl: developmental changes in morningness-eveningness from new-borns to early adulthood. *Scientific Reports*, *7*, 45874. https://doi.org/10.1038/srep45874

Re, V. (2019). Shedding light on the invisible: addressing the potential for groundwater contamination by plastic microfibers. *Hydrogeology Journal*, *27*(7), 2719–2727. https://doi.org/10.1007/s10040-019-01998-x

Rees, G. & Pond, K. (1995). Marine litter monitoring programmes—A review of methods with special reference to national surveys. *Marine Pollution Bulletin*, *30*(2), 103–108. https://doi.org/10.1016/0025-326X(94)00192-C

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

Roenneberg, T., Kuehnle, T., Pramstaller, P. P., Ricken, J., Havel, M., Guth, A. & Merrow, M. (2004). A marker for the end of adolescence. *Current Biology*, *14*(24), R1038-9. https://doi.org/10.1016/j.cub.2004.11.039

Russo, P. M., Leone, L., Penolazzi, B. & Natale, V. (2012). Circadian Preference and the Big Five: The Role of Impulsivity and Sensation Seeking. *Chronobiology International*, *29*(8), 1121–1126. https://doi.org/10.3109/07420528.2012.706768

Sattler, S. & Bogner, F. X. (2017). Short- and long-term outreach at the zoo: cognitive learning about marine ecological and conservational issues. *Environmental Education Research*, *23*(2), 252–268. https://doi.org/10.1080/13504622.2016.1144173

Schmid, S. & Bogner, F. X. (2018). Is there more than the sewage plant? University freshmen's conceptions of the urban water cycle. *PLOS ONE*, *13*(7), e0200928. https://doi.org/10.1371/journal.pone.0200928

Schneiderhan-Opel, J. & Bogner, F. X. (2019). Between Environmental Utilization and Protection: Adolescent Conceptions of Biodiversity. *Sustainability*, *11*(17), 4517. https://doi.org/10.3390/su11174517

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

Schnell, R., Hill, P. B. & Esser, E. (2018). *Methoden der empirischen Sozialforschung* (11. Auflage). De Gruyter Oldenbourg.

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

Schrenk, M., Gropengießer, H., Groß, J., Hammann, M., Weitzel, H. & Zabel, J. (2019). Schülervorstellungen im Biologieunterricht. In J. Groß, M. Hammann, P. Schmiemann & J. Zabel (Hg.), *Biologiedidaktische Forschung: Erträge für die Praxis* (S. 3–20). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-58443-9_1

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

Sellmann, D. & Bogner, F. X. (2013). Effects of a 1-day environmental education intervention on environmental attitudes and connectedness with nature. *European Journal of Psychology of Education*, *28*(3), 1077–1086. https://doi.org/10.1007/s10212-012-0155-0

Setälä, O., Fleming-Lehtinen, V. & Lehtiniemi, M. (2014). Ingestion and transfer of microplastics in the planktonic food web. *Environmental Pollution*, *185*, 77–83. https://doi.org/10.1016/j.envpol.2013.10.013

Seybold, B., Braunbeck, T. & Randler, C. (2014). Primate Conservation: An evaluation of two different educational programs in Germany. *International Journal of Science and Mathematics Education*, *12*(2), 285–305. https://doi.org/10.1007/s10763-013-9405-0

Shaw, K. R. M., van Horne, K., Zhang, H. & Boughman, J. (2008). Essay Contest Reveals Misconceptions of High School Students in Genetics Content. *Genetics*, *178*(3), 1157–1168. https://doi.org/10.1534/genetics.107.084194

Smith, J. P., diSessa, A. A. & Roschelle, J. (1994). Misconceptions Reconceived: A Constructivist Analysis of Knowledge in Transition. *Journal of the Learning Sciences*, *3*(2), 115–163. https://doi.org/10.1207/s15327809jls0302_1

Somrei, E. (1997). Unterricht nicht nur in der Schule - Zum Stellenwert und den Möglichkeiten außerschulischer Lernorte. In H. Gesing (Hg.), *Praxishilfen Schule. Pädagogik und Didaktik der Grundschule* (S. 269–275). Luchterhand.

Stanton, T., Kay, P., Johnson, M., Chan, F. K. S., Gomes, R. L., Hughes, J., Meredith, W., Orr, H. G., Snape, C. E., Taylor, M., Weeks, J., Wood, H. & Xu, Y. (2020). It's the product not the polymer: Rethinking plastic pollution. *Wiley Interdisciplinary Reviews: Water*, *8*(1), https://doi.org/10.1002/wat2.1490

Stöckert, A. & Bogner, F. X. (2020). Cognitive Learning about Waste Management: How Relevance and Interest Influence Long-Term Knowledge. *Education Sciences*, *10*(4), 102. https://doi.org/10.3390/educsci10040102

Sturm, H. & Bogner, F. X. (2010). Learning at workstations in two different environments: A museum and a classroom. *Studies in Educational Evaluation*, *36*(1-2), 14–19. https://doi.org/10.1016/j.stueduc.2010.09.002

Tavakol, M. & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, *2*, 53–55. https://doi.org/10.5116/ijme.4dfb.8dfd

Thompson, R. C. (2015). Microplastics in the Marine Environment: Sources, Consequences and Solutions. In M. Bergmann, L. Gutow & M. Klages (Hg.), *Marine Anthropogenic Litter* (S. 185–200). Springer International Publishing.

Thompson, R. C., Moore, C. J., vom Saal, F. S. & Swan, S. H. (2009). Plastics, the environment and human health: current consensus and future trends. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1526), 2153–2166. https://doi.org/10.1098/rstb.2009.0053

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

Tonetti, L., Adan, A., Di Milia, L., Randler, C. & Natale, V. (2015). Measures of circadian preference in childhood and adolescence: A review. *European Psychiatry*, *30*(5), 576–582. https://doi.org/10.1016/j.eurpsy.2015.01.006

Treagust, D. F. & Duit, R. (2008). Conceptual change: a discussion of theoretical, methodological and practical challenges for science education. *Cultural Studies of Science Education*, *3*(2), 297–328. https://doi.org/10.1007/s11422-008-9090-4

Tsaousis, I. (2010). Circadian preferences and personality traits: A meta-analysis. *European Journal of Personality*, *24*, 356–373. https://doi.org/10.1002/per.754

van Cauwenberghe, L., Vanreusel, A., Mees, J. & Janssen, C. R. (2013). Microplastic pollution in deep-sea sediments. *Environmental Pollution*, *182*, 495–499. https://doi.org/10.1016/j.envpol.2013.08.013

Vennix, J., den Brok, P. & Taconis, R. (2017). Perceptions of STEM-based outreach learning activities in secondary education. *Learning Environments Research*, *20*(1), 21–46. https://doi.org/10.1007/s10984-016-9217-6

Vennix, J., den Brok, P. & Taconis, R. (2018). Do outreach activities in secondary STEM education motivate students and improve their attitudes towards STEM? *International Journal of Science Education*, *40*(11), 1263–1283. https://doi.org/10.1080/09500693.2018.1473659

Völker, C., Kramm, J. & Wagner, M. (2019). On the Creation of Risk: Framing of Microplastics Risks in Science and Media. *Global Challenges*, *4*(6), 1900010. https://doi.org/10.1002/gch2.201900010

Vollmer, C., Pötsch, F. & Randler, C. (2013). Morningness is associated with better gradings and higher attention in class. *Learning and Individual Differences*, *27*, 167–173. https://doi.org/10.1016/j.lindif.2013.09.001

von Moos, N., Burkhardt-Holm, P. & Köhler, A. (2012). Uptake and Effects of Microplastics on Cells and Tissue of the Blue Mussel *Mytilus edulis L*. after an Experimental Exposure. *Environmental Science & Technology*, *46*(20), 11327–11335. https://doi.org/10.1021/es302332w

Wandersee, J. H., Mintzes, J. J. & Novak, J. D. (1994). Research on alternative conceptions. In D. L. Gabel (Hg.), *Handbook of research on science teaching and learning: A project of the National Science Teachers Association* (S. 177–210). MacMillan.

Werquin, P. (2010). *Recognising Non-Formal and Informal Learning*. OECD. https://doi.org/10.1787/9789264063853-en

Wirth, W. (1997). *Von der Information zum Wissen: Die Rolle der Rezeption für die Entstehung von Wissensunterschieden. Ein Beitrag zur Wissenskluftforschung*. *Studien zur Kommunikationswissenschaft: Bd. 23*. VS Verlag für Sozialwissenschaften. https://doi.org/10.1007/978-3-322-91678-5

Wiseman, M. & Bogner, F. X. (2003). A higher-order model of ecological values and its relationship to personality. *Personality and Individual Differences*, *34*(5), 783–794. https://doi.org/10.1016/S0191-8869(02)00071-5

Wiseman, M., Wilson, G. & Bogner, F. X. (2012). Environmental Values and Authoritarianism. *Journal of Psychology Research*, *2*(1), 25–31. https://doi.org/10.17265/2159-5542/2012.01.003

Zabel, J. & Gropengiesser, H. (2011). Learning progress in evolution theory: climbing a ladder or roaming a landscape? *Journal of Biological Education*, *45*(3), 143–149. https://doi.org/10.1080/00219266.2011.586714

5 TEILARBEITEN

5.1. Publikationsliste

(A) Raab, P. & Bogner, F. X. (2018)
How Young "Early Birds" Prefer Preservation, Appreciation and Utilization of Nature. *Sustainability*, *10*(11), 4000. https://doi.org/10.3390/su10114000

(B) Raab, P. & Bogner, F. X. (2021)
Knowledge Acquisition and Environmental Values in a Microplastic Learning Module: Does the Learning Environment Matter? *Studies in Educational Evaluation*, *71*(8), 101091. https://doi.org/10.1016/j.stueduc.2021.101091

(C) Raab, P. & Bogner, F. X. (2020)
Microplastics in the Environment: Raising Awareness in Primary Education. *American Biology Teacher*, *82*(7), 478-487. https://doi.org/10.1525/abt.2020.82.7.478

(D) Raab, P. & Bogner, F. X. (2021)
Conceptions of University Students on Microplastics in Germany. *PLOS ONE*, *16*(9), e0257734. https://doi.org/10.1371/journal.pone.0257734

Publikation, die nicht Teil der Dissertation ist:

Trotter, B., Ramsperger, A. F. R. M., Raab, P., Haberstroh, J., Laforsch, C. (2019)
Plastic waste interferes with chemical communication in aquatic ecosystems. *Scientific Reports*, *9*(1), 5889. https://doi.org/10.1038/s41598-019-41677-1

5.2. Darstellung des Eigenanteils

Alle Teilarbeiten wurden von mir als Erstautorin eigenständig verfasst und unter der Betreuung von Herrn Prof. Franz X. Bogner überarbeitet.

Der Fragebogen der **Teilarbeit A** wurde durch mich konzipiert. Die verwendeten Skalen zur Überprüfung der Tageszeitpräferenz und der Umwelteinstellungen wurden der Literatur entnommen. Die Daten wurden von Frau Margaret Farren und Herrn Thomas Blaine in Irland erhoben. Die statistischen Analysen sowie deren Interpretation erfolgten durch mich. Das Manuskript wurde von mir als Erstautorin in Kooperation mit Herrn Prof. Christoph Randler und Herrn Prof. Franz X. Bogner verfasst.

Die Fragen zur Überprüfung des Wissens in **Teilarbeit B** wurden von Frau Tabea Loermann-Knöchel entwickelt. Die verwendete Skala zur Überprüfung der Umwelteinstellungen wurde der Literatur entnommen. Die Intervention am außerschulischen Lernort mit 137 Schülern wurde durch Frau Tabea Loermann-Knöchel durchgeführt. Die Durchführung der Intervention innerhalb der Schule mit 333 Schülern und einer Kontrollgruppe mit 50 Schülern erfolgte durch mich. Die statistischen Analysen wurden von mir vorgenommen. Das Manuskript wurde von mir als Erstautorin verfasst.

Das Unterrichtsmodul der **Teilarbeit C** wurde von Frau Tabea Loermann-Knöchel initiiert. Das Unterrichtsmodul wurde von mir für dessen Veröffentlichung überarbeitet. Das Manuskript wurde von mir als Erstautorin verfasst.

Die Studierendenvorstellungen der **Teilarbeit D** wurden von Frau Tabea Loermann-Knöchel erhoben. Das Kategoriensystem wurde von mir entworfen. Die statistischen Analysen und deren Interpretation erfolgten durch mich. Die Überprüfung der Interrater-Reliabilität wurde von einer unbeteiligten Person durchgeführt. Das Manuskript wurde von mir als Erstautorin verfasst.

5.3. Teilarbeit A

Sustainability, 2018, 10(11), 4000

How Young "Early Birds" Prefer Preservation, Appreciation and Utilization of Nature

Patricia Raab[1*], Christoph Randler[2] & Franz X. Bogner[1]

[1]Centre of Math & Science Education (Z-MNU), Department of Biology Education, University of Bayreuth, NW1, 95447 Bayreuth, Germany

[2]Department of Biology, Eberhard Karls University of Tuebingen, Auf der Morgenstelle 24, 72076 Tuebingen, Germany

*Correspondence: patricia.raab@uni-bayreuth.de

How Young "Early Birds" Prefer Preservation, Appreciation and Utilization of Nature

Abstract

Since the 1990s, the Two Major Environmental Value model (2-MEV) has been applied to measure adolescent environmental attitudes by covering two higher order factors: (i) Preservation of Nature (PRE) which measures protection preferences and (ii) Utilization of Nature (UTL) which quantifies preferences towards exploitation of nature. In addition to the 2-MEV scale, we monitored the Appreciation of Nature (APR) which, in contrast to the UTL, monitors the enjoyable utilization of nature. Finally, we employed the Morningness–Eveningness Scale for Children (MESC) which monitors the diurnal preferences and associates with personality and behavioral traits. In this study, we analyzed data from 429 Irish students (14.65 years; ±1.89 *SD*) with the aim of reconfirming the factor structure of the 2-MEV+APR and monitoring the relationship between the MESC and the environmental values (PRE, UTL, APR). Our findings identified a significant association between PRE and APR with MESC. In addition, we observed a gender difference. Our results suggest that morningness preference students are more likely to be protective of and appreciative towards nature. Recommendations for outreach programs as well as conclusions for environmental education initiatives in general are discussed.

Keywords: 2-MEV model; preservation; appreciation; utilization; environmental attitudes; circadian preference; morningness–eveningness

1. Introduction

Until the 1990s, reliable instruments for the measurement of green attitudinal variables were disputed. A meta-analysis by Leeming et al. [1] reviewed all existing psychometric approaches dealing with environmental attitudes and values, and reached the conclusion that they lacked sufficient rigorousness. Many instruments trying to cover children's environmental values have been criticized, inter alia, due to their weak psychometric properties or the lack of a clear theoretical framework [2]. For a long time, the only accepted instrument was the New Environmental Paradigm (NEP) Scale which was originally designed for adults and later revised for children [3,4]. Three decades later, Dunlap et al. [5] theoretically revised and enlarged the instrument, renaming it the New Ecological Paradigm Scale (still abbreviated NEP) but with 15 items. As the construct that underlies the NEP Scale regards environmental perception as unidimensional, environmental attitudes and behavior can only be insufficiently studied [5,6]. There still is an ongoing debate in the literature about the number of dimensions of the NEP scale [5].

In the 1990s, the development of the Two Major Environmental Value model (2-MEV) scale provided a first instrument for adolescents [7]. In contrast to the NEP approach [3,5], the 2-MEV scale uses a two-dimensional construct. Subsequent studies refined the 2-MEV and reduced the initial 69 items to a set of 20 [8–11]. Ten of these items load on the Preservation factor, whereas the other ten items load on the Utilization factor. With a total of 20 items, the two higher order factors Preservation (PRE) and Utilization (UTL) can be sufficiently examined on the basis of primary factors. Originally, the higher order factor of Preservation consisted of three primary factors, namely Intent of Support, Care with Resources, and Enjoyment of Nature; while the higher order factor of Utilization included, for instance, Altering Nature and Human Dominance [12]. The Preservation of Nature measures the intention of adolescents to preserve the environment and is "a biocentric dimension that reflects conservation and protection of the environment" [13] (p. 787). In contrast, the Utilization of Nature measures the tendency of adolescents towards utilizing/exploiting the environment and is "an anthropocentric dimension that reflects the utilization of natural resources" [13] (p. 787). According to Rokeach [14], the term "attitudes" stands for item-set based first-order factors and the term "values" for higher-order factors. We will therefore use the term "environmental values" hereafter.

After the implementation of the 2-MEV in the 1990s, multiple cross-validation studies were conducted to validate the instrument. Bogner et al. [15] described the relationship between environmental values and personality variables (more accurately risk-taking) and observed that preservers are prone to cautious behavior, while utilizers are prone to risky behavior. The study supported the two orthogonal dimensions Preservation and Utilization [15]. Additionally, Wiseman and Bogner

[13] also backed the orthogonal structure of Preservation and Utilization in their study on the relationship between personality variables "Psychoticism", "Extraversion" and "Neuroticism", environmental values and social desirability [13,16]. In this study, preservers favored otherwise-orientated gratification and utilizers favored self-orientated gratification. The study of Wiseman et al. [17] measured the relationship between Authoritarianism and the two environmental values. They described that preservers correlate negatively with Authoritarianism, while utilizers correlate positively with Authoritarianism. The application of the 2-MEV in different European countries (*e.g.*, Ireland, Denmark, France and Switzerland) also supported the orthogonal, two-dimensional structure of Preservation and Utilization [8,11,18,19]. A 2-MEV study with pre- and in-service teachers extended the applicability of the model to a higher age group [20]. These cross-validation studies dealt with different personality variables, diverging age groups, multiple languages and diverse cultural backgrounds. Together these variables added to the validity and reliability of the 2-MEV scale and supported its construct stability.

Over recent years, the 2-MEV model was scrutinized using different structural and methodological adaptations. Munoz et al. [21] modified the items for adults, while Schneller et al. [22] adapted the item-set to populations in subtropical ecosystems. However, slight changes such as the reduction or exchange of items did not influence the structure of the 2-MEV model. The 2-MEV proved to be a robust, reliable and valid scale. This was even true in instances where the positive wording of some items was rephrased negatively [23]: Negatively formulated Utilization items loaded on Preservation and negatively formulated Preservation items loaded on Utilization. A refusal of Preservation, therefore, entails Utilization and a refusal of Utilization entails Preservation [23].

Utilization of Nature is a complex, equivocal value as it summarizes different behaviors towards nature. On one end of the utilization spectrum is the exploitative usage of nature, while an appreciative usage of nature is the counter on the other end of the spectrum. It has been shown that people with an exploitative attitude towards nature selfishly exploit resources, while people with an appreciative attitude towards nature reply on it for recreational purposes with minimal exploitation [23]. The letter dimension, namely Appreciation of Nature, extended the 2-MEV model [24]. Bogner [24] was able to report a positive association between Preservation and Appreciation indicating that people who appreciate nature have a preservative attitude [25].

Morningness–Eveningness or circadian preference describes the individuals' preference for and behavior at given times of a day and their time-dependent intellectual and physical peak performance [26]. Classically, a morning person gets up early in the morning and goes to bed early in the evening, while evening persons stay in bed for longer in the morning and turn in later. Usually, morning persons reach their peak performance during morning hours, while evening people reach it during the afternoon or even during the night [26]. As some evidence suggests that there is a hereditable component to this trait which was linked to candidate genes, it is considered an individual difference trait with a close link to personality. Differences are observed across the lifespan, whereby children are morning oriented, while adolescents become rapidly evening oriented. Towards the end of adolescence, this trait oscillates towards morningness again, but this change is more slowly [27,28]. Some studies indicate gender differences whereby women tend to be more morning oriented compared to men, however, these results only had small effect sizes [29].

The construct of morningness–eveningness has been linked to different personality and behavioral traits. For example, conscientiousness, a dimension of the Big Five personality inventory [30], was strongly associated with morning people [31]. Other aspects, such as school achievement, were also related to morningness with higher morning orientation being related with better school achievements [32]. Similarly, further personality traits were linked with morningness, *e.g.*, proactivity [33]. Also thinking and behaving styles have been connected to morningness. Morning-types tend to rely on personal experience, creating knowledge from specific incidents [34]. Furthermore, rational thinking styles and dutifulness were related with morningness [34]. Concerning the psychological construct of time perspective (see details in Zimbardo and Boyd [35]), it is noteworthy that higher morningness scores were positively associated with future time perspectives [36]. On the other end of the morningness–eveningness continuum, eveningness was associated with the personality aspect of sensation seeking, *i.e.*, looking for high arousal activities, such as bungee jumping [37]. Similar to this finding, risk-taking was related to a higher eveningness [34,38]. Moreover, unconventional and dissenting behavior was associated with eveningness [34]. The correlations between morningness–eveningness and the different personality and behavioral traits may lead to the assumption that morningness–eveningness may also be associated with environmental values. As seen from this individual difference perspective with a focus on personality, one would expect a positive relationship between pro-environmental values and morningness. Assuming that morning oriented people tend to possess higher proactivity, conscientiousness and a sense of duty, we hypothesize that they may also have a higher pro-environmental attitude. Furthermore, pronounced future oriented people with rational thinking styles may also be interested in the conservation of an intact environment and therefore inhabit pro-environmental attitudes. In support of this hypothesis is a study by Vollmer and Randler [39] reporting that morningness is related to social values and eveningness to individual values. This suggests that morning people might generally feel more responsibility for society and the environment. A time-budget approach showed that evening people spend more time with electronic media and less time with physical activity compared to morning people, consequently decreasing the time they spend outdoors experiencing nature [40]. It is worth noting, however, that these studies are based on correlational analyses which do not allow to draw solid conclusions on causal relationships between the investigated personality traits.

To our knowledge, this is the first-ever study to investigate the relationship between morningness–eveningness and environmental values. Thus, the objectives of our study were three-fold. Our first aim was to apply the Morningness–Eveningness Scale for Children (MESC) in an Irish adolescent sample. Our second aim was the reconfirmation of the factor structure of the Two-Major Environmental Values (2-MEV: consisting of Preservation of Nature (PRE) and Utilization of Nature (UTL)) and the Appreciation of Nature (APR). Finally, we aimed to unveil the relationship between MESC and 2-MEV+APR.

2. Materials and Methods

We recruited a convenience sample of 429 students from primary and secondary Irish schools, whereby the majority of the sample stemmed from the secondary schools. The average age was 14.65 years (±1.89 *SD*), 32.9 % were female. During regular school lessons, all students completed a paper-and-pencil questionnaire comprising the 2-MEV scale, the APR scale and the Morningness–Eveningness Scale for Children (MESC). The 2-MEV consisted of 14 items monitoring the orthogonal dimensions Preservation and Utilization of Nature [12,23,24]. The APR assessed the Appreciation of Nature with six items [24,41,42]. The response pattern followed a 5-point Likert scale ranging from totally disagree (1) to totally agree (5). The MESC, originating in Carskadon et al. [43], was adapted from the Composite Scale of Morningness [44] to children and adolescents and was recommended by Tonetti et al. [45] as a scale for assessing morningness–eveningness in children and adolescents. The MESC is a unidimensional scale [43,45], has been widely used since 1992 and is available in Brazilian, Italian, Croatian, Turkish, Spanish, American and Australian English [45–49]. It was applied in large samples (N = 345–1393) and in a broad age range (12–20 years), with an internal consistency ranging from 0.68–0.77 and a test-retest reliability between 0.53–0.59 (see Tonetti et al. [45] for details). The MESC has not yet been employed in Ireland, but the original English version was applied in the USA and Australia [45]. The scale consisted of 10 items in a Likert type response format. Three questions were scaled from 1–5 and seven from 1–4. For exemplary items of the MESC scale see Table 1. The items add up to a total score of 43, where a high score reflects a strong morning preference, and a low score a minimal morning preference. The morningness–eveningness scales can be used as a continuum (see Natale and Cocogna [50]), but there are also cutoff-values provided for the MESC. Given the higher statistical power of continuous scales and the loss of qualitative information when using cut-off scores, we opted for using the raw scores in the correlational analysis.

Table 1. Exemplary items of the Morningness–Eveningness Scale for Children (MESC) scale.

MESC_1	MESC_8
Imagine: School is canceled! You can get up whenever you want to. When would you get out of bed? Between…	When does your body start to tell you it's time for bed (even if you ignore it)? Between…
5:00 and 6:30 a.m.	8:00 and 9:00 p.m.
6:30 and 7:45 a.m.	9:00 and 10:15 p.m.
7:45 and 9:45 a.m.	10:15 p.m. and 12:30 a.m.
9:45 and 11:00 a.m.	12:30 and 1:45 a.m.
11:00 a.m. and noon	1:45 and 3:00 a.m.
MESC_2	**MESC_5**
Is it easy for you to get up in the morning?	When do you have the most energy to do your favorite things?
No way!	Morning! I'm tired in the evening
Sort of	Morning more than evening
Pretty easy	Evening more than morning
It's a cinch	Evening! I'm tired in the morning

All statistical analyses were conducted in IBM SPSS Statistics version 24 (IBM, Armonk, NY, USA). First, a principal component analysis (PCA) with oblique rotation for the 2-MEV+APR was applied to assure the correspondence with the results of Bogner [24]. The Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity were used to investigate the appropriateness of the sample for factor analysis [51]. For the detection of variables which should be excluded, very small ($r < 0.3$) and very high ($r > 0.9$) correlations were examined in the correlation matrix. The anti-image matrix was checked for diagonal elements with values <0.5. As the data was not accurate for the usage of the Kaiser-Guttmann criterion, we therefore opted for the scree plot to determine the retaining factors [52,53]. To investigate the relationship between the environmental values and the morningness–eveningness preference, in the case of PRE, UTL and APR mean scores were calculated, while we used sum scores for the MESC. Due to the normal distribution of MESC using Shapiro-Wilk (p = 0.100), the analyses concerning the relationships between PRE, UTL, APR and MESC were calculated based on parametric tests. The correlations between the mean values of PRE, UTL and APR and the sum scores of MESC were calculated using the Pearson correlation.

3. Results

3.1. MESC in an Irish Sample

The MESC score average was 25.50 (±5.458 *SD*) and the values were normally distributed. The internal consistency of the present sample was high with a Cronbach's alpha of 0.78. There were no differences between boys (M = 25.53, SD = 5.40) and girls (M = 25.43, SD = 5.59) in MESC scores ($t(422)$ = 0.243, p = 0.808). A negative association was observed for age and MESC scores (r = -0.103, p = 0.034), indicating that younger age is better linked to morningness; a finding reliably described in the literature.

3.2. Factor Structure of 2-MEV+APR

Using an exploratory factor analysis with oblique rotation, we were able to extract a three-factor structure from the 2-MEV+APR, showing consistency with Bogner [24]. The Kaiser-Meyer-Olkin (KMO) test (0.813) (acceptable limit 0.5, [52]) and Bartlett's test of sphericity ($p < 0.001$) confirmed the appropriateness of the sample for factor analysis. According to Ferketich [54], the scores in the correlation matrix should range between 0.3 and 0.9. When examining the correlation matrix in detail, four items did not meet this desirable threshold. UTL_8, UTL_12, UTL_13 and PRE_17 had correlations below 0.3. However, as previous studies supported the value of these items for the 2-MEV and correlations were very close to the critical value of 0.3, they were not excluded from further analysis. In the anti-image matrix all diagonal elements were equal or above 0.620 and the off-diagonal elements were mainly small (<0.445). Based on the analysis of the scree plot, which is supporting the assumption of a three-factor structure, the factors Appreciation, Utilization and Preservation were extracted from the 2-MEV+APR (see Table 2). The three-factor solution explained 43.24 % of the total variance. All factor loadings producing scores exceeding 0.35 are shown (see Table 2). According to Kline [55], a Cronbach's alpha of 0.76 was appropriate.

Table 2. Factor loadings were extracted via principal component analysis (direct oblimin rotation, delta = 0), loadings below 0.35 were suppressed. Wording of the seven Appreciation of Nature (APR), seven Utilization of Nature (UTL) and six Preservation of Nature (PRE) items is shown.

Component				
APR	**UTL**	**PRE**		
0.817			APR_1	I consciously watch or listen to birds
0.737			APR_3	I deliberately take time to watch stars at night
0.734			APR_2	I take time to watch the clouds pass by
0.729			APR_4	I take time to consciously smell flowers
0.663			APR_5	I enjoy gardening
0.607			APR_7	Listening to the sounds of nature makes me relax
0.567			APR_6	I personally take care of plants
	0.686		UTL_14	We need to clear forests in order to grow crops
	0.626		UTL_9	Nature is always able to restore itself
	0.609		UTL_10	Our planet has unlimited resources
	0.603		UTL_11	We do not need to set aside areas to protect endangered species
	0.543		UTL_8	We must build more roads so people can travel to the countryside
	0.496		UTL_12	People worry too much about pollution
	0.388		UTL_13	The quiet nature outdoors makes me anxious
		0.745	PRE_15	Humans don't have the right to change nature as they see fit
		0.653	PRE_20	Not only plants and animals of economic importance need to be protected
		0.649	PRE_16	Human beings are not more important than other creatures
		0.600	PRE_19	Humankind will die out if we don't live in tune with nature
		0.484	PRE_17	I save water by taking a shower instead of a bath (in order to spare water)
		0.473	PRE_18	Dirty industrial smoke from chimneys makes me angry

3.3. Relationship between MESC and 2-MEV+APR

The environmental value score yielded a mean for PRE of 3.50 (*SD* = 0.73; min = 1; max = 5), for UTL of 2.46 (*SD* = 0.68; min = 1; max = 5) and for APR of 2.70 (*SD* = 0.89; min = 1; max = 5).

Concerning the mean scores of PRE and APR, a significant difference was found between girls and boys (PRE: $t(424) = -3.057$, $p = 0.002$; APR: $t(423) = -4.812$, $p < 0.001$). The girls' mean scores for PRE ($M = 3.66$, $SD = 0.75$) and APR ($M = 2.99$, $SD = 0.90$) were higher than the boys' mean scores for PRE ($M = 3.43$, $SD = 0.70$) and APR ($M = 2.56$, $SD = 0.85$). For UTL, no difference between girls' ($M = 2.51$, $SD = 0.66$) and boys' ($M = 2.43$, $SD = 0.69$) mean scores was observed ($t(423) = -1.068$, $p = 0.286$).

The PRE, UTL and APR mean scores were tested regarding their correlations with each other and the MESC sum scores (Table 3). No relationship could be found between APR and UTL ($r = 0.079$, $p = 0.104$) and the factors PRE and UTL ($r = -0.078$, $p = 0.110$). As expected, a positive correlation between the factors APR and PRE was detected ($r = 0.446$, $p < 0.001$). Regarding the relationship between the environmental values and MESC, APR and MESC ($r = 0.195$, $p < 0.001$) as well as PRE and MESC ($r = 0.143$, $p = 0.003$) correlated positively, whereas UTL did not ($r = -0.005$, $p = 0.926$) (Table 3). In this context, a gender difference was evident. Among boys, positive correlations emerged for APR and PRE ($r = 0.445$, $p < 0.001$), APR and MESC ($r = 0.247$, $p < 0.001$) and PRE and MESC ($r = 0.196$, $p = 0.001$) (Table 4). For girls, only a positive correlation between the environmental values APR and PRE ($r = 0.395$, $p < 0.001$) was observed (Table 5).

Table 3. Pearson Correlations between mean scores of APR, PRE and UTL and sum scores of MESC (2–tailed) [total sample].

	Test Statistics	APR	PRE	UTL	MESC
APR	Pearson Correlation	1.000	0.446 ***	0.079	0.195 ***
	Sig. (2-tailed)		0.000	n.s.	0.000
PRE	Pearson Correlation		1.000	-0.078	0.143 **
	Sig. (2-tailed)			n.s.	0.003
UTL	Pearson Correlation			1.000	-0.005
	Sig. (2-tailed)				n.s.

$^{**}p < 0.01$, $^{***}p < 0.001$.

Table 4. Pearson Correlations between mean scores of APR, PRE and UTL and sum scores of MESC (2–tailed) [males only].

	Test Statistics	APR	PRE	UTL	MESC
APR	Pearson Correlation	1.000	0.445 ***	0.048	0.247 ***
	Sig. (2-tailed)		0.000	n.s.	0.000
PRE	Pearson Correlation		1.000	-0.073	0.196 **
	Sig. (2-tailed)			n.s.	0.001
UTL	Pearson Correlation			1.000	-0.063
	Sig. (2-tailed)				n.s.

$^{**}p < 0.01$, $^{***}p < 0.001$.

Table 5. Pearson Correlations between mean scores of APR, PRE and UTL and sum scores of MESC (2–tailed) [females only].

	Test Statistics	APR	PRE	UTL	MESC
APR	Pearson Correlation	1.000	0.395 ***	0.113	0.117
	Sig. (2-tailed)		0.000	n.s.	n.s.
PRE	Pearson Correlation		1.000	-0.116	0.051
	Sig. (2-tailed)			n.s.	n.s.
UTL	Pearson Correlation			1.000	0.119
	Sig. (2-tailed)				n.s.

*** $p < 0.001$.

4. Discussion

This study aimed to examine morningness–eveningness in an Irish sample and to confirm the structure of the 2-MEV+APR. Subsequently, it explored the relationship between the environmental values PRE, UTL and APR and morningness–eveningness in adolescents.

4.1. MESC in an Irish Sample

This first application of the MESC in Ireland produced a Cronbach's alpha of 0.78 showing an acceptable internal consistency. It is within the range of other studies from different languages and countries (0.68-0.77; [45]). Therefore, the original MESC as provided by Carskadon et al. [43] is applicable in our chosen country. However, further studies should assess the convergent validity of this scale with actigraphy, or dim light melatonin secretion as objective biological markers as well as with other empirical scales of circadian preference for children and adolescents that are currently in use (see Tonetti et al. [45]). A significant, negative correlation between age and MESC scores was observed, indicating that younger students tend to be more morning oriented, while older students tend to be more evening oriented. This is in line with Randler et al. [27], who described age-related variability concerning morningness–eveningness from young children to early adulthood (age range: 0-30 years) in a German sample. In Germany, school starts around 8 a.m., while Irish schools start one hour later. Apparently, the start of the school day does not impact students' preferred time to rise in the morning. In this study, we observed no gender differences contrary to literature which describes that girls score higher on morningness than boys [29]. The effect sizes of these differences reported in the literature, however, are rather small [29] and developmental effects in our sample may have masked any existing gender differences. Our sample was on average 14.65 years old which may have contributed to pubertal development overlaying these gender differences.

4.2. Factor Structure of 2-MEV+APR

A precursor of the 2-MEV scale, first published by Bogner and Wilhelm [7] in the 1990s, has been applied to Irish samples confirming the suitability of the item selection for that country [8]. However, at that time the factor structure was not yet finally elaborated because further bi-national studies and cross-validation studies were still ongoing (*e.g.*, [11,18,19]). Therefore, a reconfirmation was advisable, especially as APR was not part of the original set of items. The two-dimensional structure of the 2-MEV was already independently supported by many different researchers from different fields of expertise [2, 6,56–58]: (i) Milfont and Duckitt [56] took a psychometric point of view and confirmed the secondary higher-order structure of Preservation and Utilization. (ii) Johnson and Manoli [2,6] approached from an educational point of view when they were searching for an appropriate instrument for evaluating US-wide earth education programs. (iii) Boeve-de Pauw and van Petegem [57] came at it from a pedagogical angle, assuring the two-dimensional structure as well. Finally, (iv) Borchers et al. [58], coming from a psychological-pedagogical background, confirmed the two-factor second order structure in a study conducted in West Africa. Bogner [24] expanded the repeatedly confirmed 2-MEV scale with items measuring the Appreciation of Nature and found a clear three-dimensional structure. The current study is adding to this literature. It confirms the three-factor structure of the 2-MEV+APR as described by Bogner [24].

The 2-MEV+APR scale is a valid and reliable instrument to measure the environmental values Preservation of Nature, Utilization of Nature and Appreciation of Nature. The proposed reduction of the 2-MEV+APR item set to a set of 20 items, omitting one appreciation item which covers the relationship to pets, seems reasonable [24]. With the 20-item assessment, the three factors PRE, UTL and APR explain 43.24 % of the total variance. The appreciation item "I consciously watch or listen to birds" (APR_1) holds the highest communality with 0.68. The communality of a factor gives information about the extent to which every single variable is explained by the factors. Communalities represent a loss of information; its value indicates the extent to which the factors explain the original data [52]. The high relevance of this appreciation item was also found in Bogner [24]. The utilization item "The quiet nature outdoors makes me anxious" (UTL_13) holds the lowest factor loading (see Table 2). This may be a starting point for further examinations. This item is the only affective one in the Utilization subscale, which directly inquires about personal emotions of the participants. One possible explanation for the low communality and factor loading of this item may be the participants' doubts to reveal their anxieties. Furthermore, Ireland has a low population density compared to other European countries. Quiet nature may be nothing unusual or frightening for Irish primary and secondary school students, assuming that they grew up in Ireland. This assumption may also be supported by the high factor loadings of the Appreciation items which evaluate the enjoyment of listening to birds and the sounds of nature (APR_1, APR_7; see Table 2).

The Appreciation of Nature adds another important aspect to the 2-MEV architecture. As Utilization covers the anthropocentric part of environmental values, it includes the preferences to dominate, harm or even exploit nature [24]. The addition of items covering the Appreciation of Nature enables a more precise evaluation of the Utilization value [23]. Including these items allows to capture the Utilization of Nature as a source of relaxation and tranquility. Therefore, the inclusion of the additional value Appreciation of Nature was statistically validated. Seven variables strongly load onto this factor (≥0.567), whereby the loadings of these items onto other factors are negligible. The selected items, therefore, seem to reliably measure Appreciation of Nature.

4.3. Relationship between MESC and 2-MEV+APR

In contrast to Bogner and Wiseman [19], we observed no negative correlation between PRE and UTL and no differences in UTL mean scores for female and male students. A positive correlation between PRE and APR was found for the total sample as well as for girls and boys only. People who demonstrate an appreciative attitude towards nature may also have a higher tendency to preservative, pro-environmental thoughts and actions [25,59]. This result is also important for the further development of educational purposes. The strong emphasis on negative examples and impacts of the exploitative usage of nature seems to be insufficient in promoting protective behavior among adolescents [60,61]. A promising approach to encourage pro-environmental behavior is the emphasis of an appreciative attitude towards nature [59,62,63].

Morningness clearly appears associated with a higher appreciation and a higher preservation of nature. This result was found for the total sample as well as for males only. Within the subsample of females-only, none of these relationships manifested. As the gender distribution of our study was not equally balanced (consisting of 67 % male and 33 % female students), a bias regarding the overrepresented male participants may exist. Together with the fact that girls scored higher mean values on preservation and appreciation of nature than boys (independent of morningness–eveningness), the described gender specifics might need further elaboration in future studies.

People with a high morning preference scored high on appreciative and preservative attitudes towards nature. Rising early may allow individuals to experience the calm and awakening nature, especially during weekends. Goulet et al. [64] reported that morning and evening people are exposed to different amounts of light exposure. Morning individuals showed more daily bright light exposure (>1000 lux) than evening persons [64], indicating that the former spend more time outdoors [65]. The motivation why morningness people spend more time outdoors—whether that might be because of the appreciation of nature in its own right or because of other leisure activities—has not been studied yet. While the fact that morning types spend more time outdoors does not implicate that they spend this time in nature, at least the chance to encounter nature is given. It needs to be noted that modern life in cities hampers the contact to nature, however, nature encounters can still occur in popular leisure localities such as parks or bathing lakes. Those potential experiences of an intact nature may be a trigger for an environmentally friendly mindset and ensuing appreciative and protective actions. In contrast, evening people, sleeping longer than morning people, especially on the weekends, might feel distracted by the sunrise lightening their room and the dawn song of birds, both deteriorating their sleep. As a consequence, they might develop a neutral or negative attitude towards the environment. These are, however, still speculations and need to be scrutinized by further empirical work. One might argue that evening people can gain their positive experiences in nature in the evening hours, *e.g.*, enjoying sunset. However, two lines of evidence contradict this: First, in central/northern Europe, the sunset is early in comparison to usual bed times of adolescents. Therewith, even morning people are still awake when the sun goes down. Second, evening pupils differ from morning people in their media usage. They spend more time with digital media in the evening (rather than going out for nature experience) [40].

The associations between morningness–eveningness and individual and behavioral traits found in previous studies may give further indications of the relationship between MESC and 2-MEV+APR. Those studies revealed that people with morning preferences tend to be more proactive, more conscientious and more future-oriented in their time perspective [30,33,36]. These personality and individual difference traits suggest that morningness may also be related to a higher pro-environmental attitude [26,31,33]. Moreover, personal habits concerning the usage of spare time may provide a further explanatory approach for the found relationships. Compared to evening persons, morning types spend more time with physical activity and less time with electronic media [40]. As physical activities are often performed in nature, morning people might spend a greater amount of their leisure time outdoors. As such, they might have more contact with the environment, both, qualitatively and quantitatively, fostering mostly positive emotions. As a consequence, appreciative and preservative attitudes towards the environment might arise. A study by Ewert et al. [66] also suggested that among others appreciative and consumptive outdoor activities in early-life may influence adults' attitude towards the environment. As outlined before, evening people tend to spend more time with electronic media [40]. This manner may reduce their opportunities of outdoor activities and nature-encounters, diminishing the probability of pro-environmental attitudes. However, this line of research has to be further developed to enable characterizations of morning and evening oriented people concerning their leisure activities and time spent outdoors.

4.4. Conclusions

Our results show that students preferring morning hours tend to possess a higher appreciative and preservative attitude towards nature. This is an important finding when planning and implementing educational programs, such as outreach programs. Therefore, one recommendation may be to take this individual difference trait into account when applying educational programs dealing with environmental aspects, because it seems likely that morning people should achieve better scores on such teaching programs. On the basis of our results on morningness students, further questions arose which may be a possible starting point for future research: Do morningness students also have greater knowledge about and interest in the environment and environmental problems in particular?

Do these students perform more or less pro-environmental behavior than their eveningness preferring classmates? Does the students' socioeconomic background influence their morningness–eveningness and environmental values? The results may be of special interest for the conception of outreach programs as their beginning can be flexibly adapted in many cases. Furthermore, outreach programs can be tailored towards morningness students with concrete learning opportunities such as bird watching in the morning hours, or towards eveningness students with activities supporting an appreciative attitude towards nature in the evening hours. Consequences of these assumptions might interfere with effects of environmental education interventions on environmental values, as some previous studies reported a lack or a partial lack of effects (*e.g.*, Sellmann and Bogner [67], Liefländer and Bogner [68], Dieser and Bogner [69]). Finally, it is important to note that students' responses on questionnaires on their environmental preferences may be influenced by social desirability [70]. A combination of questions covering morningness–eveningness and environmental values may provide a realistic picture of students' attitudes and hereby offering an option to fine-tune programs accordingly.

Morningness–eveningness or circadian preference has been measured with a self-report instrument. Future studies may use objective measures, but usually the correlations between objectively measured sleep-wake behavior and the scores on the questionnaires are above 0.5 [71], suggesting that these questionnaires are reliable. Another aspect to be covered in future studies may be the changes in sleeping behavior during the adolescent lifespan. A recent study in Germany showed that adolescents become evening oriented during puberty, but turn back towards morningness around the age of 17–20 years [27]. Within this context, a long-term analysis monitoring the relationship between morningness–eveningness and the environmental values might unveil changes in the environmental values according to the changes in circadian preferences.

Like many others, this study on the 2-MEV was mainly conducted on secondary school students. Data from various school types, ages, social backgrounds and countries would contribute to a better representativeness and greater understanding of environmental values. Environmental education programs are often implemented on secondary school students [72–74]. In the future, an investigation of primary students' environmental values might be of great importance. Knowledge about the environmental values of younger children might help applying environmental education programs not only in secondary schools, but also in earlier stages of school education [68]. This approach may prepone and intensify students' awareness for the environment and lead to a better engagement with nature long term.

Author Contributions: P.R. initiated the first draft. All authors subsequently worked on the manuscript.

Funding: This research was funded by the University of Bayreuth, by PLAWES (BMBF-Grant: 03F0789A) as well as by the German Research Foundation (DFG-Grant: LA 2159/8-6; within the funding program Open Access Publishing).

Acknowledgments: The authors are very grateful to the teachers and students who contributed to the study as well as to Thomas Blaine and Margaret Farren for assisting the data collection.

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

References

1. Leeming, F. C.; Dwyer, W. O.; Porter, B. E.; Cobern, M. K. Outcome Research in Environmental Education: A Critical Review. *J. Environ. Educ.* **1993,** *24*, 8–21, DOI: 10.1080/00958964.1993.9943504.
2. Johnson, B.; Manoli, C. C. The 2-MEV Scale in the United States: A Measure of Children's Environmental Attitudes Based on the Theory of Ecological Attitude. *J. Environ. Educ.* **2011,** *42*, 84–97, DOI: 10.1080/00958964.2010.503716.
3. Dunlap, R. E.; van Liere, K. D. The "New Environmental Paradigm". *J. Environ. Educ.* **1978,** *9*, 10–19, DOI: 10.1080/00958964.1978.10801875.
4. Manoli, C. C.; Johnson, B.; Dunlap, R. E. Assessing Children's Environmental Worldviews: Modifying and Validating the New Ecological Paradigm Scale for Use with Children. *J. Environ. Educ.* **2007,** *38*, 3–13, DOI: 10.3200/JOEE.38.4.3-13.
5. Dunlap, R. E.; van Liere, K. D.; Mertig, A. G.; Jones, R. E. New Trends in Measuring Environmental Attitudes: Measuring Endorsement of the New Ecological Paradigm: A Revised NEP Scale. *J. Social. Issues.* **2000,** *56*, 425–442, DOI: 10.1111/0022-4537.00176.
6. Johnson, B.; Manoli, C. C. Using Bogner and Wiseman's Model of Ecological Values to measure the impact of an earth education programme on children's environmental perceptions. *Environ. Educ. Res.* **2008,** *14*, 115–127, DOI: 10.1080/13504620801951673.
7. Bogner, F. X.; Wilhelm, M. G. Environmental perspectives of pupils: the development of an attitude and behaviour scale. *Environmentalist.* **1996,** *16*, 95–110, DOI: 10.1007/BF01325101.
8. Bogner, F. X. Environmental perceptions of Irish and Bavarian pupils: an empirical study. *Environmentalist.* **1998,** *18*, 27–38, DOI: 10.1023/A:1006578101077.
9. Bogner, F. X. The Influence of Short-Term Outdoor Ecology Education on Long-Term Variables of Environmental Perspective. *J. Environ. Educ.* **1998,** *29*, 17–29, DOI: 10.1080/00958969809599124.
10. Bogner, F. X.; Wiseman, M. Environmental perception of rural and urban pupils. *J. Environ. Psychol.* **1997,** *17*, 111–122, DOI: 10.1006/jevp.1997.0046.
11. Bogner, F. X.; Wiseman, M. Environmental Perspectives of Danish and Bavarian Pupils: towards a methodological framework. *Scand. J. Educ. Res.* **1997,** *41*, 53–71, DOI: 10.1080/0031383970410104.
12. Bogner, F. X.; Wiseman, M. Toward Measuring Adolescent Environmental Perception. *Eur. Psychol.* **1999,** *4*, 139–151, DOI: 10.1027//1016-9040.4.3.139.
13. Wiseman, M.; Bogner, F.X. A higher-order model of ecological values and its relationship to personality. *Pers. Individ. Dif.* **2003,** *34*, 783–794, DOI: 10.1016/S0191-8869(02)00071-5.
14. Rokeach, M. *Beliefs, Attitude and Values: A Theory of Organization and Change;* Jossey-Bass: San Francisco, CA, USA, 1968.
15. Bogner, F. X.; Brengelmann, J. C.; Wiseman, M. Risk-taking and environmental perception. *Environmentalist.* **2000,** *20*, 49–62, DOI: 10.1023/A:1006656011403.
16. Eysenck, H. J.; Eysenck, S. B. G. *Personality Structure and Measurement;* Routledge and Kegan Paul: London, UK, 1969.

17. Wiseman, M.; Wilson, G.; Bogner, F. X. Environmental Values and Authoritarianism. *Psychol. Res.* **2012,** *2*, 25–31, DOI: 10.17265/2159-5542/2012.01.003.
18. Bogner, F. X.; Wiseman, M. Environmental perception of Swiss and Bavarian pupils: An empirical evaluation. *Swiss J. Sociol.* **1998,** *24*, 547–566.
19. Bogner, F. X.; Wiseman, M. Environmental perception of French and some Western European secondary school students. *Eur. J. Psychol. Educ.* **2002,** *17*, 3–18, DOI: 10.1007/BF03173201.
20. Oerke, B.; Bogner, F. X. Gender, age and subject matter: impact on teachers' ecological values. *Environmentalist.* **2010,** *30*, 111–122, DOI: 10.1007/s10669-009-9250-4.
21. Munoz, F.; Bogner, F. X.; Clement, P.; Carvalho, G. S. Teachers' conceptions of nature and environment in 16 countries. *J. Environ. Psychol.* **2009,** *29*, 407–413, DOI: 10.1016/j.jenvp.2009.05.007.
22. Schneller, A. J.; Johnson, B.; Bogner, F. X. Measuring children's environmental attitudes and values in northwest Mexico: validating a modified version of measures to test the Model of Ecological Values (2-MEV). *Environ. Educ. Res.* **2015,** *21*, 61–75, DOI: 10.1080/13504622.2013.843648.
23. Kibbe, A.; Bogner, F. X.; Kaiser, F. G. Exploitative vs. appreciative use of nature – Two interpretations of utilization and their relevance for environmental education. *Stud. Educ. Eval.* **2014,** *41*, 106–112, DOI: 10.1016/j.stueduc.2013.11.007.
24. Bogner, F. X. Environmental Values (2-MEV) and Appreciation of Nature. *Sustainability.* **2018,** *10*, 350, DOI: 10.3390/su10020350.
25. Nord, M.; Luloff, A. E.; Bridger, J. C. The Association of Forest Recreation with Environmentalism. *Environ. Behav.* **1998,** *30*, 235–246, DOI: 10.1177/0013916598302006.
26. Adan, A.; Archer, S. N.; Hidalgo, M. P.; Di Milia, L.; Natale, V.; Randler, C. Circadian typology: a comprehensive review. *Chronobiol. Int.* **2012,** *29*, 1153–1175, DOI: 10.3109/07420528.2012.719971.
27. Randler, C.; Faßl, C.; Kalb, N. From Lark to Owl: developmental changes in morningness-eveningness from new-borns to early adulthood. *Sci. Rep.* **2017,** *7*, 45874, DOI: 10.1038/srep45874.
28. Roenneberg, T.; Kuehnle, T.; Pramstaller, P. P.; Ricken, J.; Havel, M.; Guth, A.; Merrow, M. A marker for the end of adolescence. *Curr. Biol.* **2004,** *14*, R1038-9, DOI: 10.1016/j.cub.2004.11.039.
29. Randler, C. Gender differences in morningness–eveningness assessed by self-report questionnaires: A meta-analysis. *Pers. Individ. Dif.* **2007,** *43*, 1667–1675, DOI: 10.1016/j.paid.2007.05.004.
30. Costa, P. T.; McCrae, R. R. Four ways five factors are basic. *Pers. Individ. Dif.* **1992,** *13*, 653–665, DOI: 10.1016/0191-8869(92)90236-I.
31. Tsaousis, I. Circadian preferences and personality traits: A meta-analysis. *Eur. J. Pers.* **2010,** *29*, n/a-n/a, DOI: 10.1002/per.754.
32. Arbabi, T.; Vollmer, C.; Dörfler, T.; Randler, C. The influence of chronotype and intelligence on academic achievement in primary school is mediated by conscientiousness, midpoint of sleep and motivation. *Chronobiol. Int.* **2015,** *32*, 349–357, DOI: 10.3109/07420528.2014.980508.
33. Randler, C. Proactive People Are Morning People. *J. Appl. Soc. Psychol.* **2009,** *39*, 2787–2797, DOI: 10.1111/j.1559-1816.2009.00549.x.
34. Díaz-Morales, J. F. Morning and evening-types: Exploring their personality styles. *Pers. Individ. Dif.* **2007,** *43*, 769–778, DOI: 10.1016/j.paid.2007.02.002.
35. Zimbardo, P. G.; Boyd, J. N. Putting time in perspective: a valid, reliable individual-differences metric. *J. Pers. Soc. Psychol.* **1999,** *77*, 1271–1288.
36. McGowan, N. M.; Brannigan, R.; Doyle, D.; Coogan, A. N. Diurnal preference, circadian phase of entrainment and time perspectives: Just what are the relationships? *Pers. Individ. Dif.* **2017,** *112*, 79–84, DOI: 10.1016/j.paid.2017.02.051.
37. Russo, P. M.; Leone, L.; Penolazzi, B.; Natale, V. Circadian preference and the big five: the role of impulsivity and sensation seeking. *Chronobiol. Int.* **2012,** *29*, 1121–1126, DOI: 10.3109/07420528.2012.706768.
38. Ponzi, D.; Wilson, M. C.; Maestripieri, D. Eveningness is associated with higher risk-taking, independent of sex and personality. *Psychol. Rep.* **2014,** *115*, 932–947, DOI: 10.2466/19.12.PR0.115c28z5.
39. Vollmer, C.; Randler, C. Circadian preferences and personality values: Morning types prefer social values, evening types prefer individual values. *Pers. Individ. Dif.* **2012,** *52*, 738–743, DOI: 10.1016/j.paid.2012.01.001.

40. Kauderer, S.; Randler, C. Differences in time use among chronotypes in adolescents. *Biol. Rhythm. Res.* **2013,** *44*, 601–608, DOI: 10.1080/09291016.2012.721687.
41. Brügger, A.; Kaiser, F. G.; Roczen, N. One for All? *Eur. Psychol.* **2011,** *16*, 324–333, DOI: 10.1027/1016-9040/a000032.
42. Kaiser, F. G.; Brügger, A.; Hartig, T.; Bogner, F. X.; Gutscher, H. Appreciation of nature and appreciation of environmental protection: How stable are these attitudes and which comes first? *Eur. Rev. Appl. Psychol.* **2014,** *64*, 269–277, DOI: 10.1016/j.erap.2014.09.001.
43. Carskadon, M. A.; Vieira, C.; Acebo, C. Association between Puberty and Delayed Phase Preference. *Sleep.* **1993,** *16*, 258–262, DOI: 10.1093/sleep/16.3.258.
44. Smith, C. S.; Reilly, C.; Midkiff, K. Evaluation of three circadian rhythm questionnaires with suggestions for an improved measure of morningness. *J. Appl. Psychol.* **1989,** *74*, 728–738, DOI: 10.1037/0021-9010.74.5.728.
45. Tonetti, L.; Adan, A.; Di Milia, L.; Randler, C.; Natale, V. Measures of circadian preference in childhood and adolescence: A review. *Eur. Psychiatry.* **2015,** *30*, 576–582, DOI: 10.1016/j.eurpsy.2015.01.006.
46. Arrona-Palacios, A.; Díaz-Morales, J. F. Morningness-eveningness is not associated with academic performance in the afternoon school shift: preliminary findings. *Br. J. Educ. Psychol.* **2018,** *88*, 480–498, DOI: 10.1111/bjep.12196.
47. Díaz-Morales, J. F. Morningness–Eveningness Scale for Children (MESC): Spanish normative data and factorial invariance according to sex and age. *Pers. Individ. Dif.* **2015,** *87*, 116–120, DOI: 10.1016/j.paid.2015.07.027.
48. Koscec, A.; Radosevic-Vidacek, B.; Bakotic, M. Morningness-eveningness and sleep patterns of adolescents attending school in two rotating shifts. *Chronobiol. Int.* **2014,** *31*, 52–63, DOI: 10.3109/07420528.2013.821128.
49. Önder, İ.; Beşoluk, Ş. Adaptation of the morningness eveningness scale for children into Turkish. *Biol. Rhythm. Res.* **2013,** *44*, 313–323, DOI: 10.1080/09291016.2012.681848.
50. Natale, V.; Cicogna, P. Morningness-eveningness dimension: is it really a continuum? *Pers. Individ. Dif.* **2002,** *32*, 809–816, DOI: 10.1016/S0191-8869(01)00085-X.
51. Kaiser, H. F. A second generation little jiffy. *Psychometrika.* **1970,** *35*, 401–415, DOI: 10.1007/BF02291817.
52. Field, A. *Discovering Statistics Using IBM SPSS Statistics*, 5th ed.; Sage: Los Angeles, CA, USA, 2018, ISBN 9781526419514.
53. Stevens, J. P. *Applied Multivariate Statistics for the Social Sciences*, 4th ed.; Erlbaum: Hillsdale, MI, USA, 2002, ISBN 0805837760.
54. Ferketich, S. Focus on psychometrics. Aspects of item analysis. *Res. Nurs. Health.* **1991,** *14*, 165–168, DOI: 10.1002/nur.4770140211.
55. Kline, P. *The handbook of psychological testing*, 2nd ed.; Routledge: London, UK, 1999, ISBN 0415211581.
56. Milfont, T. L.; Duckitt, J. The structure of environmental attitudes: A first- and second-order confirmatory factor analysis. *J. Environ. Psychol.* **2004,** *24*, 289–303, DOI: 10.1016/j.jenvp.2004.09.001.
57. de Pauw, J.B.; Van Petegem, P. The Effect of Flemish Eco-Schools on Student Environmental Knowledge, Attitudes, and Affect. *Int. J. Sci. Educ.* **2011,** 33, 1513–1538, DOI: 10.1080/09500693.2010.540725.
58. Borchers, C.; Boesch, C.; Riedel, J.; Guilahoux, H.; Ouattara, D.; Randler, C. Environmental Education in Côte d'Ivoire/West Africa: Extra-Curricular Primary School Teaching Shows Positive Impact on Environmental Knowledge and Attitudes. *Int. J. Sci. Educ.* **2013,** *4*, 240–259, DOI: 10.1080/21548455.2013.803632.
59. Roczen, N.; Kaiser, F. G.; Bogner, F. X.; Wilson, M. A Competence Model for Environmental Education. *Environ. Behav.* **2014,** *46*, 972–992, DOI: 10.1177/0013916513492416.
60. Dewey, J. *Experience and Nature;* Open Court: La Salle, IL, USA, 1925.
61. Kaiser, F. G.; Oerke, B.; Bogner, F. X. Behavior-based environmental attitude: Development of an instrument for adolescents. *J. Environ. Psychol.* **2007,** *27*, 242–251, DOI: 10.1016/j.jenvp.2007.06.004.
62. Roczen, N.; Kaiser, F. G.; Bogner, F. X. Umweltkompetenz-Modellierung, Entwicklung und Förderung [Environmental Competence-Modeling, development and promotion]. *Zeitschrift für Pädagogik [Online]* **2010,** No. 56, 126–134.

63. Mayer, F.S.; Frantz, C. M. The connectedness to nature scale: A measure of individuals' feeling in community with nature. *J. Environ. Psychol.* **2004,** *24*, 503–515, DOI: 10.1016/j.jenvp.2004.10.001.
64. Goulet, G.; Mongrain, V.; Desrosiers, C.; Paquet, J.; Dumont, M. Daily light exposure in morning-type and evening-type individuals. *J. Biol. Rhythms.* **2007,** *22*, 151–158, DOI: 10.1177/0748730406297780.
65. Roenneberg, T.; Wirz-Justice, A.; Merrow, M. Life between clocks: daily temporal patterns of human chronotypes. *J. Biol. Rhythms.* **2003,** *18*, 80–90, DOI: 10.1177/0748730402239679.
66. Ewert, A.; Place, G.; Sibthorp, J. Early-Life Outdoor Experiences and an Individual's Environmental Attitudes. *Leis. Sci.* **2005,** *27*, 225–239, DOI: 10.1080/01490400590930853.
67. Sellmann, D.; Bogner, F. X. Effects of a 1-day environmental education intervention on environmental attitudes and connectedness with nature. *Eur. J. Psychol. Educ.* **2013,** *28*, 1077–1086, DOI: 10.1007/s10212-012-0155-0.
68. Liefländer, A. K.; Bogner, F. X. The Effects of Children's Age and Sex on Acquiring Pro-Environmental Attitudes Through Environmental Education. *J. Environ. Educ.* **2014,** *45*, 105–117, DOI: 10.1080/00958964.2013.875511.
69. Dieser, O.; Bogner, F. X. How individual environmental values influence knowledge acquisition of adolescents within a week-long outreach biodiversity module. *J. Glob. Res. Educ. Soc. Sci.* **2017,** *9*, 213–224.
70. Oerke, B.; Bogner, F. X. Social Desirability, Environmental Attitudes, and General Ecological Behaviour in Children. *Int. J. Sci. Educ.* **2013,** *35*, 713–730, DOI: 10.1080/09500693.2011.566897.
71. Thun, E.; Bjorvatn, B.; Osland, T.; Martin Steen, V.; Sivertsen, B.; Johansen, T.; Halvor Lilleholt, T.; Udnes, I.; Hilde Nordhus, I.; Pallesen, S. An actigraphic validation study of seven morningness-eveningness inventories. *Eur. Psychol.* **2012,** *17*, 222–230, DOI: 10.1027/1016-9040/a000097.
72. Fančovičová, J.; Prokop, P. Plants have a chance: outdoor educational programmes alter students' knowledge and attitudes towards plants. *Environ. Educ. Res.* **2011,** *17*, 537–551, DOI: 10.1080/13504622.2010.545874.
73. Sattler, S.; Bogner, F. X. Short- and long-term outreach at the zoo: cognitive learning about marine ecological and conservational issues. *Environ. Educ. Res.* **2017,** *23*, 252–268, DOI: 10.1080/13504622.2016.1144173.
74. Schönfelder, M. L.; Bogner, F. X. Two ways of acquiring environmental knowledge: by encountering living animals at a beehive and by observing bees via digital tools. Int. J. Sci. Educ. **2017,** 39, 723–741, DOI: 10.1080/09500693.2017.1304670.

5.4. Teilarbeit B

Studies in Educational Evaluation, 2021, 71(8), 101091

Knowledge Acquisition and Environmental Values in a Microplastic Learning Module: Does the Learning Environment Matter

Patricia Raab[1*], Franz X. Bogner[1]

[1]Centre of Math & Science Education (Z-MNU), Department of Biology Education, University of Bayreuth, NW1, 95447 Bayreuth, Germany

*Correspondence: patricia.raab@uni-bayreuth.de

Knowledge Acquisition and Environmental Values in a Microplastic Learning Module: Does the Learning Environment Matter?

Abstract

Microplastic pollution is a growing issue of concern requiring appropriate classroom instruction. Educational initiatives within this context are supposed to provide relevant background knowledge, raise awareness, and ideally lead to sustainable behavior. We implemented an identical educational module within two different learning environments: formal (in-school) and informal (out-of-school). In both settings, 444 primary school students self-reliably completed hands-on activities at workstations. We monitored students' short-term (directly after the module) and long-term (after six weeks) cognitive achievement. Additionally, when examining the participants' environmental values (Preservation, Utilization) and the Appreciation of Nature, the program similarly appealed to all students independent of the environmental values' intensity. Preservation, Utilization, and the Study Group predicted knowledge levels after program participation; Appreciation did not. While Preservation positively influenced knowledge, Utilization did the contrary. Subsequent implications on learning strategies based on our results are discussed.

Keywords: microplastics, environmental values, knowledge acquisition, workstations, formal and informal learning, primary school students

1. Introduction

1.1. Microplastics in the Environment

Microplastic pollution is an ever-growing environmental concern all over the world. Since the beginning of mass production in the 1950s, plastic production levels have grown exponentially (PlasticsEurope, 2020). Characteristic attributes like light weight, strength, excellent durability, and low price proved plastics more advantageous than other materials (Andrady, 2011; Wright et al., 2013). Therefore, plastics, as well as microplastics (plastics < 5 mm), are present in everyday life situations as usages range from packaging, building, and automotive materials to household products (van Cauwenberghe, Devriese, Galgani, Robbens, & Janssen, 2015). The massive application, especially in disposable products, inevitably results in large waste volumes, which may pose serious challenges when entering the environment on different pathways (Barboza & Gimenez, 2015; Barnes et al., 2009; Browne et al., 2011; Dris et al., 2015; Duis & Coors, 2016). Studies prove the marine, freshwater, and terrestrial ecosystems as polluted with plastics and microplastics (Eerkes-Medrano et al., 2015; Piehl et al., 2018; Rochman, 2018; Thompson et al., 2004). With the increasing accumulation in the environment, encounters with wildlife become more likely. The consequences of microplastics' ubiquity are the subject of scientific studies that still produce inconclusive results due to microplastics' large number of influencing properties (Bucci et al., 2020).

1.2. Outreach Learning

Outreach activities provide an excellent opportunity for school classes to access researchers or experts from different sectors (Vennix et al., 2017). According to early definitions, formal learning takes place in-school, more precisely in the classroom, as an organized, well-structured learning environment with the specific aim to promote students' knowledge (Gerber et al., 2001; Werquin, 2010). On the contrary, informal learning occurs independently of classical classroom learning environments, including everyday experiences at home, in nature, or at extracurricular learning centers (Bell et al., 2009). In the scope of science education, Rennie similarly included all activities "that are not part of a formal, assessable curriculum offered by an educational institution" in the term "informal science education" (2014, p. 121). In earlier studies, non-formal learning is recognized as another category to designate organized learning outside the formal sector (Coombs et al., 1973). However, as these definitions seem to be oversimplified, disagreement between experts regarding the strict separation of formal and informal learning remains (Eshach, 2007). Due to this uncertainty, definitions change depending on the context and background (Werquin, 2010). Hofstein and Rosenfeld (1996) suggested a continuum between formal and informal learning along which learning occasions can be positioned for bridging the gap. Due to the definitions' ambiguity, Werquin (2010) concluded a pointlessness in strictly separating the concepts and therefore suggested degrees of formality. Thus, there are efforts to link formal and informal learning (Fallik et al., 2013).

Overcoming the strict separation of formal and informal learning environments gives both environments various instructional options, which enrich each other. The incorporation of outreach activities into a classroom includes real-life elements, cooperative work in groups, and tasks that demand problem-solving and scientific competence in a per se formal learning environment (Laursen et al., 2007). Outreach activities in out-of-school learning environments provide the initial informal learning environment with structure without diminishing its originality, novelty, and authenticity. Both learning environments can increase their respective potential to intervene with individual interest, motivation, or fascination, and of course, with cognitive learning (*e.g.*, DeWitt & Storksdieck, 2008). In our outreach activity on the topic of microplastics, we combined elements from formal with elements from informal learning environments. The learning program provided the out-of-school learning environment with the familiar structure of everyday classrooms and the in-school learning environment with authentic learning materials.

1.3. Impacts of Learning Environment on Cognitive Achievement

Before venturing into the question of influential factors on learning, we want to define learning. Depending on the discipline, definitions of learning differ strongly. Following Skinner (1950), the 'functional' approach understands learning as a behavioral change (de Houwer et al., 2013) with experience as a source of information learned (Kandel et al., 2013). This constructivist view on learning, which respects prior knowledge in the process of constructing new knowledge, is commonly accepted and can be adapted to our research field. In the school context, teachers can provide various opportunities for students to make appropriate experiences and thus initiate active learning. We chose hands-on activities with authentic everyday material, which were investigated with scientific equipment and were embedded in workstations the students cooperatively completed.

In out-of-school learning environments, several aspects may influence learning. Purposeful out-of-school learning requires attention to teaching factors, field trip factors, and student factors. Concerning the degree of structure, moderately structured visits, with worksheets guiding the students, may benefit learning outcomes (Kisiel, 2003). Adequate preparation and follow-up of the visit to the out-of-school learning site are prerequisites teachers must consider for efficient out-of-school learning (Lee et al., 2020; Rennie, 1994). The setting's novelty degree may detract students from the learning content; hence, teachers should strive for a medium novelty to support learning (Boeve-de Pauw et al., 2019). Furthermore, the chosen methods and abundance of tasks may be decisive. Compared to ordinary school days, visits to out-of-school learning sites consist of firsthand and new educational activities (Eshach, 2007) which are paused by location changes and discussions with students and educators. The number of educational activities may decrease while the intensity of engagement may increase, possibly influencing the learning outcome. Moreover, the visit's duration may be decisive. An extended stay for several days may intensify students' preoccupation with the learning site and the subject. Also social interactions between students may favorably influence affective and cognitive learning (DeWitt & Storksdieck, 2008). Small groups allow for exchange, mutual help, the activity of each individual, and intensive engagement with tasks and experiments – a form of instruction already suggested by Price and Hein (1991). As it is the case for every learning setting, prior knowledge influences cognitive learning also out-of-school (Hewson & Hewson, 1983). Finally, students' interests and experiences at the learning site may be decisive for learning effectiveness (DeWitt & Storksdieck, 2008).

Different educational studies frequently investigated educational programs' influence on the participants' learning outcomes at various learning sites. A significant knowledge improvement is often visible directly after participation in in-school interventions (Schmid & Bogner, 2015), and sometimes the long-term knowledge remains constant without any decrease after six weeks (Stöckert & Bogner, 2020). A similar pattern exists for out-of-school studies, for instance, in natural history museums (Sturm & Bogner, 2010), water supply institutions (Fremerey & Bogner, 2015), meadows (Fančovičová & Prokop, 2011), or a combination of different ecosystems, *e.g.*, freshwater, meadow, and wood (Prokop et al., 2007).

1.4. Environmental Awareness

In the context of environmental education, students' environmental awareness is of high relevance. Environmental awareness consists of environmental knowledge, values, and behavior. Hence, within a broad educational frame, various environmentally relevant topics intend to transmit knowledge, support pro-environmental activities, and build awareness in the long term. In the late 1980ies, Hines et al. (1987) concluded in their meta-analysis that the amount of knowledge relates to the likelihood of engaging in environmentally friendly behavior. The intensity of knowledge's influence on behavior underwent an intensive discussion after the competence model of Kaiser et al. (2008) and Roczen et al. (2014) was launched. This model showed a close link between environmental values, ecological behavior, and different types of knowledge. Subsequent intervention studies interacted with all those variables. Very recently, for instance, Maurer and Bogner (2020) applied the model's frame within a 19-lesson classroom intervention dealing with energy consumption.

1.5. Educational Efforts

Anchored in the Sustainable Development Goals (SDGs), environmental protection is a crucial task our generation must pursue (United Nations, 2019). The school career is a vital stage in the development to adulthood, in which the foundation for sustainable, environmentally conscious citizenship can be laid. Hence, science education must address issues related to environmental protection. Even if the intensity of the connection to behavior needs further research, environmental knowledge and environmental values are essential starting points for education on environmentally relevant topics. The challenge of reducing plastic contamination of the environment is represented in several SDGs (United Nations, 2019). Hence, our outreach program's topic, microplastics, with its long-term, irreversible consequences on the environment, must be a central theme of environmental education in the future, especially since plastic production continues to rise (PlasticsEurope, 2020). Education on the topic may provide students with adequate tools for a conscious consumption and handling of plastics and microplastics.

Under the educational umbrella, our study combines different aspects: 1) education on microplastics, 2) knowledge acquisition, 3) environmental values, and 4) learning environment. By scrutinizing knowledge at different points in time, we evaluate whether the outreach activity containing hands-on tasks is a suitable method to generate knowledge acquaintance among students on the topic of microplastics. Furthermore, we investigate whether there is a relationship between environmental values and knowledge on the environmentally relevant subject of microplastics. To ascertain whether the physical setting may affect cognitive achievement, we implemented the identical outreach activity in two different learning environments: in-school and out-of-school. Thereby, the study aims to assess the relevance of the learning environment further.

In conclusion, the objectives of our study focused on three research questions:

(1) To what extent does the learning program influence the students' short- and long-term knowledge about microplastics?

(2) How do students of Study 1 (in-school) and Study 2 (out-of-school) differ concerning their knowledge acquisition and environmental values?

(3) To what extent do the students' environmental values relate to their knowledge acquisition?

2. Methods and Procedures

2.1. Students' Sample

The sample consisted of 444 3rd and 4th graders in Bavaria, Germany. 312 students participated in Study 1, in which the learning program was implemented in the classroom (47.8 % female; age $M \pm SD$ = 9.27 ± .62). In Study 2, 132 students completed the learning program in an out-of-school setting, namely a country hostel (55.3 % female; age $M \pm SD$ = 9.62 ± .69). A test-retest sample of 44 3rd graders (52.3 % female; age $M \pm SD$ = 8.82 ± .58) functioned as a control group. They solely completed the knowledge questionnaire, neither receiving our learning program nor any other schooling on the topic of microplastics during the study period. The test-retest sample's function was excluding any learning effects arising from the repeated answering of the questionnaire on microplastics. In total, we collected data from 26 classes and 13 different schools. The study was approved by the appropriate authority (Government of Upper Franconia) and made public in Upper Franconian schools and country hostels. For students' participation, the teachers registered their class for the learning program. All applications were accepted, and no further selection criteria existed. As final requirements, the parents gave their consent to their children's participation in the study, and students were informed about voluntary participation.

2.2. Education Program

The environmental learning program named "Plastic Detectives – The Search For Plastic", which accompanies our study, is designed for primary education, more precisely 3rd and 4th graders. The underlying knowledge dealt with environmentally relevant topics of microplastics. Students participated in a 160-minute learning program comprising an introduction, workstations, and an evaluation phase (each lasting 20 min). Students cooperatively worked in groups of three or four when completing the workstations with the help of provided workbooks. The latter were self-explaining and included all the necessary information to complete each workstation. All stations were supplied twice in the classroom to ensure smooth running. After completion of a workstation, the students checked their own results. The final evaluation ensured the students' understanding and consolidated their achieved knowledge.

2.2.1. Hands-on Activities

Knowledge should not be the product but a tool that students can use in their private lives to solve problems (Herrington & Oliver, 2000). Also within our student-centered module, we aimed to foster usable knowledge. Hence, we decided to offer the students authentic hands-on activities with high relevance to their everyday lives. Everyday life elements and scientific equipment (*e.g.*, microscope) created an authentic learning activity (Brown et al., 1989) during the learning program, devoting the students' attention to the global microplastic challenges.

The choice of hands-on activities has different practical teaching reasons. Tasks holding an excellent relevance for students and real-life connections possess authenticity and increase motivation (Choi & Hannafin, 1995). Furthermore, student-centered lessons sideline the teachers by lowering their presence and altering their tasks to an observer and mediator (Settlage, 2000). This methodical approach has already proven advantageous over traditional teacher-centered methods (Burrowes, 2003; Randler & Bogner, 2009). Moreover, hands-on activities give the students the time for discussion and individual involvement in active experimenting. In a learning program on soil ecology, students participating in hands-on experiments gained a knowledge advantage over teacher-centered approaches four weeks after the intervention (Randler & Hulde, 2007). Fančovičová and Prokop (2011) implemented an outdoor learning program on plants. In this study, the students worked practically exclusively: after the program, the significant increase in student's knowledge of and attitude towards plants remained even after three months (Fančovičová & Prokop, 2011). Finally, a frequent application of hands-on activities can positively influence students' science achievements (Stohr-Hunt, 1996), indicating hands-on activities' appropriateness in our outreach learning program.

2.2.2. Cooperative Learning

The students worked on all detective tasks in groups. Cooperative learning at hands-on activities maximizes students' learning outcomes by working in small groups (Johnson & Johnson, 1989). It enables students to interact and engage in problem-solving tasks, for which they need to find solutions through cooperation, thereby improving their knowledge (Knight & Wood, 2005; Lord, 2001; Young, 1993). The tasks' close connection to students' reality gave them a reason to interact and fostered verbal interaction, which is considered essential for successful cooperative learning (Hooper, 1992). Moreover, positive interdependence is deemed crucial to cooperative learning (Johnson & Johnson, 1989), which we aimed to promote by emphasizing teamwork as plastic detectives. The cooperative work at our workstations was performed in groups of three to four, which is regarded as a sufficient group size in fostering students' knowledge gain (Lou et al., 1996). Consequently, the application of workstations may expand the traditional formal learning in classrooms and facilitate learning success.

2.2.3. Learning Goals

The learning program's primary aim was to explain the microplastic problem in the environment to young students. Creating awareness is a relevant approach for changing the individual dealing with plastics. For this purpose, the program targeted six sub-goals that educate about microplastics in the household, their pathway into the environment, possible consequences, and action strategies. (1) The module provides an overview of microplastics in aquatic ecosystems. (2) The module informs about the term microplastic. (3) The module reveals drugstore items and textiles as potential microplastic sources. (4) The module elucidates possible ways of microplastics to the environment. (5) The module explains the potential adverse effects of microplastics on marine animals. (6) The module raises awareness to reduce plastic and microplastic entry into the environment. In conclusion, the module provided students with the necessary background knowledge to rethink their behavior in connection with plastics. A particular focus laid on the final discussion about individual action strategies the students can take at home. Since every environmentally-friendly action is relevant in terms of changing the dealing with plastics, different alternative activities were discussed with the students to show how diverse their contribution can be. The results of this conversation included reducing the use of plastic items, using sustainable alternatives, and conscious consumption of unavoidable products.

2.2.4. Study Setting

Students of Study 1 and Study 2 participated in the same program with only one fundamental difference. For students of Study 1, the learning program was performed in their school, while for students of Study 2, the learning program was performed at an out-of-school location, namely a country hostel, during their stay of several days. The Study 1 sample was taught in their regular classroom or a school's multifunctional room. The students of Study 2 were in a multifunctional room in the country hostel equipped with typical student desks very similar to a classroom. The in-school and out-of-school students participated during regular school hours.

We pursued various strategies to minimize any variable other than the learning site affecting the outcome during the whole study. We took special measures to ensure that solely the learning site differentiated Study 1 from Study 2. In- and out-of-school, we enriched the classrooms with the same learning program: workstations with the same experimental materials, identical worksheets, and work assignments for hands-on activities around the topic of microplastics. Consequently, the learning program took place in similar rooms both inside and outside the school with identical hands-on activities. Furthermore, we conducted statistical tests, which showed no difference in students' prior knowledge of Study 1, Study 2, and the test-retest-group. Next, in-school and out-of-school learning programs were conducted by two experts in the field. Each instructor was responsible for one of the two learning sites. Both worked in close cooperation using identical teaching methods. Finally, to ensure equal treatment of the students, both instructors followed detailed instructions for implementation and strict guidelines for answering questions and providing help. After completing the study, the test-retest sample perceived selective activities from the module, supervised by one of the two instructors to ensure fair treatment of the students.

2.3. Instruments and Design

The study followed a quasi-experimental design with a paper-and-pencil questionnaire at three test dates. The students completed the pre-test two weeks before (T0), a post-test directly after (T1), and a retention test six weeks after (T2) participation. The completion of each questionnaire took about 25 min. For every test date, the item sequence was randomized. The pre-, post-, and retention tests were identical for the two subsamples (Study 1 and Study 2; see Fig. 1).

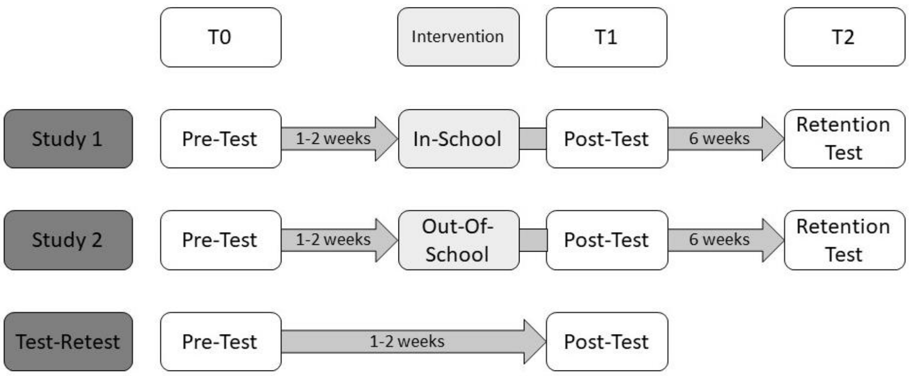


Fig. 1 Study design of Study 1, Study 2 and the control group, illustrating the time course of the intervention and the inquiry.

The ad-hoc knowledge test consisted of seven items, which comprised four answer options, of which one answer was correct. The knowledge questions covered the learning program's fundamental content and aimed to quantify students' cognitive achievement. Cronbach's Alpha coefficient (*N* = 444) scored, for instance, for the T1-schedule .558. Although scores above .8 are considered for a good range, we accepted the scale, as first, it was an ad-hoc scale (as all knowledge scales are program dependent), and second, the number of items was low (Tavakol & Dennick, 2011). For exemplary items, see Table 1.

Table 1 Knowledge item examples. Correct answers in bold.

Item Example
KN_1 What is microplastic?
(a) A small plastic part, smaller than 10 cm.
(b) **A plastic part, which is smaller than 5 mm.**
(c) A large plastic part.
(d) A lump of plastic.
KN_2 What clothing can produce microplastic?
(a) Clothing made of wool.
(b) Silk clothing.
(c) Cotton clothing.
(d) **Fleece clothing.**
KN_4 What is true? Microplastic …
(a) … is a good nutritional supplement.
(b) … is good for the environment.
(c) **… accumulates in animals, *e.g.*, the mussel.**
(d) … is healthy.

The 2-Major Environmental Values (2-MEV) scale consisted of 13 items measuring Preservation (six items) and Utilization (seven items) of Nature (Bogner, 2018). The Appreciation of Nature scale contained seven items (Kaiser et al., 2014; Kibbe et al., 2014). The response format followed a 5-point Likert scale, covering the range from totally disagree (1) to totally agree (5). The loading pattern of the principal component analysis (PCA) is shown in Table 2. The 2-MEV scale is a widely used instrument to evaluate adolescents' environmental values (Bogner & Wilhelm, 1996; Bogner & Wiseman, 1999). The two higher-order factors, Preservation of Nature (PRE) and Utilization of Nature (UTL) contain various primary factors within this two-dimensional construct. While Preservation covers eco-centric ambitions to preserve the environment, Utilization favors anthropocentric purposes to utilize (and even exploit) the environment (Bogner & Wiseman, 1999; Wiseman & Bogner, 2003). Various other factors can contribute, as is the case for Appreciation of Nature (APR), highlighting the individual enjoyment of nature and its appreciative use, *e.g.*, for recreational purposes (Bogner, 2018). After developing the 2-MEV scale in the 1990s, intern cross-validation studies assured the construct (Wiseman et al., 2012). Finally, independent confirmation studies by different working groups brought worldwide acceptance to the scale and documented its construct stability (Boeve-de Pauw & van Petegem, 2011; Borchers et al., 2014; Braun et al., 2017; Johnson & Manoli, 2011; Milfont & Duckitt, 2004). Currently, 33 language translations are known for having been applied (Bogner, 2018).

Table 2 Loading pattern of the principal component analysis (direct oblique rotation, delta = 0), loadings below 0.29 were suppressed. Wording of the seven Appreciation of Nature (APR), seven Utilization of Nature (UTL), and six Preservation of Nature (PRE) items is shown.

Component			
APR	**UTL**	**PRE**	
.784			I take time to watch the clouds passing by
.751			I consciously watch or listen to birds
.700			I take time to consciously smell flowers
.669			I personally take care of plants
.652			Listening to the sounds of nature makes me relax
.612			I deliberately take time to watch stars at night
.580			I enjoy gardening
	.634		We must build more roads so people can travel to the countryside
	.624		We do not need to set aside areas to protect endangered species
	.560		We need to clear forests in order to grow crops
	.422		People worry too much about pollution
	.416		Nature is always able to restore itself
	.407		Our planet has unlimited resources
	.367		The quiet nature outdoors makes me anxious
		.744	Humankind will die out if we don't live in tune with nature
		.643	I save water by taking a shower instead of a bath (to spare water)
		.560	Dirty industrial smoke from chimneys makes me angry
		.395	Human beings are not more important than other creatures
		.319	Humans don't have the right to change nature as they see fit
		.294	Not only plants and animals of economic importance need protection

2.4. Statistical Analysis

For all statistical analyses, IBM SPSS statistics version 24 was used. The correct answers were coded with "1" and incorrect answers with "0" within the knowledge questionnaire. The sum scores of the items denote the students' knowledge at each testing time: low scores indicate poor comprehension, while high scores indicate good understanding (maximum score: 7). The item difficulty at T0 ranged between .34 and .79, which represents an appropriate range. However, the knowledge acquisition results reveal that the item difficulty after participation may be estimated as relatively easy (minimum: .72; maximum: .95) (see Fig. 2).

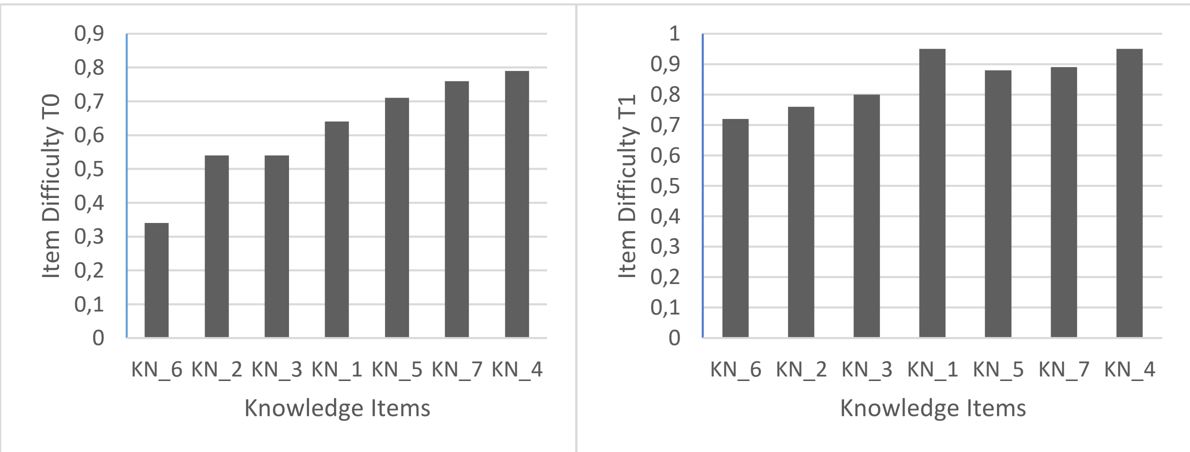


Fig. 2 Distribution of item difficulties of the seven knowledge items at T0 and T1. Low scores indicate difficult items, high scores indicate easy items.

Due to a non-normal distribution using Shapiro-Wilk ($p \leq .001$) and Q-Q-plots, non-parametric tests were applied. Knowledge differences between the test times T0, T1, and T2, were evaluated by Friedman's ANOVA. For all group differences, Mann-Whitney-*U*-tests were performed. To avoid cumulative Type-I-errors due to multiple testing, we applied Bonferroni correction. For significant results, the effect sizes *r* were calculated following Field (2018). The values of 0.1, 0.3, and 0.5 were interpreted as small, medium, and large effect sizes (Cohen, 1992).

We calculated a multiple linear regression to analyze influential factors on knowledge at T1. Knowledge at T1 served as the dependent variable. Preservation, Utilization, Appreciation, and the Study Group worked as the independent variables. To investigate the link of the environmental values Preservation, Utilization, and Appreciation, and the knowledge acquisition in more detail, we calculated quartile splits assigning the bottom quartile to low scorer and the upper quartile to high scorer. Subsequently, low and high scorer's knowledge was investigated using Friedman's ANOVA and Mann-Whitney-*U*-tests. Figures show medians, while in the text, grouped medians are reported.

3. Results

3.1. Knowledge Profiles of Both Learning Modules

With the exception of the test-retest group (Mdn_{T0} = 4.6 (4.0–5.8); Mdn_{T1} = 4.7 (3.0–6.0); $\chi2$ (1) = .030, p = n.s.), wherefore learning effects due to repeated reply of the knowledge questions can be excluded, all students showed a significant knowledge gain. Participants of Study 1 significantly increased their knowledge ($\chi2$ (2) = 295.016, $p \leq .001$) with median levels of 4.6 (3.3–5.8) at T0, 6.3 (6.00–7.00) at T1 and 6.2 (5.0–7.0) at T2. Likewise, participants of Study 2 received a significant knowledge growth ($\chi2$ (2) = 95.322, $p \leq .001$) with median perceived knowledge levels of 4.3 (3.0–5.0) at T0, 6.0 (5.0–7.0) at T1 and 5.9 (5.0–7.0) at T2. The pairwise comparison showed for Study 1 a significant knowledge increase at T1, directly after the intervention (T1-T0: z = - 13.471, $p \leq .001$, r = .54). After six weeks (T2), the knowledge remained at the level of T1 (T2-T1: z = .400, p = n.s.), still being significantly higher compared to T0 (T2-T0: z = - 13.070, $p \leq .001$, r = .52). The pairwise comparison results of Study 2 resemble those of Study 1: the students significantly improved their knowledge directly after the intervention (T1-T0: z = - 7.847, $p \leq .001$, r = .48). Their knowledge remained stable even after six weeks (T2-T1: z = .739, p = n.s.), owning a significant difference to the knowledge before the learning program (T2-T0: z = - 7.109, $p \leq .001$, r = .44). Fig. 3 illustrates the change in the knowledge scores of Study 1 and Study 2.

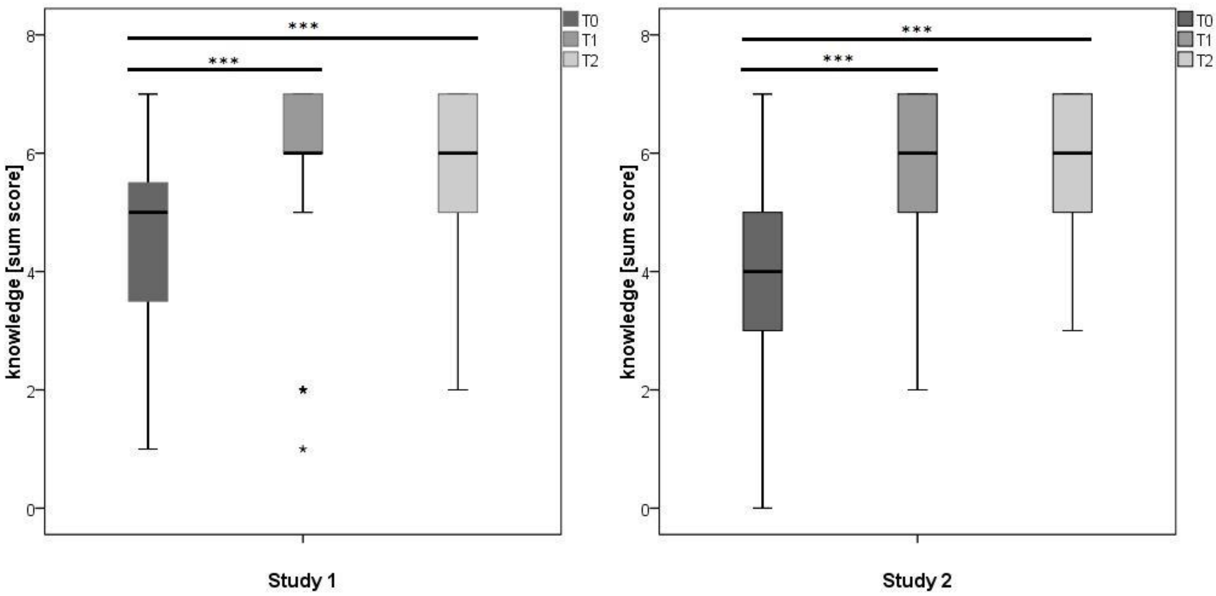


Fig. 3 Knowledge sum scores of Study 1 (in-school) and Study 2 (out-of-school) at the three test times.

A Kruskal-Wallis Test was applied to unveil potential differences in knowledge between Study 1, Study 2 and the test-retest group. Before participation (T0) no difference appeared in knowledge between students of Study 1 (Mdn = 4.6), Study 2 (Mdn = 4.3) and the test-retest group (Mdn = 4.6), H (2) = 2.26, *p* = n.s. After the intervention (T1), the three treatments significantly differed concerning their cognitive achievement (H (2) = 41.92, $p \leq .001$). The cognitive achievement increased in-school and out-of-school, without producing differences between them: Study 1 (Mdn = 6.3) and Study 2 (Mdn = 6.0), pairwise comparison with the adjusted p-values ($z = -2.164$, *p* = n.s.). In contrast, the test-retest group's knowledge scores remained constant (Mdn = 4.7) and differed from those of Study 1 ($z = 6.404$, $p \leq .001$, $r = .34$) and Study 2 ($z = 4.633$, $p \leq .001$, $r = .35$). A subsequent Mann-Whitney-*U*-test of the knowledge levels six weeks after the intervention (T2) pointed to differences between both study designs: Study 1 (Mdn = 6.2) and Study 2 (Mdn = 5.9), $U = 23727.00$, $z = 2.671$, $p = .024$, $r = .13$ (adjusted *p*-value).

3.2. Relation Between Knowledge and Environmental Perception

The factor loadings of the 2-MEV and Appreciation of Nature scale using an exploratory factor analysis with oblique rotation are shown in Table 2. The Kaiser-Meyer-Olkin (KMO) test (.780), lies above the acceptable limit of .5 (Field, 2018), and the Bartlett's test of sphericity ($p \leq .001$) was significant. The environmental values did not significantly differ between both study groups (Appreciation: $Mdn_{Study1} = 3.1$ (2.4–3.6); $Mdn_{Study2} = 2.9$ (2.6–3.3); $U = 21345.00$, $z = .983$, *p* = n.s.; Preservation: $Mdn_{Study1} = 3.6$ (3.0–4.2); $Mdn_{Study2} = 3.7$ (3.0–4.2); $U = 19562.00$, $z = -.609$, *p* = n.s.; Utilization: $Mdn_{Study1} = 2.1$ (1.7–2.7); $Mdn_{Study2} = 2.3$ (1.7–2.7); $U = 19963.00$, $z = -.405$, *p* = n.s.).

A multiple linear regression was calculated to predict knowledge at T1 based on the environmental values Preservation, Utilization, and Appreciation, and the Study Group. The results indicated that the model was a significant predictor of knowledge after the learning program (*F* (4, 433)

= 21.35, $p \leq .001$), with an adjusted R2 of .17 indicative for a moderate goodness-of-fit according to Cohen (1988). It was found that Utilization (B = - .692, $p \leq .001$), Preservation (B = .265, $p \leq .001$) and the Study Group (B = .255, p =, 039) were significant predictors, while Appreciation was not a significant predictor (B = - .085, p = n.s.), see Table 3.

Table 3 Multiple regression analysis with Preservation, Utilization, Appreciation and Study Group as predictors of knowledge at T1.

Variable	Unstandardized	Standardized	Std. Error
Constant	6.358		
Appreciation	-.085	-.055	.070
Utilization	-.692***	-.340***	.092
Preservation	.265***	.157***	.077
Study Group	.255*	.091*	.123
R^2	.165		
Corr. R^2	.157		
F (4, 433)	21.347***		

* $p < .05$; ***$p \leq .001$.

To unveil whether the intensity of the individual environmental value influenced the pre-existing and achieved knowledge after the intervention, the participants were grouped into low and high scorer concerning Preservation, Utilization, and Appreciation. In Study 1, both extreme groups increased their knowledge over the three test times (low UTL: $\chi 2$ (2) = 68.485, $p \leq .001$; high UTL: $\chi 2$ (2) = 48.163, $p \leq .001$; low PRE: $\chi 2$ (2) = 51.890, $p \leq .001$; high PRE: $\chi 2$ (2) = 67.855, $p \leq .001$; low APR: $\chi 2$ (2) = 86.283, $p \leq .001$; high APR: $\chi 2$ (2) = 72.920, $p \leq .001$). This also applies to Study 2 (low UTL: $\chi 2$ (2) = 25.200, $p \leq .001$; high UTL: $\chi 2$ (2) = 31.702, $p \leq .001$; low PRE: $\chi 2$ (2) = 29.534, $p \leq .001$; high PRE: $\chi 2$ (2) = 18.000, $p \leq .001$; low APR: $\chi 2$ (2) = 23.706, $p \leq .001$; high APR: $\chi 2$ (2) = 20.689, $p \leq .001$). Table 4 presents the pairwise comparisons with adjusted p-vales of students' knowledge, depending on the intensity of their environmental values at the three times of testing of Study 1 and Study 2.

Table 4 Pairwise comparison of students' knowledge levels with low, respectively, high environmental values at different times of testing of Study 1 and Study 2.

	Study 1			Study 2		
	z	*p*	*r*	*z*	*p*	*r*
[a]low Preservation						
T1-T0	-5.661	≤ .001	.44	-4.661	≤ .001	.56
T2-T0	-5.700	≤ .001	.45	-3.765	≤ .001	.45
T2-T1	-.039	n.s.	n.s.	.896	n.s.	n.s.
[b]high Preservation						
T1-T0	-6.511	≤ .001	.58	-3.348	.002	.44
T2-T0	-5.478	≤ .001	.49	-3.151	.005	.41
T2-T1	1.033	n.s.	n.s.	.197	n.s.	n.s.
[c]low Utilization						
T1-T0	-6.436	≤ .001	.59	-4.260	≤ .001	.55
T2-T0	-5.477	≤ .001	.50	-3.292	.003	.42
T2-T1	.959	n.s.	n.s.	.968	n.s.	n.s.
[d]high Utilization						
T1-T0	-5.475	≤ .001	.44	-4.359	≤ .001	.50
T2-T0	-5.597	≤ .001	.45	-4.072	≤ .001	.47
T2-T1	-.122	n.s.	n.s.	.287	n.s.	n.s.

^{e}low Appreciation						
T1-T0	-7.416	≤ .001	.55	-3.679	≤ .001	.47
T2-T0	-7.006	≤ .001	.52	-4.067	≤ .001	.53
T2-T1	.410	n.s.	n.s.	-.387	n.s.	n.s.
^{f}high Appreciation						
T1-T0	-6.481	≤ .001	.51	-3.808	≤ .001	.49
T2-T0	-6.755	≤ .001	.53	-2.776	.017	.36
T2-T1	-.273	n.s.	n.s.	1.033	n.s.	n.s.

Study 1: ^{a}n = 82; ^{b}n = 62; ^{c}n = 60; ^{d}n = 76; ^{e}n = 90; ^{f}n = 82; Study 2: ^{a}n = 35; ^{b}n = 29; ^{c}n = 30; ^{d}n = 38; ^{e}n = 30; ^{f}n = 30.

In Study 1, high Preservation scorer (Mdn_{T0} = 5.1; Mdn_{T1} = 6.5; Mdn_{T2} = 6.3) possessed significantly more knowledge than low scorer (Mdn_{T0} = 4.1; Mdn_{T1} = 6.0; Mdn_{T2} = 5.9) at T0 and T1 (T0: U = 3388.50, z = 3.487, $p \leq .001$, r = .29; T1: U = 3294.00, z = 3.224, $p \leq .001$, r = .27), but not at T2 (T2: U = 3104.00, z = 2.378, p = n.s.). Conversely, low Utilization scorer (Mdn_{T0} = 5.2; Mdn_{T1} = 6.7; Mdn_{T2} = 6.5) knew more than high scorer (Mdn_{T0} = 3.8; Mdn_{T1} = 5.5; Mdn_{T2} = 5.6) at all times of testing (T0: U = 1220.50, z = - 4.731, $p \leq .001$, r = .41; T1: U = 1078.00, z = - 5.600, $p \leq .001$, r = .48; T2: U = 1252.50, z = - 4.726, $p \leq .001$, r = .41). High Appreciation scorer (Mdn_{T0} = 4.8; Mdn_{T1} = 6.3; Mdn_{T2} = 6.4) knew significantly more than the low scorer (Mdn_{T0} = 4.1; Mdn_{T1} = 6.1; Mdn_{T2} = 6.0) at T0 and T2 (T0: U = 4543.50, z = 2.670, p = .024, r = .20; T2: U = 4.483.50, z = 2.578, p = .030, r = .20), but not at T1, where no difference appeared (T1: U = 4276.00, z = 1.901, p = n.s.).

Conversely to Study 1, high Preservation scorer of Study 2 (Mdn_{T0} = 4.9; Mdn_{T1} = 6.3; Mdn_{T2} = 6.2) did not know more than low scorer (Mdn_{T0} = 4.2; Mdn_{T1} = 5.9; Mdn_{T2} = 5.5) at all test times (T0: U = 672.50, z = 2.281, p = n.s.; T1: U = 609.00, z = 1.436, p = n.s.; T2: U = 676.50, z = 2.364, p = n.s.). Low Utilization scorer (Mdn_{T0} = 5.3; Mdn_{T1} = 6.6; Mdn_{T2} = 6.3) knew significantly more than the high scorer (Mdn_{T0} = 3.1; Mdn_{T1} = 5.0; Mdn_{T2} = 5.1) at all times of testing (T0: U = 159.00, z = - 5.165, $p \leq .001$, r = .63; T1: U = 168.00, z = - 5.139, $p \leq .001$, r = .62; T2: U = 239.00, z = - 4.220, $p \leq .001$, r = .51). Low (Mdn_{T0} = 3.9; Mdn_{T1} = 6.1; Mdn_{T2} = 6.1) and high (Mdn_{T0} = 4.6; Mdn_{T1} = 5.9; Mdn_{T2} = 5.6) Appreciation scorer did not differ concerning knowledge levels at all testing dates (T0: U = 527.50, z = 1.163, p = n.s.; T1: U = 429.50, z = - .315, p = n.s.; T2: U = 366.50, z = - 1.279, p = n.s.). Fig. 4 demonstrates the between-group comparison of low and high Preservation, Utilization, and Appreciation scorer for the three times of testing of Study 1 and Study 2 with adjusted p-values.

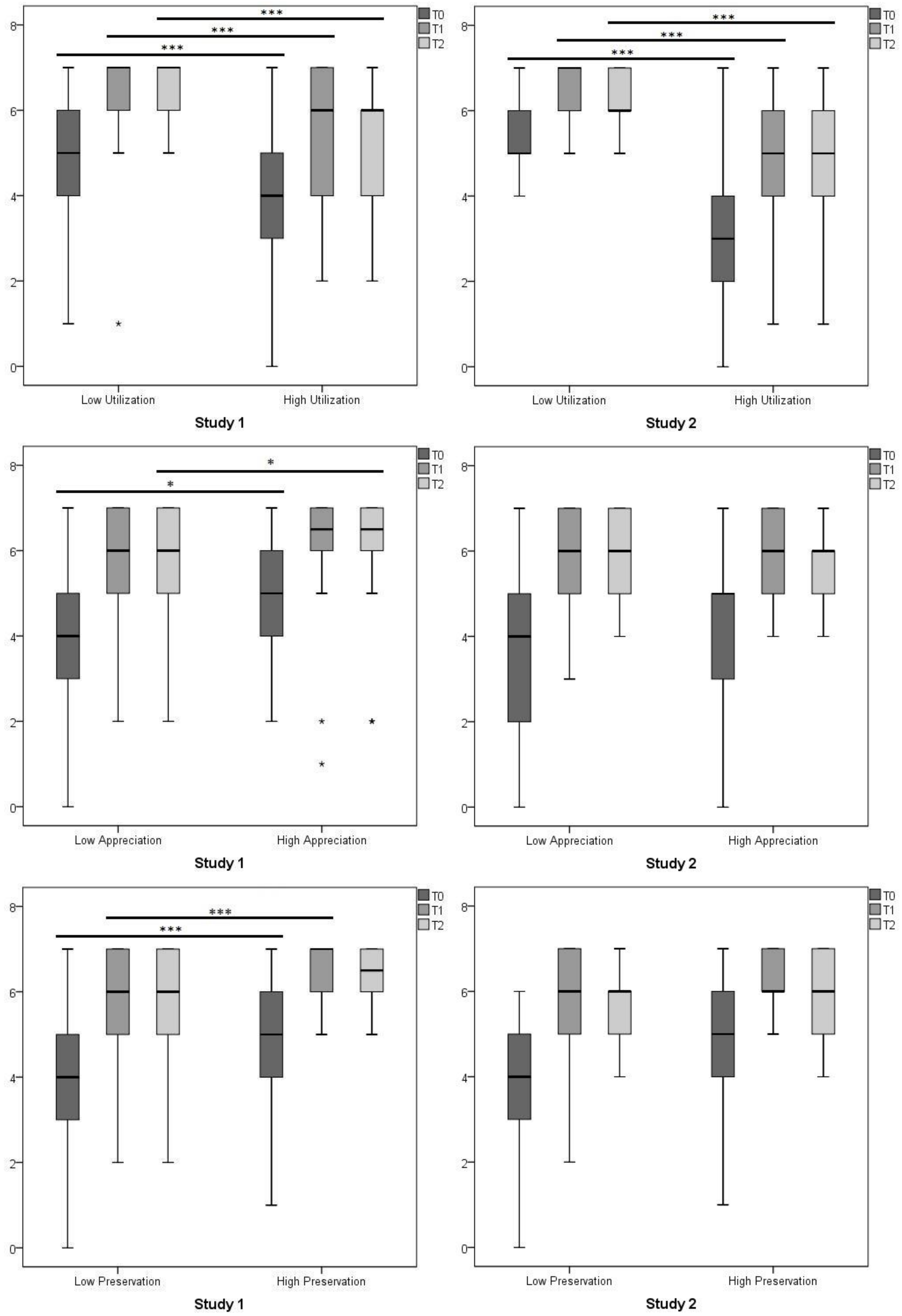


Fig. 4 Knowledge sum scores of the extreme groups for the three test times displayed for both study designs. T0 = pre-test, T1 = post-test, T2= retention test.

4. Discussion

4.1. Short- and Long-term Knowledge Acquisition

Both environmental settings, in-school and out-of-school, lead to a significant cognitive achievement: both sub-samples successfully acquired short- and long-term knowledge. The test-retest group's knowledge remained constant, in line with the literature (Schneiderhan-Opel & Bogner, 2020). Several environmental in-school programs have reported similar learning success. Schumm and Bogner (2016) accounted for a three-lesson lasting module covering renewable energies on work-stations a short-term knowledge acquisition followed by a moderate drop six weeks later. Schneiderhan-Opel and Bogner (2020) evaluated a four-lesson long module on biodiversity: the 10th graders achieved a significant knowledge gain directly after the intervention, which sank at the time of the retention test (after six weeks) but remained well above the pre-knowledge level. Results such as these were also found in out-of-school settings. Fremerey and Bogner (2015) reported a lower knowledge level six weeks after their learning module participation than the knowledge immediately after the interventions in a water supply institution. Sattler and Bogner (2017) implemented a four-lesson-long environmental program for 10th graders in a German zoo. After a significant knowledge gain following the module, knowledge scores after six weeks slightly dropped again.

In contrast to the mentioned in-school and out-of-school studies, in our case, the knowledge level did not drop after six weeks but remained steady. Our module supported the consistency of newly gained knowledge, even in the period of a few weeks. When evaluating this long-term persistence of knowledge, we must consider that other sources of information might reach a student either at home or due to media consumption (as the retention test is delayed for up to six weeks). Stöckert and Bogner (2020) also reported a continuity concerning students' knowledge in their waste management module. Therefore, educational programs on waste, especially plastics or microplastics, seem promising to enhance students' knowledge about these special topics sustainably. The intervention of Hartley et al. (2015) focused on marine litter, especially plastics. It gives indications that far-reaching positive changes due to participation are possible besides a knowledge increase. After the intervention, students changed their perceptions and attitudes and reduced their waste generation (Hartley et al., 2015). Emphasizing plastics and microplastics when dealing with waste management seems reasonable as plastic waste accounts for a large share of the total waste volume in the marine environment. This is supported by the study of Derraik (2002), who reported the plastic waste percentage in 26 of 37 examined areas 60 % or higher. Hence, our study's stable long-term knowledge is a promising result, as even short-term outreach activities seem to impact students' knowledge of this issue positively.

In all the described studies, the knowledge level remained far above the one before the learning program; however, they leave the question unanswered, how much of the acquired knowledge will stay beyond the covered six weeks. To investigate this long-term retention potential, Schmid and Bogner (2015) and Marth and Bogner (2017) extended the testing cycle to 12 weeks or, in the case of the latter study, even to one year after program implementation. The 135-minute lasting intervention of Schmid and Bogner (2015) on the phenomenon of hearing was performed in-school. Comparable with the other studies, the 9th graders recorded a drop in their knowledge after six weeks; however, afterward, the knowledge level remained stable. This result is in concordance with the out-of-school study of Marth and Bogner (2017). In their learning program on bionics in a zoo, the students maintained the knowledge level which they possessed six weeks after the zoo visit, even 12 weeks and one year later. Those results indicate that knowledge, which is still available six weeks after participation in an educational initiative, might stay present in the long-term.

4.2. In- and Out-of-school Settings as Productive Learning Environments

Evaluating the effectiveness of a learning site, a variety of factors might possess influencing effects. First and utmost, the nature of the out-of-school site itself is decisive. Visits to zoos or museums may offer completely differing opportunities for learning than field centers or country hostels. Depending on the out-of-school learning program's location, novelty, social interactions, degree of structure, quantity, and abundance of activities and instructors may vary, potentially affecting student learning. Our study aimed to minimize influential factors by implementing the identical learning program called "Plastic Detectives – The Search For Plastic" with identical work material, supervised by instructed experts in an in-school classroom and a multifunctional room in an out-of-school country hostel. As the comparison of learning at two different sites presents a great challenge, the evaluation allows identifying tendencies but no definitive conclusions about learning sites in general. Thus, the following discussion on the effectiveness of the two learning sites should be read accordingly.

All participating students started at a similar level of prior knowledge. Students of Study 1, Study 2, and the test-retest group did not significantly differ concerning their knowledge at T0, which is an essential prerequisite for further comparisons and is quite in line with the literature (Schneiderhan-Opel & Bogner, 2020). Surprisingly, the out-of-school setting was not more effective than the in-school setting: achieved knowledge levels directly after participation were similar for both studies. Solely six weeks later, students of the in-school program showed more knowledge than students of the out-of-school program. However, the knowledge advantage of the classroom group had a small effect size only. Thus, when implementing the same learning program, covering the same content, in the same way, the learning location itself seems to play a subordinate role. In the last years, several studies have investigated the outcome of out-of-school learning. Due to many influencing factors, the results give a diverse picture concerning students' achievement. Seybold et al. (2014) compared an in-school and zoo program for 5th and 6th graders on primate conservation and found the out-of-school environment to be advantageous regarding knowledge increase. Sturm and Bogner (2010) completed the identical intervention in-school and out-of-school in a natural history museum with 6th graders. In this study, the museum group outperformed the classroom sample immediately after the program and even six weeks later. On the contrary, Geier and Bogner (2010) found their in-school intervention to be more effective than the out-of-school intervention. They evaluated an anti-smoking program for 5th graders, which was performed in-school and out-of-school at a youth camp. Both groups increased their knowledge with no difference directly after the program. However, the decrease rate was higher for the youth camp group.

Studies, which described beneficial impacts of out-of-school interventions, took place in learning environments like zoos and museums. As opposed to this, Geier and Bogner (2010) and we executed the program in a youth camp during a school field trip. Hence, the learning environments in-school and out-of-school resembled each other. In both cases, the program took place in indoor classrooms, which were equipped with identical workstations. In both settings, in-school and out-of-school, we used workstations, which are a student-centered approach, and included practical hands-on activities, cooperative work, and laboratory activities. We modified the out-of-school setting with formal activities and the in-school setting with informal activities. Thus, providing the same content in the same way and enriching the respective learning environments, comparable learning success can be achieved in different learning settings.

4.3. Relation Between Environmental Values and Knowledge Acquisition

As expected, students of Study 1 and Study 2 did not differ concerning their environmental values. Overall, the multiple regression analysis showed that the variables explained knowledge after the intervention moderately. This is an understandable result since knowledge and learning depend on numerous factors we could not control. Preservation, Utilization, and the Study Group predicted knowledge at T1; Appreciation did not. The environmental value Preservation positively influenced knowledge at T1. Most past studies consistently found a significant correlation of Preservation with knowledge in out-of-school (Bogner & Wiseman, 2004; Dieser & Bogner, 2017; Fremerey & Bogner, 2015) and in-school programs (Schneiderhan-Opel & Bogner, 2020), supporting our results. Merely Liefländer and Bogner (2016) reported an almost complete absence of correlation between Preservation and knowledge. The environmental value Utilization negatively influenced knowledge at T1 and had the most considerable effect. Previous studies found Utilization correlating negatively with knowledge at all times of testing. This result was reported in out-of-school (Dieser & Bogner, 2017) and in-school programs (Boeve-de Pauw & van Petegem, 2011; Liefländer & Bogner, 2016). The more pronounced Utilization was, the less knowledge the students possessed after the intervention. Our results from the extreme groups support this: high Utilizers knew less than low Utilizers in-school and out-of-school. Relatively speaking, it is interesting that the negative influence of Utilization was greater than the positive impact of Preservation. Other studies have also shown that Utilization affects primary school students, as pro-environmental views develop only gradually (Dieser & Bogner, 2017). Hence, when aiming to build awareness on environmentally relevant topics, educators should try to reduce Utilization tendencies in the long-term. Next to the other variables, the Study Group, namely in-school and out-of-school participation, influenced learning. Compared to Preservation and especially Utilization, the impact of the Study Group in this model was negligible. In-school predicted higher knowledge after the intervention; however, knowledge did not differ significantly among students of Study 1 and Study 2, indicating the smallness of the learning environments' influence.

By investigating environmental values' extreme groups, we gained a more in-depth insight into their knowledge acquisition. The program similarly appealed to all students independent of the environmental values' intensity. In both subgroups, low and high Preservation, Utilization, and Appreciation scorer showed a knowledge growth without loss at T2. In Study 1, low Appreciation scorer caught up their knowledge disadvantage to T1 but could not maintain this performance to T2. The high Preservation scorer of Study 1 maintained their knowledge advantage over the low Preservation scorer until T1, but not at T2. The low Utilization scorer of Study 1 and Study 2 possessed more knowledge than the high Utilization scorer at all testing times. This is in line with the subsample of Schönfelder and Bogner (2017), which was taught at a beehive on the school ground. In Study 2, low and high Preservation scorers held the same knowledge level at all test dates, which was also found by Schönfelder and Bogner (2017). The Appreciation scorer also showed this result in Study 2. Therefore, the low Preservation and Appreciation scorer learned as well as high Preservation and Appreciation scorer in the out-of-school setting. However, especially for the results of Preservation and Appreciation of Study 2, we have to take the questions' level of difficulty into account, which possibly limited the actual presentation of high scorers' potential knowledge achievement (ceiling effect).

4.4. Limitations

We used an ad-hoc knowledge scale tailored to the content of the intervention. Due to primary school students' young age, we reduced the intervention's content to make the complex topic of microplastics comprehensible. Hence, we kept the questionnaire as short as possible to ensure that the students answered the questions thoroughly without losing concentration. However, these are clear limitations of the study. Firstly, the questionnaire may contain more knowledge questions to receive more robust data on the knowledge gain in future research. Secondly, the item difficulty needs to be increased to get a more differentiated picture of the students' performance. As further encounters with microplastics due to extracurricular activities in the period between the learning program and the retention test might have influenced the long-term knowledge, future research should control such variables. Finally, as some basics are known, future studies need to extend the number of monitored variables, possibly influencing cognitive performance in different learning environments.

4.5. Conclusion

Living in the era of plastic, outreach programs constitute a valuable potential to raise awareness for the topic. Informing students about the most relevant content relating to plastics, microplastics and alternatives at an early stage of their school career seems advantageous as foundations for further encounterings with this issue are laid. For this purpose, our short-term learning program presents a promising approach to promote environmental knowledge on microplastics in primary education. The outreach activities produced in-school and out-of-school a significant knowledge increase about microplastics which remained stable even after six weeks. A knowledge advantage (with a small effect size) of the in-school learning environment appeared six weeks after program participation. However, planning environmental education learning programs, the environmental values Utilization and Preservation proved to have greater importance than the learning site. Even though all students, regardless of the intensity of their environmental values, significantly learned without forgetting, Utilization of Nature was the most important and only negative predictor of knowledge after the program. Given that low Utilization scorers knew more than high Utilization scorers at all test times and regardless of the learning environment, these students are most important to address in future environmental learning programs. In conclusion, we regard the student-centered hands-on activities at workstations as a suitable method of educating students. It is a promising supplement to everyday school life, enriching environmental and science education in-school as well as out-of-school.

Funding: This research was funded by the University of Bayreuth and by PLAWES (BMBF-Grant: 03F0789A). This article reflects only the authors' views, and BMBF is not liable for any use that might be made of the information contained herein.

CRediT authorship contribution statement: Patricia Raab: Conceptualization, Methodology, Formal analysis, Investigation, Visualization, Writing - original draft. Franz X. Bogner: Funding acquisition, Supervision, Writing - review & editing.

Declaration of Competing Interest: The authors report no declarations of interest.

Acknowledgments: First of all, we are very grateful to Tabea Loermann-Knöchel, who designed the module "Plastic Detectives – The Search for Plastic" and collected the data at the out-of-school learning site. Moreover, we want to thank all the participating teachers and students for taking part in our learning module and study as well as the country hostels Weißenstadt and Steinbach am Wald for providing their facilities for the study.

References

Andrady, A. L. (2011). Microplastics in the marine environment. *Marine Pollution Bulletin*, *62*(8), 1596–1605. https://doi.org/10.1016/j.marpolbul.2011.05.030

Barboza, L. G. A., & Gimenez, B. C. G. (2015). Microplastics in the marine environment: Current trends and future perspectives. *Marine Pollution Bulletin*, *97*(1-2), 5–12. https://doi.org/10.1016/j.marpolbul.2015.06.008

Barnes, D. K. A., Galgani, F., Thompson, R. C., & Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *364*(1526), 1985–1998. https://doi.org/10.1098/rstb.2008.0205

Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (2009). *Learning Science in Informal Environments: People, Places, and Pursuits*. National Academies Press. https://doi.org/10.17226/12190

Boeve-de Pauw, J., van Hoof, J., & van Petegem, P. (2019). Effective field trips in nature: the interplay between novelty and learning. *Journal of Biological Education*, *53*(1), 21–33. https://doi.org/10.1080/00219266.2017.1418760

Boeve-de Pauw, J., & van Petegem, P. (2011). The Effect of Flemish Eco-Schools on Student Environmental Knowledge, Attitudes, and Affect. *International Journal of Science Education*, *33*(11), 1513–1538. https://doi.org/10.1080/09500693.2010.540725

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

Bogner, F. X., & Wilhelm, M. G. (1996). Environmental perspectives of pupils: the development of an attitude and behaviour scale. *Environmentalist (the Environmentalist)*, *16*(2), 95–110.

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

Bogner, F. X., & Wiseman, M. (2004). Outdoor Ecology Education and Pupils' Environmental Perception in Preservation and Utilization. *Science Education International*, *15*(1), 27–48.

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

Braun, T., Cottrell, R., & Dierkes, P. (2017). Fostering changes in attitude, knowledge and behavior: demographic variation in environmental education effects. *Environmental Education Research*, *24*(6), 899–920. https://doi.org/10.1080/13504622.2017.1343279

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated Cognition and the Culture of Learning. *Educational Researcher*, *18*(1), 32–42. https://doi.org/10.2307/1176008

Browne, M. A., Crump, P., Niven, S. J., Teuten, E., Tonkin, A., Galloway, T., & Thompson, R. (2011). Accumulation of microplastic on shorelines worldwide: Sources and sinks. *Environmental Science & Technology*, *45*(21), 9175–9179. https://doi.org/10.1021/es201811s

Bucci, K., Tulio, M., & Rochman, C. M. (2020). What is known and unknown about the effects of plastic pollution: A meta-analysis and systematic review. *Ecological Applications*, *30*(2). https://doi.org/10.1002/eap.2044

Burrowes, P. A. (2003). A Student-Centered Approach to Teaching General Biology That Really Works: Lord's Constructivist Model Put to a Test. *The American Biology Teacher*, *65*(7), 491–502. https://doi.org/10.2307/4451548

Choi, J.-I., & Hannafin, M. (1995). Situated cognition and learning environments: Roles, structures, and implications for design. *Educational Technology Research and Development*, *43*(2), 53–69. https://doi.org/10.1007/BF02300472

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2. Auflage). Lawrence Erlbaum Associates.

Cohen, J. (1992). A power primer. *Psychological Bulletin*, *112*(1), 155–159. https://doi.org/10.1037/0033-2909.112.1.155

Coombs, P. H., Prosser, R. C., & Ahmed, M. (1973). *New Paths to Learning for Rural Children and Youth.*

de Houwer, J., Barnes-Holmes, D., & Moors, A. (2013). What is learning? On the nature and merits of a functional definition of learning. *Psychonomic Bulletin & Review*, *20*(4), 631–642. https://doi.org/10.3758/s13423-013-0386-3

Derraik, J. G. B. (2002). The pollution of the marine environment by plastic debris: a review. *Marine Pollution Bulletin*, *44*(9), 842–852. https://doi.org/10.1016/S0025-326X(02)00220-5

DeWitt, J., & Storksdieck, M. (2008). A Short Review of School Field Trips: Key Findings from the Past and Implications for the Future. *Visitor Studies*, *11*(2), 181–197. https://doi.org/10.1080/10645570802355562

Dieser, O., & Bogner, F. X. (2017). How individual environmental values influence knowledge acquisition of adolescents within a week-long outreach biodiversity module. *Journal of Global Research in Education and Social Science*, *9*(4), 213–224.

Dris, R., Imhof, H., Sanchez, W., Gasperi, J., Galgani, F., Tassin, B., & Laforsch, C. (2015). Beyond the ocean: contamination of freshwater ecosystems with (micro-)plastic particles. *Environmental Chemistry*, *12*(5), 539–550. https://doi.org/10.1071/EN14172

Duis, K., & Coors, A. (2016). Microplastics in the aquatic and terrestrial environment: Sources (with a specific focus on personal care products), fate and effects. *Environmental Sciences Europe*, *28*(2), 1–25. https://doi.org/10.1186/s12302-015-0069-y

Eerkes-Medrano, D., Thompson, R. C., & Aldridge, D. C. (2015). Microplastics in freshwater systems: A review of the emerging threats, identification of knowledge gaps and prioritisation of research needs. *Water Research*, *75*, 63–82. https://doi.org/10.1016/j.watres.2015.02.012

Eshach, H. (2007). Bridging In-school and Out-of-school Learning: Formal, Non-Formal, and Informal Education. *Journal of Science Education and Technology*, *16*(2), 171–190. https://doi.org/10.1007/s10956-006-9027-1

Fallik, O., Rosenfeld, S., & Eylon, B.-S. (2013). School and out-of-school science: a model for bridging the gap. *Studies in Science Education*, *49*(1), 69–91. https://doi.org/10.1080/03057267.2013.822166

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

Field, A. (2018). *Discovering Statistics Using IBM SPSS Statistics* (5. Auflage). SAGE.

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

Geier, C. S., & Bogner, F. X. (2010). Student-centred anti-smoking education: Comparing a classroom-based and an out-of-school setting. *Learning Environments Research*, *13*(2), 147–157. https://doi.org/10.1007/s10984-010-9069-4

Gerber, B. L., Marek, E. A., & Cavallo, A. M. L. (2001). Development of an informal learning opportunities assay. *International Journal of Science Education*, *23*(6), 569–583. https://doi.org/10.1080/09500690116959

Hartley, B. L., Thompson, R. C., & Pahl, S. (2015). Marine litter education boosts children's understanding and self-reported actions. *Marine Pollution Bulletin*, *90*(1-2), 209–217. https://doi.org/10.1016/j.marpolbul.2014.10.049

Herrington, J., & Oliver, R. (2000). An instructional design framework for authentic learning environments. *Educational Technology Research and Development*, *48*(3), 23–48. https://doi.org/10.1007/BF02319856

Hewson, M. G., & Hewson, P. W. (1983). Effect of instruction using students' prior knowledge and conceptual change strategies on science learning. *Journal of Research in Science Teaching*, *20*(8), 731–743. https://doi.org/10.1002/tea.3660200804

Hines, J. M., Hungerford, H. R., & Tomera, A. N. (1987). Analysis and Synthesis of Research on Responsible Environmental Behavior: A Meta-Analysis. *The Journal of Environmental Education*, *18*(2), 1–8. https://doi.org/10.1080/00958964.1987.9943482

Hofstein, A., & Rosenfeld, S. (1996). Bridging the Gap Between Formal and Informal Science Learning. *Studies in Science Education*, *28*(1), 87–112. https://doi.org/10.1080/03057269608560085

Hooper, S. (1992). Cooperative learning and computer-based instruction. *Educational Technology Research and Development*, *40*(3), 21–38. https://doi.org/10.1007/BF02296840

Johnson, D. W., & Johnson, R. T. (1989). *Cooperation and competition: Theory and research*. Interaction Book Company.

Johnson, B., & Manoli, C. C. (2011). The 2-MEV Scale in the United States: A Measure of Children's Environmental Attitudes Based on the Theory of Ecological Attitude. *The Journal of Environmental Education*, *42*(2), 84–97. https://doi.org/10.1080/00958964.2010.503716

Kaiser, F. G., Brügger, A., Hartig, T., Bogner, F. X., & Gutscher, H. (2014). Appreciation of nature and appreciation of environmental protection: How stable are these attitudes and which comes first? *European Review of Applied Psychology*, *64*(6), 269–277. https://doi.org/10.1016/j.erap.2014.09.001

Kaiser, F. G., Roczen, N., & Bogner, F. X. (2008). Competence formation in environmental education: Advancing ecology-specific rather than general abilities. *Umweltpsychologie*, *12*(2), 56–70. https://doi.org/10.5167/UZH-9249

Kandel, E. R., Schwartz, J. H., Jessell, T., Siegelbaum, S. A., Hudspeth, A. J., & Mack, S. (Eds.). (2013). *Principles of neural science* (Fifth edition). McGraw-Hill Medical.

Kibbe, A., Bogner, F. X., & Kaiser, F. G. (2014). Exploitative vs. appreciative use of nature – Two interpretations of utilization and their relevance for environmental education. *Studies in Educational Evaluation*, *41*, 106–112.

Kisiel, J. F. (2003). Teachers, Museums and Worksheets: A Closer Look at a Learning Experience. *Journal of Science Teacher Education*, *14*(1), 3–21. https://doi.org/10.1023/A:1022991222494

Knight, J. K., & Wood, W. B. (2005). Teaching more by lecturing less. *Cell Biology Education*, *4*(4), 298–310. https://doi.org/10.1187/05-06-0082

Laursen, S., Liston, C., Thiry, H., & Graf, J. (2007). What good is a scientist in the classroom? Participant outcomes and program design features for a short-duration science outreach intervention in K-12 classrooms. *CBE Life Sciences Education*, *6*(1), 49–64. https://doi.org/10.1187/cbe.06-05-0165

Lee, H., Stern, M. J., & Powell, R. B. (2020). Do pre-visit preparation and post-visit activities improve student outcomes on field trips? *Environmental Education Research*, *26*(7), 989–1007. https://doi.org/10.1080/13504622.2020.1765991

Liefländer, A. K., & Bogner, F. X. (2016). Educational impact on the relationship of environmental knowledge and attitudes. *Environmental Education Research*, *24*(4), 611–624. https://doi.org/10.1080/13504622.2016.1188265

Lord, T. R. (2001). 101 Reasons for Using Cooperative Learning in Biology Teaching. *The American Biology Teacher*, *63*(1), 30–38. https://doi.org/10.2307/4451027

Lou, Y., Abrami, P. C., Spence, J. C., Poulsen, C., Chambers, B., & d'Apollonia, S. (1996). Within-Class Grouping: A Meta-Analysis. *Review of Educational Research*, *66*(4), 423–458. https://doi.org/10.3102/00346543066004423

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

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

Milfont, T. L., & Duckitt, J. (2004). The structure of environmental attitudes: A first- and second-order confirmatory factor analysis. *Journal of Environmental Psychology*, *24*(3), 289–303. https://doi.org/10.1016/j.jenvp.2004.09.001

Piehl, S., Leibner, A., Löder, M. G. J., Dris, R., Bogner, C., & Laforsch, C. (2018). Identification and quantification of macro- and microplastics on an agricultural farmland. *Scientific Reports*, *8*, 17950. https://doi.org/10.1038/s41598-018-36172-y

PlasticsEurope. (2020). *Plastics - the Facts 2019: An analysis of European plastics production, demand and waste data*. Brussels. Plastics Europe: Association of Plastic Manufacturers.

Price, S., & Hein, G. E. (1991). More than a field trip: science programmes for elementary school groups at museums. *International Journal of Science Education*, *13*(5), 505–519. https://doi.org/10.1080/0950069910130502

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

Randler, C., & Bogner, F. X. (2009). Efficacy of Two Different Instructional Methods Involving Complex Ecological Content. *International Journal of Science and Mathematics Education*, *7*(2), 315–337. https://doi.org/10.1007/s10763-007-9117-4

Randler, C., & Hulde, M. (2007). Hands-on versus teacher-centred experiments in soil ecology. *Research in Science & Technological Education*, *25*(3), 329–338. https://doi.org/10.1080/02635140701535091

Rennie, L. J. (1994). Measuring affective outcomes from a visit to a Science Education Centre. *Research in Science Education*, *24*(1), 261–269. https://doi.org/10.1007/BF02356352

Rennie, L. J. (2014). Learning science outside of school. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of research on science education* (pp. 120–144). Routledge.

Rochman, C. M. (2018). Microplastics research-from sink to source. *Science*, *360*(6384), 28–29. https://doi.org/10.1126/science.aar7734

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

Sattler, S., & Bogner, F. X. (2017). Short- and long-term outreach at the zoo: cognitive learning about marine ecological and conservational issues. *Environmental Education Research*, *23*(2), 252–268. https://doi.org/10.1080/13504622.2016.1144173

Schmid, S., & Bogner, F. X. (2015). Does Inquiry-Learning Support Long-Term Retention of Knowledge? *International Journal of Learning, Teaching and Educational Research*, *10*(4), 51–70.

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

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

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

Settlage, J. (2000). Understanding the learning cycle: Influences on abilities to embrace the approach by preservice elementary school teachers. *Science Education*, *84*(1), 43–50. https://doi.org/10.1002/(SICI)1098-237X(200001)84:1<43::AID-SCE4>3.0.CO;2-F

Seybold, B., Braunbeck, T., & Randler, C. (2014). Primate Conservation: An evaluation of two different educational programs in Germany. *International Journal of Science and Mathematics Education*, *12*(2), 285–305. https://doi.org/10.1007/s10763-013-9405-0

Skinner, B. F. (1950). Are theories of learning necessary? *Psychological Review*, *57*(4), 193–216. https://doi.org/10.1037/h0054367

Stöckert, A., & Bogner, F. X. (2020). Cognitive Learning about Waste Management: How Relevance and Interest Influence Long-Term Knowledge. *Education Sciences*, *10*(4), 102. https://doi.org/10.3390/educsci10040102

Stohr-Hunt, P. M. (1996). An analysis of frequency of hands-on experience and science achievement. *Journal of Research in Science Teaching*, *33*(1), 101–109. https://doi.org/10.1002/(SICI)1098-2736(199601)33:1<101::AID-TEA6>3.0.CO;2-Z

Sturm, H., & Bogner, F. X. (2010). Learning at workstations in two different environments: A museum and a classroom. *Studies in Educational Evaluation*, *36*(1-2), 14–19. https://doi.org/10.1016/j.stueduc.2010.09.002

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, *2*, 53–55. https://doi.org/10.5116/ijme.4dfb.8dfd

Thompson, R. C., Olsen, Y., Mitchell, R. P., Davis, A., Rowland, S. J., John, A. W. G., McGonigle, D., & Russell, A. E. (2004). Lost at sea: Where is all the plastic? *Science*, *304*(5672), 838. https://doi.org/10.1126/science.1094559

United Nations. (2019). *The Sustainable Development Goals Report 2019*. *Sustainable Development Goals report: Vol. 2019*. United Nations.

van Cauwenberghe, L., Devriese, L., Galgani, F., Robbens, J., & Janssen, C. R. (2015). Microplastics in sediments: A review of techniques, occurrence and effects. *Marine Environmental Research*, *111*, 5–17. https://doi.org/10.1016/j.marenvres.2015.06.007

Vennix, J., den Brok, P., & Taconis, R. (2017). Perceptions of STEM-based outreach learning activities in secondary education. *Learning Environments Research*, *20*(1), 21–46. https://doi.org/10.1007/s10984-016-9217-6

Werquin, P. (2010). *Recognising Non-Formal and Informal Learning*. OECD. https://doi.org/10.1787/9789264063853-en

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

Wiseman, M., Wilson, G., & Bogner, F. X. (2012). Environmental Values and Authoritarianism. *Journal of Psychology Research*, *2*(1), 25–31. https://doi.org/10.17265/2159-5542/2012.01.003

Wright, S. L., Thompson, R. C., & Galloway, T. S. (2013). The physical impacts of microplastics on marine organisms: A review. *Environmental Pollution*, *178*, 483–492. https://doi.org/10.1016/j.envpol.2013.02.031

Young, M. F. (1993). Instructional design for situated learning. *Educational Technology Research and Development*, *41*(1), 43–58. https://doi.org/10.1007/BF02297091

5.5. Teilarbeit C

American Biology Teacher, 2020, 82(7), 478-487

Microplastics in the Environment: Raising Awareness in Primary Education

Patricia Raab[1*], Franz X. Bogner[1]

[1]Centre of Math & Science Education (Z-MNU), Department of Biology Education, University of Bayreuth, NW1, 95447 Bayreuth, Germany

*Correspondence: patricia.raab@uni-bayreuth.de

Microplastics in the Environment: Raising Awareness in Primary Education

Abstract

Microplastic pollution is an environmental threat with substantial effects on ecosystems. Persistence and ubiquity are the central causes of the problems microplastics generate, especially throughout water-based food webs. To limit microplastic pollution, accountability of individuals is needed, which requires reliable information for an individual to act accordingly. Knowledge about sources, contamination, fate, and effects of microplastic in the environment may be an essential element in enhancing students' motivation and sense of responsibility. Our module "Plastic Detectives – The Search for Plastic" offers consciousness-raising tasks that involve students in hands-on learning activities. Within student-centered activities, different tasks on sources in everyday life, sinks in aquatic ecosystems, effects on marine animals, and prevention strategies for microplastics are in focus. With an appropriate overview, students may be sufficiently enabled to ponder their purchase decisions and potentially limit microplastic pollution in everyday life.

Keywords: microplastic pollution; environmental behavior; hands-on lesson; primary education.

Introduction

Plastic is everywhere. The increasing use of plastic at every occasion is a universal phenomenon. Around the globe, plastic finds practical application in diverse segments of the economy (*e.g.*, automotive, packaging, and construction; PlasticsEurope, 2019). Consequently, it comes as no surprise that supermarkets, households, transport, and even schools are unthinkable without plastic. Therefore, students can hardly avoid it. They start their day by brushing their teeth with a plastic toothbrush, using a plastic toothpaste tube, pouring breakfast cereals from plastic packaging, putting on synthetic clothes, and taking the bus to school, where almost any school material includes at least some plastic. After short- or long-term use, all of those plastic items will inevitably become garbage. Such plastic debris, which intentionally or unintentionally enters every ecosystem on Earth, is considered the most common source of plastic in the environment (Duis & Coors, 2016).

Next to this obvious, visible plastic debris, microplastics (*i.e.*, particles smaller than 5 mm; GESAMP, 2016) are an ever-growing environmental concern because of their presence in marine, freshwater, and terrestrial ecosystems (Rochman, 2018). In the household, microplastic enters the environment as microbeads from rinse-off products ("primary microplastic"; *e.g.*, in shampoo, shower gel, hand washing gel, or exfoliating cream; Fendall & Sewell, 2009) and through the release of fibers from synthetic textiles during washing ("secondary microplastic"; Browne et al., 2011; Browne, 2015; Napper & Thompson, 2016). Another source of microplastics is large plastic items that disintegrate, through degradation processes, into smaller pieces, ending up as secondary microplastic. The small size of microplastic makes it an even more serious threat than large pieces of plastic (Xanthos & Walker, 2017). Small particles are more difficult to perceive visually; are more easily available to a variety of organisms (Browne et al., 2007; Cole et al., 2011); and possess a high surface-to-volume ratio; therefore, pollutants sorb to microplastic more readily (Duis & Coors, 2016). Once microplastic is in the environment, it is transported over long distances, accumulates (for example, in the Great Pacific Garbage Patch; Goldstein et al., 2012), cannot be removed, and is therefore ubiquitous (Barnes et al., 2009).

Because of the far-reaching consequences of microplastics, the topic is a subject of lively discussion – driven by a constant flow of new scientific findings – in society, media, and politics (Hartley et al., 2015). Recently, for example, Wetherbee et al. (2019) showed that plastic particles present in the Rocky Mountains entered the ecosystem by incorporation into raindrops. Reports like these offer food for thought in considering societal changes to deal with this pollution, such as bans on single-use plastic items like straws, plates, and wrappers. Unlike many countries, the United States still lacks restrictions on the use of plastic bags (Xanthos & Walker, 2017). On the other hand, after several states prohibited products containing microbeads, the federal Microbead-Free Waters Act of 2015 banned the production and distribution of microbead rinse-off cosmetics and nonprescription drugs nationwide (United States, 2015). However, the problem of microbeads in makeup and other personal-care products remains.

Therefore, individual responsibility is all the more crucial. Students often lack knowledge of the ingredients in cosmetic products, the composition of textiles, or eco-friendly alternatives to plastics and microplastics. This circumstance may lead to poor purchase decisions. Insights of students into the ecological problem of microplastics and the contribution of purchased products are the basis for a sense of responsibility. Students need reliable information about the current state of knowledge on sources, contamination, fate, and effects of microplastic. Our module "Plastic Detectives – The Search for Plastic" starts on this proposition and aims to enlighten and sensitize young students to this environmental concern.

Learning Objectives

Our module focuses on microplastics' sources, sinks in aquatic ecosystems, effects on marine animals, and prevention strategies.

The objectives for students are sevenfold:

(1) to receive an overview of the topic;

(2) to understand the term microplastic;

(3) to identify drugstore items and textiles containing microplastic;

(4) to gain an understanding of possible ways that microplastic enters the environment;

(5) to come to realize the adverse effects of microplastic on marine animals;

(6) to discover the advantages and disadvantages of single-use, multiple-use, and alternative products; and

(7) to develop awareness of how to reduce an individual's release of plastic and microplastic into the environment.

Initially, the module was designed for fourth-graders; however, the topic of microplastic and the comprised thematic areas are relevant across grades; the experiments of stations 1 and 2, especially, can easily be modified for any grade. The stations apply threedimensional learning, which was defined by the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013). A detailed description of the disciplinary core ideas is provided in Table 1.

Table 1. Alignment of the station learning with the Next Generation Science Standards (NGSS Lead States, 2013).

Disciplinary Core Ideas	**Student Outcomes**
K-ESS3-3. Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.	Students understand that their way of life (*e.g.*, usage of plastic bottles) influences the environment. Students discuss and collect treatment options to reduce the entry of plastic and microplastic into the environment.

5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.	Students understand that their activities in everyday life, especially their usage of everyday products and textiles, cause the entry of microplastic into the environment.
5-LS2-1. Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.	Students create a flow chart of a food web by which they realize that animals and humans are burdened by microplastic due to its indigestibility.
MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.	Students discuss the impacts of humans on the environment and evaluate solutions to reduce the entry of plastic and microplastic into the environment.
MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.	Students create a flow chart of a food web by which they realize that animals and humans are burdened by microplastic due to its indigestibility.
HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.	Students discuss and collect treatment options to minimize humans' changes in the environment.
HS-ESS3-4. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.	Students collect and assess possible solutions to reduce pollution and waste.

The learning activities contain science and engineering practices that address K-ESS3-3 and 5-ESS3-1 (Obtaining, Evaluating, and Communicating Information); 5-LS2-1 (Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena); MS-ESS3-3 (Constructing Explanations and Designing Solutions); and MS-LS2-3 (Developing and Using Models); and different crosscutting concepts that address K-ESS3-3 and MS-ESS3-3 (Cause and Effect); 5-ESS3-1 and 5-LS2-1 (Systems and System Models); 5-ESS3-1 and MS-ESS3-3 (Science Addresses Questions about the Natural and Material World); MS-LS2-3 (Scientific Knowledge Assumes an Order and Consistency in Natural Systems); HS-LS2-7 (Stability and Change); and HS-ESS3-4 (Influence of Engineering, Technology, and Science on Society and the Natural World).

Learner-Centered Module & Exercises

To enable young students to learn cooperatively, all tasks were carried out in groups of three or four at working stations. In total, the module requires 180 minutes; the introduction, the processing of each station, and the evaluation take 20 minutes each. This learner-centered module consists of seven learning stations. Figure 1 presents an overview of the learning cycle based on the seven stations. Table 2 gives an overview of pre-activity preparation, teaching phases, activity and learning content, assessment, and required time.

Figure 1. Overview of the module "Plastic Detectives – The Search for Plastic".

Table 2. Overview of pre-activity preparation, stations, activity and learning content, assessment and required time.

Pre-activity Preparation

Printing of workbooks, sample solutions, and instructions (see Supplemental Material Appendices A, B, C)
When all materials for the experiments are ready (Tables 3–8), the teacher should schedule one hour to prepare the classroom:

- One school desk for each station
- Each station is set up twice (12 tables for stations 1–6; station 7 does not require an extra table)
- Secure placement of laptops and microscopes
- Division of the class in groups of three or four

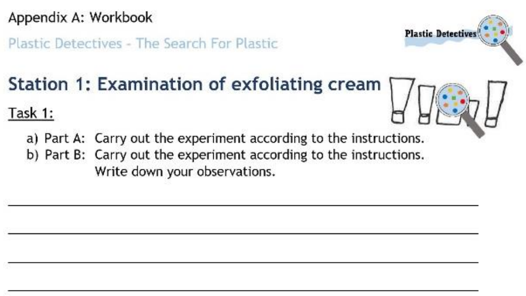
	Activity & Learning Content	Assessment	Time (min)
What is microplastic?	*Introduction (pre-group phase)* Teacher-guided learning & listening of students: • Teacher introduces into the issue "microplastic in aquatic ecosystems" • Teacher guides the students through the presentation, motivates and arouses students' interest • Teacher does not reveal too much yet, so that students are motivated to work out the content themselves • Students contribute and answer open questions in the workbook	Students independently check the correctness of their solution with the sample solution	20
The search for microplastic in everyday products	*Station 1: Examination of exfoliating cream* Hands-on learning: • Students filter exfoliating cream (dissolved in water) and extract microbeads • Students identify the plastic type of the microbeads • Students recognize problems of microbeads in sewage		20

The search for microplastic in everyday products	*Station 2: Examination of textiles* Hands-on learning: • Students wash fleece in soapy water and filter out fibers that detach from it • Students identify the plastic type of the fleece fibers • Students recognize the problems of synthetic fibers in sewage		20
The search for microplastic in everyday products	*Station 3: Mr. Experto looking for traces in the drugstore* Hands-on learning: • Students check personal-care products and detergents for microplastic		20
Microplastic in the environment	*Station 4: How does microplastic get to the beach?* Hands-on learning: • Students watch a film about insufficient filter systems in sewage treatment plants • Students create a flowchart on microplastics' path to the beach • Students define primary and secondary microplastics		20
Effects of microplastic	*Station 5: Microplastic in the environment – so what?!* Hands-on learning: • Students read a text about problems of marine animals caused by plastic • Students answer questions, create a food web, and discuss animals' and humans' burdens		20
Consumption options	*Station 6: Is there an alternative?* Hands-on learning: • Students play a plastic-memory game: they match related single-use, multiple-use, and alternative products • Students discuss the pros and cons of the products		20
Treatment strategies	*Station 7: Minimizing the problem* Hands-on learning and discussion of ideas: • Students answer questions of introduction again • Students recapitulate the content of stations and discuss approaches to reduce microplastic input into the environment		20
Evaluation	*Evaluation* Teacher-guided learning and discussion: • Students summarize and review group results • Students describe, discuss, and improve outcomes • Teacher ensures understanding and consolidates new knowledge	Joint review of the group results to overcome difficulties in comprehension, consolidate new knowledge, and extend students' interest	20

When starting the module, every student received a workbook (see Supplemental Material Appendix A), including all tasks that had to be fulfilled at each station. Further work materials and informational texts were set up at the respective stations (see Supplemental Material Appendix B). Figure 2 shows the setup of the stations in the classroom.

Figure 2. Setup of the stations in the classroom.

The tasks in the workbook and the work materials were self-explaining. The teacher acted as a supervisor or mentor and intervened only on request or in case of possible danger. After the student groups completed a station, they self-reliantly checked the correctness of their results with the sample solution (see Supplemental Material Appendix C). Thus, the groups worked uninterruptedly at their own pace. Figure 3 illustrates an example page of the workbook. Figure 4 shows the related instruction, which is placed at station 1. All other supplemental materials were available at the stations.



Appendix A: Workbook

Plastic Detectives - The Search For Plastic

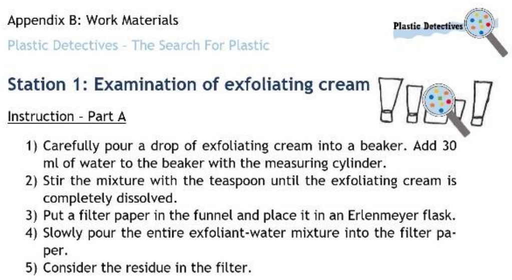
Plastic Detectives

Station 1: Examination of exfoliating cream

Task 1:

a) Part A: Carry out the experiment according to the instructions.
b) Part B: Carry out the experiment according to the instructions. Write down your observations.

Figure 3. Workbook section for station 1. Instruction and necessary materials are set up at station 1. Students filter exfoliating cream and extract microbeads. See Supplemental Material Appendix A.



Appendix B: Work Materials

Plastic Detectives - The Search For Plastic

Plastic Detectives

Station 1: Examination of exfoliating cream

Instruction - Part A

1) Carefully pour a drop of exfoliating cream into a beaker. Add 30 ml of water to the beaker with the measuring cylinder.
2) Stir the mixture with the teaspoon until the exfoliating cream is completely dissolved.
3) Put a filter paper in the funnel and place it in an Erlenmeyer flask.
4) Slowly pour the entire exfoliant-water mixture into the filter paper.
5) Consider the residue in the filter.

Figure 4. Instructions for station 1. All necessary materials are set up at the station. Students filter exfoliating cream and extract microbeads. See Supplemental Material Appendix B.

Introduction of Module

The module started with a short introductory phase, which had the objective of bringing the students to the same level of knowledge. Ensuring similar pre-knowledge has been shown earlier as essential for sufficient learning success (Scharfenberg & Bogner, 2011, 2013). The students read an explanatory dialogue (see Supplemental Material Appendix D) that addresses the environmental issue of microplastic. In this context, the students were given the lesson's focal problem: How does microplastic get to the beach? The students took the role of plastic detectives, with the goal of solving all tasks in the workbook in the course of the lesson. At the end of the introduction, the students answered questions on their own experiences with plastic, brainstormed about the entry points and whereabouts of plastics and microplastics in the environment, and formulated a standard definition of the term microplastic and wrote it down in their workbooks.

Learning Circle

The students were separated into groups to perform the detective work at the stations. Each group started at one station, worked for 20 minutes, and changed stations according to the given order (see Supplemental Material Appendix D). To ensure a smoothly running lesson, each station was set up twice. In their work as plastic detectives, the students had to track microplastic traces in everyday products as well as in textiles. Furthermore, they had to identify possible ways in which microplastics make it into the environment, potential ecological consequences, and prevention strategies. The following description of the stations gives detailed information about procedure and content.

Station 1: Examination of Exfoliating Cream

The students experimented with an exfoliating cream that contained a microplastic (polyethylene) as an exfoliator. Figure 5 shows the setup of the station in the classroom. After dissolving the exfoliating cream in water and filtering the solution, the students examined the residue under the microscope and described its shape and color (see Figure 6).

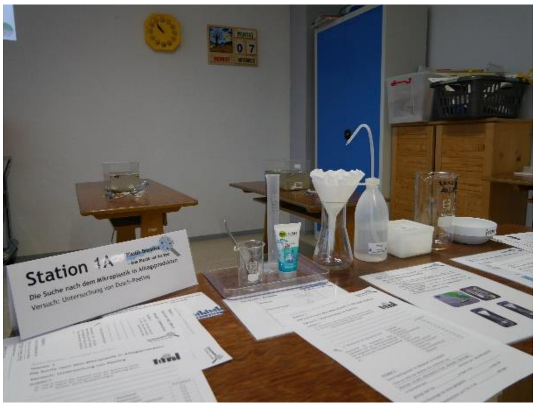
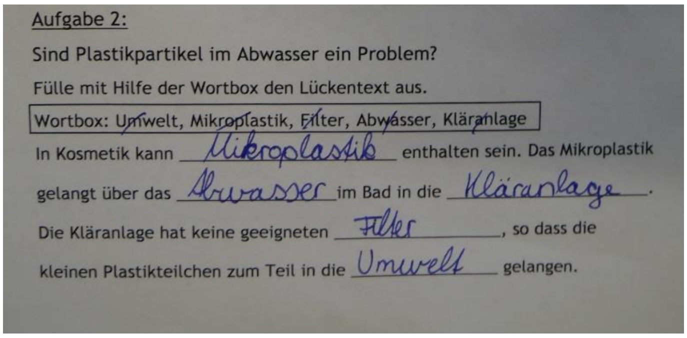


Figure 5. Setup of station 1 in the classroom.

Figure 6. Students examine microbeads under the microscope (station 1).

By studying a plastic list (Ziebarth, 2019) in the workbook, the students identified the plastic type of the residue. The students then edited a fill-in-the-blank text that informed them about insufficient filtration in sewage treatment plants bringing microbeads into waters (see Figure 7). All required materials are listed in Table 3. The material details in Tables 3–8 are based on a group size of four students.


Aufgabe 2:

Sind Plastikpartikel im Abwasser ein Problem?

Fülle mit Hilfe der Wortbox den Lückentext aus.

Wortbox: Umwelt, Mikroplastik, Filter, Abwasser, Kläranlage

In Kosmetik kann Mikroplastik enthalten sein. Das Mikroplastik gelangt über das Abwasser im Bad in die Kläranlage. Die Kläranlage hat keine geeigneten Filter, so dass die kleinen Plastikteilchen zum Teil in die Umwelt gelangen.

Figure 7. Exemplary solution of the fill-in-the-blank text at station 1. Translation: “Cosmetics may contain microplastics. Via wastewater, microplastics are transferred to the sewage treatment plant. The sewage treatment plant does not have appropriate filters, so some small plastic particles get into the environment.” For sample solution, see Supplemental Material Appendix C.

Station 2: Examination of Textiles

The students experimented by imitating the process of washing textiles in a washing machine by using a piece of cloth or blanket (fleece) in soapy water (see Figure 8). After filtering the water, the students examined the residue under the microscope. When closely looking at the shape and color of the residue, the students recognized it as small fibers, which had dissolved from the fleece during the process of washing. The label of the textile informed the students about its composition, namely 100 % polyester. A fill-in-the-blank text gave the students a further occupation with the topic of plastic particles in the laundry. Fibers that dissolve from clothes during washing enter sewage treatment plants via wastewater. Insufficient filtration by sewage treatment plants causes the introduction of microplastic fibers into waters. All required materials are listed in Table 3.

Figure 8. Students measure water for washing a piece of fleece (station 2).

Table 3. All required materials for stations 1 and 2, including quantity and estimated cost.

	Item	Quantity	Cost
Station 1 and 2	Plastic measuring cylinder (50 ml)	1	$ 4.25 [1]
	Plastic wash bottle (250 ml)	1	$ 4.95 [1]
	Plastic beaker (100 ml)	1	$ 3.00 [1]

	Plastic funnel	1	$ 1.70 [1]
	Erlenmeyer flask (250 ml)	1	$ 4.50 [1]
	Plastic tray/slide minimum size for use with filter: 10x10 cm; minimum size for use without filter: microplastic particles can be transferred to a microscope slide	1	$ 12.95 [1] (144/pack)
	Microscope for kids	1	$ 39.95 [1]
	Coffee filter (pore size 20 micrometers)	1	
	Teaspoon	1	
	Workbook (Supplementary Material Appendix A)	1 per student	
	Sample Solution (Supplementary Material Appendix C)	4	
Station 1	Laminated instructions "Part A & B" Laminated info-cards "Cosmetics" & "Exfoliating cream" Laminated lists "The most common plastics in cosmetics and their abbreviations" (Supplementary Material Appendix B)	4	
	Exfoliating cream containing microplastic	1	
Station 2	Laminated instructions "Part A & B" Laminated info-cards "Textiles" & "Polyester" (Supplementary Material Appendix B)	4	
	Piece of fleece blanket + label	1	
	Liquid soap	1	
	Teaspoon	1	

Note: If possible, the use of plastic equipment is preferable to other materials.
A possible source of supply: [1] https://labsuppliesusa.com/

Station 3: Mr. Experto Looking for Traces in the Drugstore

The students examined the ingredients of different personal-care products and detergents from a drugstore with the help of the plastic list (Ziebarth, 2019; see Supplemental Material Appendix B). By identifying products containing microplastic, the students were able to assess the eco-friendliness of products. Figure 9 shows the setup of station 3 in the classroom. All required materials are listed in Table 4.

Figure 9. Setup of station 3 in the classroom.

Table 4. All required materials for station 3.

Item	Quantity
Laminated list "The most common plastics in cosmetics and their abbreviations" (Supplemental Material Appendix B)	4
Diverse drugstore articles with and without microplastic (*e.g.*, toothpaste, bar of soap, detergent, shower gel, cream, sunscreen, exfoliating cream)	
Workbooks (Supplemental Material Appendix A)	1 per student
Sample solution (Supplemental Material Appendix C)	4

Station 4: How Does Microplastic Get to the Beach

The fourth station focused on the entry of microplastic into the environment and possible pathways to the beach. A short video (see explainitychannel, https://www.youtube.com/watch?v=49OJoTsZYO0) gave information about insufficient filter systems in sewage treatment plants, which release small microplastic particles into rivers, lakes, and finally the sea. After watching the video, the students sorted images that illustrate the microplastics' path to the sea into a flowchart (see Figures 10 and 11). Moreover, they developed ideas about how plastic products break down into smaller parts and eventually become microplastic. Thereby, the students learned the terms primary and secondary microplastics. All required materials are listed in Table 5.

Figure 10. Students watch an informational video about the entry of microplastic into the environment (station 4).

Figure 11. Students create a flowchart of microplastics' path to the sea (station 4).

Table 5. All required materials for station 4, including URL of informational video.

Item	Quantity
Laminated pictures for placement game (Supplemental Material Appendix B)	1
Sample solutions for gluing in the workbook (Supplemental Material Appendix B)	1 per student
Laptop to show video: https://www.youtube.com/watch?v=49OJoTsZYO0	1
Glue sticks	4
Workbooks (Supplemental Material Appendix A)	1 per student
Sample solution (Supplemental Material Appendix C)	4

Station 5: Microplastic in the Environment – So What?!

The students read a text named "Conference of Animals in the Sea" (for required materials, see Table 6 and Supplemental Material Appendix B). Students took on the roles of animals talking about diverse problems caused by plastic (see Figure 12). Thus, students learned that animals both small and large suffer from plastic in the sea. Small animals like plankton inadvertently ingest microplastic when filtering their food items, which has further negative impacts within the food web (*e.g.*, because plankton is food for herrings and whales). Furthermore, other animals such as birds confuse plastic or microplastic with food or eat it by mistake. The indigestibility of plastic can lead to serious health effects for the affected animals, which can even result in death by starvation. Moreover, some animals, like turtles, get injured by bigger plastic when they get caught in it. With the knowledge gained from the text, the students answered questions on the topic in their workbook. Moreover, the students created a food web and discussed the probability of animals and humans being burdened by microplastic.

Table 6. All required materials for station 5.

Item	Quantity
Laminated story "Conference of Animals in the Sea" (Supplemental Material Appendix B)	4
Red pens	4
Workbooks (Supplemental Material Appendix A)	1 per student
Sample solution (Supplemental Material Appendix C)	4

Figure 12. Students read the text "Conference of Animals in the Sea" (station 5).

Station 6: Is There an Alternative?

The students played a memory game in which they matched related single-use, multiple-use, and alternative products (Supplemental Material Appendix B). During this activity, they discussed advantages and disadvantages concerning price, weight, durability, amount of garbage, and the possibility of multiple uses. All required materials are listed in Table 7.

Table 7. All required materials for station 6.

Item	Quantity
Memory for playing (Supplemental Material Appendix B)	4
Memory for gluing in the workbook (Supplemental Material Appendix B)	1 per student
Glue sticks	4
Workbooks (Supplemental Material Appendix A)	1 per student
Sample solution (Supplemental Material Appendix C)	4

Station 7: Minimizing the Problem

The last station was edited at the end of the learning-circle activity after all students had finished stations 1–6. It aimed to recapitulate the content of the other stations and to explore possibilities for reducing the entry of microplastics and plastics into the environment. First, the students answered the questions of the introduction again and compared their answers with their initial ones. Then they collected ideas for reducing their personal microplastic and plastic use and wrote them down on leaflets (see Figures 13–15). Thus, all students could bring in their own ideas and solutions. Suggestions were communicated within the whole class and the best action strategies were discussed. As a conclusion, the leaflets were stuck to a poster in the classroom. All required materials are listed in Table 8.

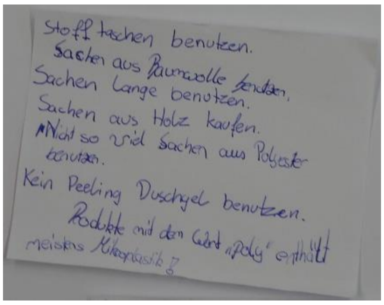


Figure 13. Exemplary leaflet with students' ideas for reducing microplastic and plastic entry into the environment at station 7. Translation: "Use cloth bags. Use cotton things. Use things for a long time. Buy things made of wood. Do not use so many polyester things. Do not use peeling shower gel. Products with the word poly mostly contain microplastic."

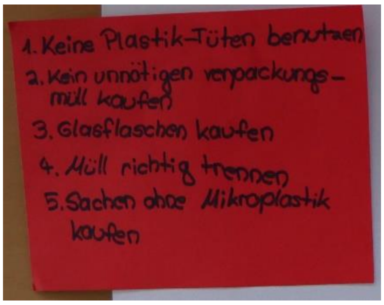


Figure 14. Exemplary leaflet with students' ideas for reducing microplastic and plastic entry into the environment at station 7. Translation: "Do not use plastic bags. Do not buy unnecessary packaging waste. Buy glass bottles. Proper separation of garbage. Buy things without microplastic."

Figure 15. Students collect ideas for how to minimize the problem of plastic and microplastic pollution (station 7).

Table 8. All required materials for station 7.

Item	Quantity
Poster (Supplemental Material Appendix B)	1
Leaflets	At least 1 per group
Glue sticks	4
Workbooks (Supplemental Material Appendix A)	1 per student
Sample solution (Supplemental Material Appendix C)	4

Evaluation

At the end of the module, the teacher recapitulated the content of every station with the whole class. A joint discussion of the results enabled the teacher to test the students' comprehensive understanding and helped the students consolidate newly gained knowledge.

Experiences from the Classroom

The module "Plastic Detectives – The Search for Plastic" was implemented with approximately 450 fourth-graders. The participating students and their teachers confirmed the suitability of the chosen methods to convey information on sources, contamination, fate, effects, and alternatives to microplastics and plastics. Students' independent work at the learning stations and in the workbook gave them an intensive engagement with the topic. During the module, the students worked swiftly and studiously. Notably, at stations 1 and 2, in which the students experimented with exfoliating cream and textiles, they developed great interest and motivation. At station 3, some students voiced difficulties with the identification of cosmetics with microplastic ingredients; however, advice regarding their readingstrategy took effect. The summarizing evaluation proved students' understanding of the module's contents.

Conclusion

Microplastic is a central environmental threat in the world of today. Plastics and microplastics that enter the environment accumulate and are distributed around the globe. Therefore, it is of high relevance to enlighten students at an early stage of their school career about the consequences of microplastic in our ecosystems. Informing students about the effects of microplastic pollution is one of the main objectives of our module "Plastic Detectives – The Search for Plastic." The module also gives students insights regarding microplastic and plastic sources in daily life, as well as eco-friendly alternatives. The final discussion about potential solutions gives the students food for thought about how to individually minimize the use of plastics and microplastics and to act as models for a sustainable life.

Supplemental Material

Appendix A: Workbook

Appendix B: Work Materials

Appendix C: Sample Solution

Appendix D: PowerPoint Presentation

Acknowledgments

First of all, we are very grateful to Tabea Loermann-Knöchel, who designed the module "Plastic Detectives – The Search for Plastic." Moreover, we want to thank all the participating students for taking part in our learning module and study. This research was funded by the University of Bayreuth and by PLAWES (BMBF-Grant: 03F0789A). This article reflects only the authors' views, and BMBF is not liable for any use that might be made of the information contained herein.

References

Barnes, D.K.A., Galgani, F., Thompson, R.C. & Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society of London*, *364*, 1985–1998.

Browne, M.A. (2015). Sources and pathways of microplastics to habitats. In M. Bergmann, L. Gutow & M. Klages (Eds.), *Marine Anthropogenic Litter* (pp. 229–244). Dordrecht, The Netherlands: Springer.

Browne, M.A., Crump, P., Niven, S.J., Teuten, E., Tonkin, A., Galloway, T. & Thompson, R. (2011). Accumulation of microplastic on shorelines worldwide: sources and sinks. *Environmental Science & Technology*, *45*, 9175–9179.

Browne, M.A., Galloway, T. & Thompson, R. (2007). Microplastic-an emerging contaminant of potential concern? *Integrated Environmental Assessment and Management*, *3*, 559–561.

Cole, M., Lindeque, P., Halsband, C. & Galloway, T.S. (2011). Microplastics as contaminants in the marine environment: a review. *Marine Pollution Bulletin*, *62*, 2588–2597.

Duis, K. & Coors, A. (2016). Microplastics in the aquatic and terrestrial environment: sources (with a specific focus on personal care products), fate and effects. *Environmental Sciences Europe*, *28*(2), 1-25.

Fendall, L.S. & Sewell, M.A. (2009). Contributing to marine pollution by washing your face: microplastics in facial cleansers. *Marine Pollution Bulletin*, *58*, 1225–1228.

GESAMP (2016). Sources, fate and effects of microplastics in the marine environment: part two of a global assessment. IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection.

Goldstein, M.C., Rosenberg, M. & Cheng, L. (2012). Increased oceanic microplastic debris enhances oviposition in an endemic pelagic insect. *Biology Letters*, *8*, 817–820.

Hartley, B.L., Thompson, R.C. & Pahl, S. (2015). Marine litter education boosts children's understanding and self-reported actions. *Marine Pollution Bulletin*, *90*, 209–217.

Napper, I.E. & Thompson, R.C. (2016). Release of synthetic microplastic plastic fibres from domestic washing machines: Effects of fabric type and washing conditions. *Marine Pollution Bulletin*, *112*, 39–45.

NGSS Lead States (2013). *Next Generation Science Standards: For States, by States*. Washington, DC: National Academies Press.

PlasticsEurope (2019). *Plastics - the Facts 2019: An analysis of European Plastics Production, Demand and Waste Data*. https://www.plasticseurope.org/de/resources/publications/2154-plastics-facts-2019.

Rochman, C.M. (2018). Microplastics research-from sink to source. *Science*, *360*, 28–29.

Scharfenberg, F.-J. & Bogner, F.X. (2011). A new two-step approach for hands-on teaching of gene technology: effects on students' activities during experimentation in an outreach gene technology lab. *Research in Science Education*, *41*, 505–523.

Scharfenberg, F.-J. & Bogner, F.X. (2013). Teaching gene technology in an outreach lab: students' assigned cognitive load clusters and the clusters' relationships to learner characteristics, laboratory variables, and cognitive achievement. *Research in Science Education*, *43*, 141–161.

United States (2015). *Microbead-Free Waters Act of 2015*. https://www.congress.gov/114/plaws/publ114/PLAW-114publ114.pdf.

Wetherbee, G.A., Baldwin, A.K. & Ranville, J.F. (2019). *It is raining plastic*. Geological Survey Open-File Report 2019-1048.

Xanthos, D. & Walker, T.R. (2017). International policies to reduce plastic marine pollution from single-use plastics (plastic bags and microbeads): A review. *Marine Pollution Bulletin*, *118*, 17–26.

Ziebarth, N. (2019). *Mikroplastik und andere Kunststoffe in Kosmetika: Der BUND-Einkaufsratgeber*. https://www.bund.net/fileadmin/user_upload_bund/publikationen/meere/meere_mikroplastik_einkaufsfuehrer.pdf.

PATRICIA RAAB (patricia.raab@uni-bayreuth.de) is a doctoral student and FRANZ X. BOGNER is a Professor in the Department of Biology Education, Z-MNU (Centre of Math & Science Education), University of Bayreuth, NW-1, D-95447, Germany.

Plastic Detectives
The Search For Plastic

Workbook

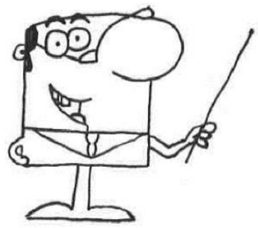
name: ______________________________

class: ______________________________

date: ______________________________

Appendix A: Workbook

Plastic Detectives – The Search For Plastic



Dear student,

This workbook will accompany you through the individual stations in the room. For each station, there are tasks that you solve in this workbook. So you learn a lot about the current topic of microplastics.

Some information about the implementation:

- Start with the station assigned to you. Then work the stations in sequence, for example: 1 → 2 → 3 → 4 → 5
- The work materials and work instructions can be found in the workplace of the station.
- Exception: Station 4 is processed by all groups at the end.
- Edit a station entirely before starting a new one. After finishing a station, put everything back the way you found it.
- Tick already completed stations in the table below.

I wish you a lot of fun, and I am glad that you work with me today.

Your Mr. Experto

	Done: ✓
Station 1	
Station 2	
Station 3	
Station 4	
Station 5	
Station 6	
Station 7	

Appendix A: Workbook

Plastic Detectives

Plastic Detectives – The Search For Plastic

Introduction: What is microplastic?

Answer the following questions.

a) Which things that you own or use are made out of plastic?

b) Where in the environment have you seen plastic or microplastic?

c) Diagram how plastic or microplastic might get from your house to the beach.

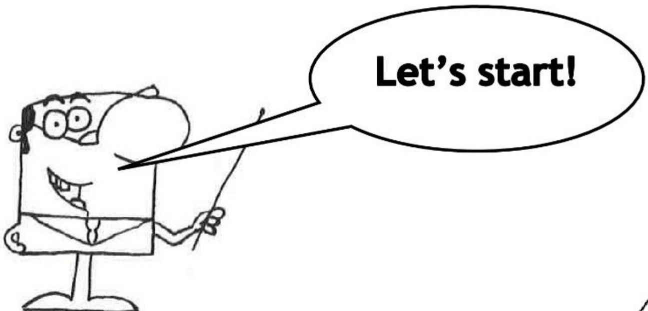
Appendix A: Workbook

Plastic Detectives – The Search For Plastic

Introduction: What is microplastic?

d) What will happen to Emma and Lenny's beach toys, if they forget them on the beach? Collect ideas with your group.

e) Define the term microplastic.



Appendix A: Workbook

Plastic Detectives – The Search For Plastic

Station 1: Examination of exfoliating cream

Task 1:

a) Part A: Carry out the experiment according to the instructions.
b) Part B: Carry out the experiment according to the instructions.
Write down your observations.

____

____

____

____

c) What could be the residue?

Examine the ingredients on the exfoliating cream package and compare it to the plastic list.

Can you identify the material?

The exfoliating cream contains microplastic called ____________________________.

Plastic in cosmetics
polyethylene
polypropylene
polyethylene terephthalate
nylon-12
nylon-6
polyurethane
acrylate copolymer
acrylate crosspolymer
polyacrylate
polymethylmethacrylate
polystyrene
polyquaternium

Task 2: Are plastic particles in wastewater a problem?

Use the word box and the card to fill in the blanks.

Word box: environment, microplastics, wastewater, sewage treatment plant, microbeads

Cosmetics may contain ____________. Exfoliating creams clean the skin with the help of abrasives (e.g., ______________). Via ____________, the microbeads are transferred to the ____________________. The sewage treatment plant cannot completely retain the microplastics, so some small plastic particles get into the ___________________.

Appendix A: Workbook

Plastic Detectives – The Search For Plastic

Station 2: Examination of textiles

Task 1:

a) Part A: Carry out the experiment according to the instructions.
b) Part B: Carry out the experiment according to the instructions.
Write down your oberservations.

____

____

____

____

c) What could be the residue?
Find out about the composition of the substance on the label.

The fabric is 100% ______________________________.

Task 2: Are plastic particles in the laundry a problem?

Use the word box and the card to fill in the blanks. Orally explain the effects of plastic particles in the wash.

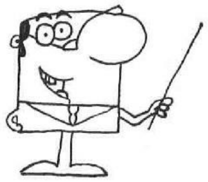
Word box: plastic, lints, sewage treatment plant, wastewater, environment, plastic particles

From the fabric (plastic fibers), which consists of ______________, __________________ dissolve. These ___________________ flow via the washing machine and its _______________________ into the ____________________________. The sewage treatment plant cannot completely retain the microplastics, so some small plastic particles get into the _____________________.

Appendix A: Workbook

Plastic Detectives – The Search For Plastic

Station 3: Mr. Experto looking for traces in the drugstore



Task:

Mr. Experto has recently been shopping in the drugstore.

Look at the ingredients of the purchased items and use the plastic list to identify the products that contain plastic. Write down these articles.

Share the work in the group and then exchange it.

Article	Plastic contained?	
	YES	NO

Attention, tell a friend!

Look at the ingredients when buying cosmetics. If plastic is included, then do not buy the item.

Tip: Words that contain "poly" are an indication of plastic.

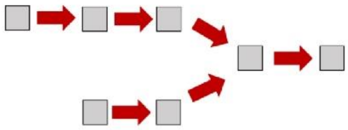
Appendix A: Workbook

Plastic Detectives – The Search For Plastic

Station 4: How does the microplastic get to the beach?

Task 1: Watch the short information film.

Task 2: Sort the laminated images into a flowchart. The lower scheme will help you.



Paste the sample solution here:

sample solution

Task 3: After you've laid and checked the pictures, explain each other the question: "How does microplastics get to the beach?".

For experts:

Try to explain the terms **primary microplastics and secondary microplastics** using the graphic.

„primary“ = first available, „secundary“ = later added

____

____

____

____

Appendix A: Workbook

Plastic Detectives – The Search For Plastic

Station 5: Microplastic in the environment – so what?!

Task 1: Take the roles of the animals in "Conference of Animals in the Sea".

Read the text and answer the following questions.

a) Why are the animals meeting for a conference?

____

____

____

b) What problem of the animals stood out to you?

____

____

____

c) Which animal do you think is struggling the most? Explain why.

____

____

____

d) What problems do the animals have with the microplastic (plastic particles smaller than 5 mm)? Tick the right sentences.

☐	Plastic can be confused with food.	☐	If an animal dies, it can affect other animals (food web).
☐	Microplastics can be digested by fish.	☐	Humans also consume microplastic via food.
☐	Microplastics can accumulate toxic substances that endanger animals.	☐	Humans protect animals from microplastics.
☐	Animals need microplastics as food.	☐	Plastic is indigestible and does not provide energy.
☐	Animals can get caught in plastic and hurt.	☐	Animals need plastic for swimming.

Appendix A: Workbook

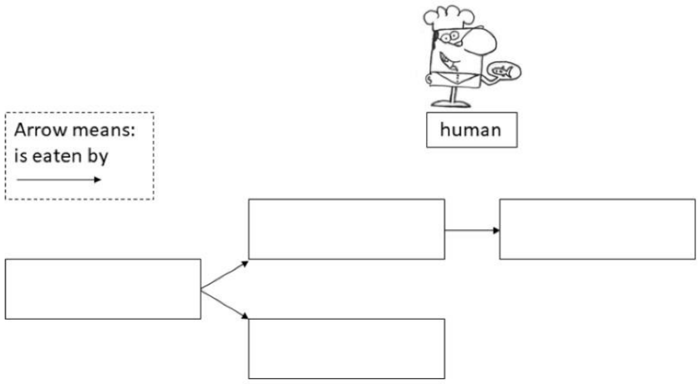
Plastic Detectives – The Search For Plastic

Station 5: Microplastic in the environment – so what?!

<u>Task 2:</u>

a) Write down the food web beginning with plankton (small crustaceans). Take the text as an aid and fill in the boxes below.

Words: blue whale, herring, plankton, tuna



b) If microplastic is present in the plankton, then it can enter the food web. Use a red pencil to surround animals burdened with microplastics.

c) Does it affect humans when microplastics are in the food web? Discuss with your group members which marine animals you like to eat and consider whether humans are also burdened by microplastics (possibly red box).

____

____

____

Appendix A: Workbook

Plastic Detectives – The Search For Plastic

Station 6: Is there an alternative?

<u>Task 1:</u> Play the plastic-memory and match the related single-use, multiple-use and alternative products, respectively the least to the most sustainable products.

<u>Task 2:</u> Paste the sample solution here.

Write down the pros and cons of the products (e.g., concerning price, weight, durability, amount of garbage, single-use/multiple-use).

____________________ ____________________ ____________________ ____________________	____________________ ____________________ ____________________ ____________________	____________________ ____________________ ____________________ ____________________
____________________ ____________________ ____________________ ____________________ ____________________	____________________ ____________________ ____________________ ____________________ ____________________	____________________ ____________________ ____________________ ____________________ ____________________

Appendix A: Workbook

Plastic Detectives – The Search For Plastic

Appendix A: Workbook

Plastic Detectives – The Search For Plastic

Appendix A: Workbook

Plastic Detectives – The Search For Plastic

Station 7: Minimizing the problem

Task 1: Answer the following questions again.

a) Which things that you own or use are made out of plastic?

____

____

____

b) Where in the environment have you seen plastic or microplastic?

____

____

____

c) Diagram how plastic or microplastic might get from your house to the beach.

d) Compare your initial with your final answers. Talk about your newly acquired knowledge with your group. Finally, we will talk about it together in class.

Appendix A: Workbook

Plastic Detectives – The Search For Plastic

Station 7: Minimizing the problem

Task 2:

In more and more ecosystems, such as rivers and seas, microplastic is found.

What can you do, so that less plastic/microplastic gets into the environment? Write down your suggestions on the leaflets and keep them until debriefing.

Finally, we will talk about the subject together and create a poster that you can hang in the classroom.

Appendix B: Work Materials

Plastic Detectives – The Search For Plastic

Station 1: Examination of exfoliating cream

<u>Instruction – Part A</u>

1) Carefully pour a drop of exfoliating cream into a beaker. Add 30 ml of water to the beaker with the measuring cylinder.
2) Stir the mixture with the teaspoon until the exfoliating cream is completely dissolved.
3) Put a filter paper in the funnel and place it in an Erlenmeyer flask.
4) Slowly pour the entire exfoliant-water mixture into the filter paper.
5) Consider the residue in the filter.

Appendix B: Work Materials

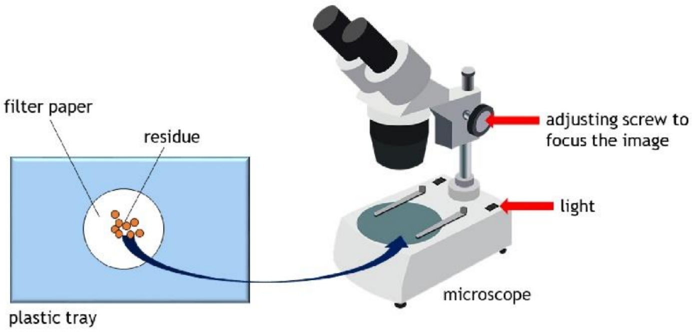
Plastic Detectives – The Search For Plastic

Station 1: Examination of exfoliating cream

Instruction – Part B

Put the filter paper in a plastic dish and place it under the microscope. Look into the microscope and focus on the image with the help of the adjusting screw.

Look at the residue with the microscope. Describe your observation and record it in your workbook.



Appendix B: Work Materials

Plastic Detectives – The Search For Plastic

Station 1: Examination of exfoliating cream

Info: Cosmetics

Cosmetics are body and beauty care products, which can be bought in the drugstore.

Info: Exfoliating cream

- Exfoliating cream is a cosmetic product, which is used to clean the skin. For this purpose, it contains small particles (abrasives) that eliminate skin impurities by applying it in circling movements.
- Abrasives can be of natural or artificial offspring:
    - Natural abrasives: e.g., sea salt, bamboo granulate, coffee
    - Synthetic abrasives: microbeads (e.g., polyethylene)
- The cosmetics industry often uses microbeads instead of natural abrasives because microbeads clean the skin thoroughly and are cheap.

Appendix B: Work Materials

Plastic Detectives – The Search For Plastic

Station 2: Examination of textiles

Instruction – Part A

1) Take a beaker, add a bit of soap ("a splash") and 30 ml of water with the measuring cylinder.
2) A small piece of cloth (Fleece®) is then placed in the soapy water and stirred well with the teaspoon.
3) Put a filter paper in the funnel and place it in an Erlenmeyer flask.
4) Slowly pour the entire wash into the filter paper.
5) Consider the residue in the filter paper.

Appendix B: Work Materials

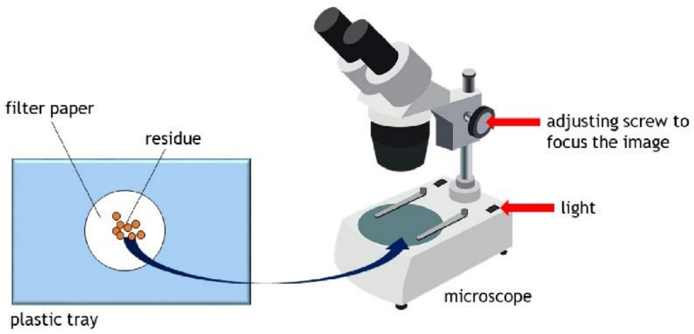
Plastic Detectives – The Search For Plastic

Station 2: Examination of textiles

Instruction – Part B

Put the filter paper in a plastic dish and place it under the microscope. Look into the microscope and focus on the image with the help of the adjusting screw.

Look at the residue with the microscope. Describe your observation and record it in your workbook.



Appendix B: Work Materials

Plastic Detectives – The Search For Plastic

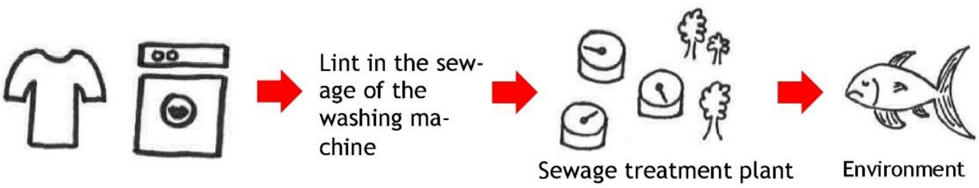
Station 2: Examination of textiles

Info: Textiles

Textiles are, for example, clothes or blankets made out of fabric.

Info: Polyester

- Polyester is a plastic, from which, among other things, many garments are made.
- From such materials (plastic fibers) lint can dissolve during washing.



Appendix B: Work Materials

Plastic Detectives – The Search For Plastic

Station 3: Mr. Experto looking for traces in the drugstore

The most common plastics in cosmetics and their abbreviations

plastic	abbreviation
polyethylene	PE
polypropylene	PP
polyethylene terephthalate	PET
nylon-12	Nylon-12
nylon-6	Nylon-6
polyurethane	PUR
acrylate copolymer	AC
acrylate crosspolymer	ACS
polyacrylate	PA
polymethylmethacrylate	PMMA
polystyrene	PS
polyquaternium	PQ

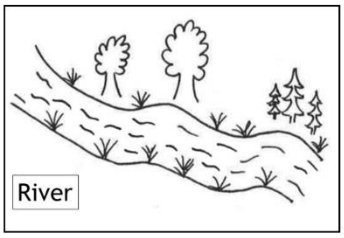
Source: Ziebarth, N. (2019). Mikroplastik und andere Kunststoffe in Kosmetika: Der BUND-Einkaufsratgeber. Bund für Umwelt und Naturschutz Deutschland: https://www.bund.net/fileadmin/user_upload_bund/publikationen/meere/meere_mikro-plastik_einkaufsfuehrer.pdf (online 01.08.2019)

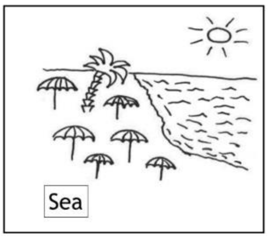
Appendix B: Work Materials

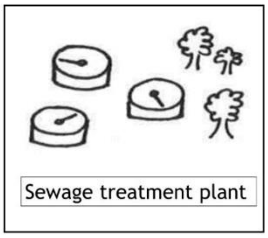
Plastic Detectives – The Search For Plastic

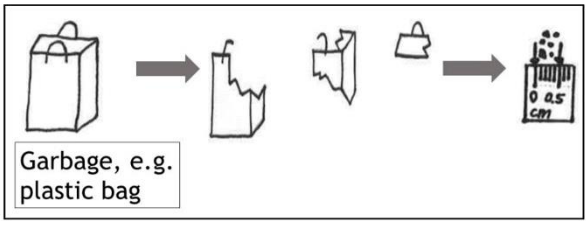
Station 4: How does the microplastic get to the beach?

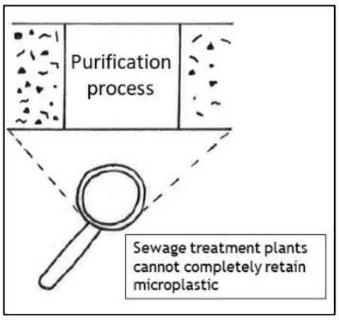
Images for the flowchart:

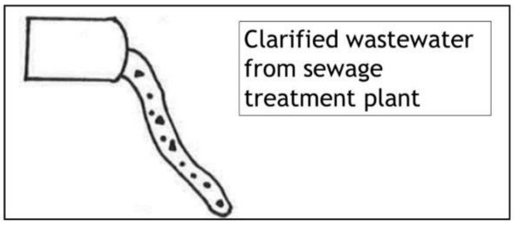








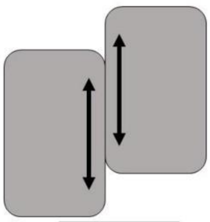




Info: Why does a plastic bag break down?

In the environment, plastic is exposed to external influences that lead to the disintegration of it into smaller plastic pieces. The UV radiation of the sun (the amount of sunlight that causes sunburn) causes the plastic to become porous and disintegrate into smaller pieces. Also the friction, e.g. through swell, favors fragmentation.

UV radiation from the sun



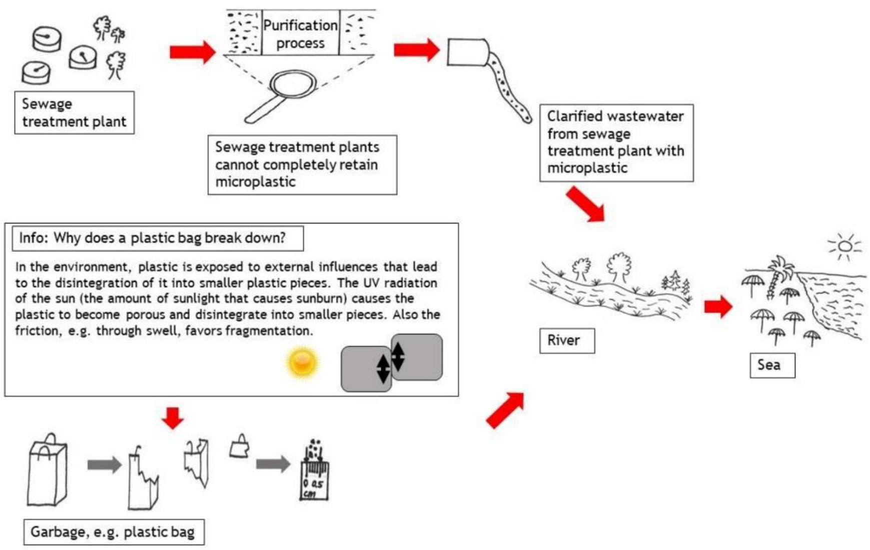
friction

Appendix B: Work Materials

Plastic Detectives – The Search For Plastic

Station 4: How does the microplastic get to the beach?

<u>Sample solution for workbook:</u>



Appendix B: Work Materials

Plastic Detectives – The Search For Plastic

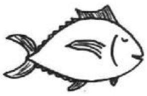
Station 5: Microplastic in the environment – so what?!

Conference of animals in the sea

In the sea, there are more and more environmental problems that affect marine life. Therefore, some sea creatures meet, although some would like to eat each other. They talk about their problems due to the growing plastic pollution.

Fred, the little herring: “Hello, my name is Fred, and I live in the sea. I like to eat plankton. Do you know what plankton is? These are tiny crustaceans floating in the sea. For a few years, I sometimes accidentally eat small plastic particles (microplastics). I was told it's called microplastic. I can eat it, but I cannot digest it. So although I eat a lot, I'm not energized. If I continue to eat microplastics now, I'll probably starve to death.“

Figure 1: Plankton.



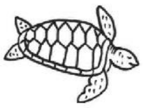
Fridolin, the big tuna: “Oh, that would be a pity. I love to eat small herrings. I eat fish, digest it, and get my energy. I can only live if I can eat enough smaller fish like Fred. If Fred and the other little fish were to die, then I would always be hungry.“

Berta, the blue whale: “What are you saying, Fred? There are small plastic particles in plankton? I eat plankton and live on it. A smart fish told me that toxic substances could adhere to tiny plastic particles (microplastics). I'm afraid I'm going to poison myself!“

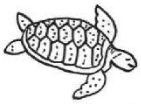
Figure 1: Microplastic can transport toxic substances.

Appendix B: Work Materials

Plastic Detectives – The Search For Plastic

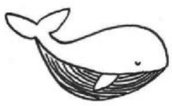


Sarah, the sea turtle: "A few days ago, I saw a turtle caught in a large plastic piece. Her whole body was deformed. If she keeps growing, she will probably die."

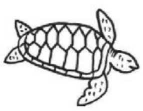


Martin, the sea turtle: "That's terrible. Something happened to me this morning, too. I wanted to eat a jellyfish for breakfast, and I noticed just in time that this jellyfish was not a jellyfish. It was a plastic bag floating in the sea. Imagine what could have happened?"

Fred, the little herring: "Listening to all this, I realize that we all have many problems due to the pollution caused by humans. I've seen people on a boat trip who just threw their plastic wrappers of the food in the sea. And some friends of mine even got caught by old fishing nets which got lost. These so-called ghost nets float uncontrollably in the sea, capturing all kinds of animals, which cannot extricate themselves out of the net and presumably die. If these nets are not removed by humans, they continue to fish for decades or longer."



Berta, the blue whale: "I cannot believe that humans behave as if they were alone in the world. But why do they think that they can do what they want? Sooner or later, humans will also suffer from our problems. Humans like to eat fish, and if they eat me, then they also take up microplastic. So far, no one knows concrete consequences."



Sarah, the sea turtle: "Humans should change their behavior to help us and eventually themselves."

Appendix B: Work Materials

Plastic Detectives

Plastic Detectives – The Search For Plastic

Station 6: Is there an alternative?


Disposable bottle


Reusable plastic bottle


Glass bottle


Foil


Plastic lunch box


Stainless steel lunch box


Chocolate surprise egg


Plastic toy


Wooden toy

Plastic soap dispenser

Refill pack


Bar of soap

Appendix B: Work Materials

Plastic Detectives – The Search For Plastic


Plastic bag

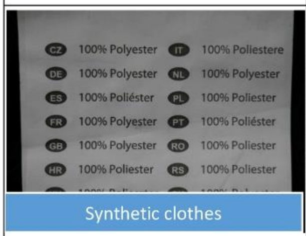

Reusable plastic bag


Jute bag


Food package


Plastic string bag


Cotton string bag



Synthetic clothes

Clothes: synthetic/natural blend

Natural clothes


Exfoliating cream with microplastic


Exfoliating cream without microplastic


Homemade exfoliating cream with natural ingredi-ents (coffee)

Appendix B: Work Materials

Plastic Detectives – The Search For Plastic

Station 7: Minimizing the problem

Poster

Plastic Detectives
The Search For Plastic

Workbook

name: ______________________________

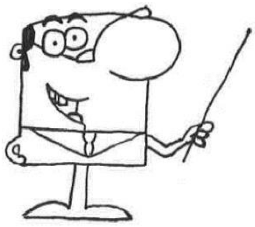
class: ______________________________

date: ______________________________

Appendix C: Sample Solution

Plastic Detectives – The Search For Plastic

Plastic Detectives



Dear student,

This workbook will accompany you through the individual stations in the room. For each station, there are tasks that you solve in this workbook. So you learn a lot about the current topic of microplastics.

Some information about the implementation:

- Start with the station assigned to you. Then work the stations in sequence, for example: 1 → 2 → 3 → 4 → 5
- The work materials and work instructions can be found in the workplace of the station.
- Exception: Station 4 is processed by all groups at the end.
- Edit a station entirely before starting a new one. After finishing a station, put everything back the way you found it.
- Tick already completed stations in the table below.

I wish you a lot of fun, and I am glad that you work with me today.

Your Mr. Experto

	Done: ✓
Station 1	
Station 2	
Station 3	
Station 4	
Station 5	
Station 6	
Station 7	

Appendix C: Sample Solution

Plastic Detectives – The Search For Plastic

Introduction: What is microplastic?

Answer the following questions.

a) Which things that you own or use are made out of plastic?

Personal opinion of the students.

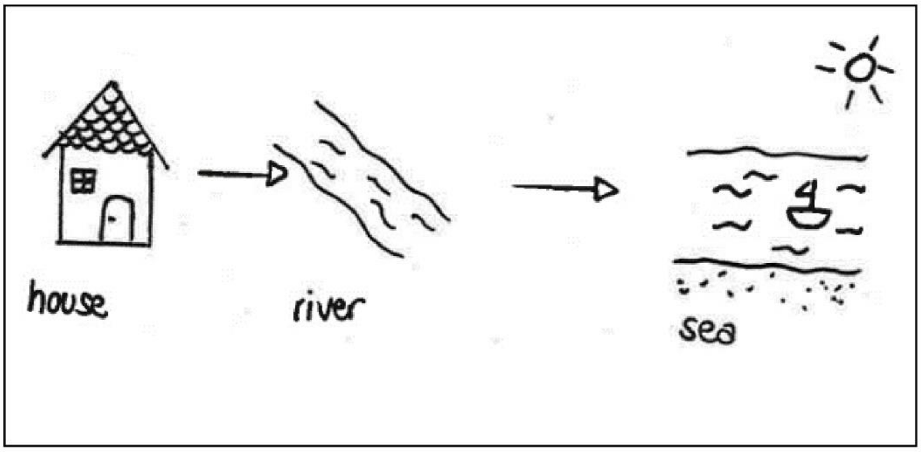
For example: toothbrush, toys, water bottle, lunchbox, pens, ruler

b) Where in the environment have you seen plastic or microplastic?

Personal experience of the students.

For example: beach, meadow, forest, river, sea, roadside

c) Diagram how plastic or microplastic might get from your house to the beach.



Appendix C: Sample Solution

Plastic Detectives – The Search For Plastic

Plastic Detectives

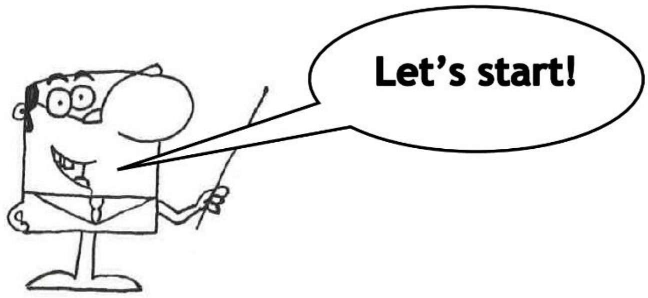
Introduction: What is microplastic?

d) What will happen to Emma and Lenny's beach toys, if they forget them on the beach?

If nobody takes the toys with him, they will lie on the beach and disintegrate into smaller pieces, e.g., through sunlight and friction.

e) Define the term microplastic.

Plastic particles that are smaller than 5 mm are called microplastic.

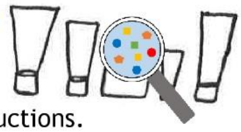


Plastic Detectives
The Search For Plastic

Appendix C: Sample Solution

Plastic Detectives – The Search For Plastic

Station 1: Examination of exfoliating cream



Task 1:

a) Part A: Carry out the experiment according to the instructions.
b) Part B: Carry out the experiment according to the instructions. Write down your observations.

When filtering the exfoliating cream, small particles remain on the filter paper. These look like little blue grains under the microscope.

c) What could be the residue?

Examine the ingredients on the exfoliating cream package and compare it to the plastic list.

Can you identify the material?

The exfoliating cream contains microplastic called polyethylene.

Plastic in cosmetics
polyethylene
polypropylene
polyethylene terephthalate
nylon-12
nylon-6
polyurethane
acrylate copolymer
acrylate crosspolymer
polyacrylate
polymethylmethacrylate
polystyrene
polyquaternium

Task 2: Are plastic particles in wastewater a problem?

Use the word box and the card to fill in the blanks.

Word box: environment, microplastics, wastewater, sewage treatment plant, microbeads

Cosmetics may contain _microplastics_. Exfoliating creams clean the skin with the help of abrasives (e.g., _microbeads_). Via _wastewater_, the microbeads are transferred to the _sewage treatment plant_. The sewage treatment plant cannot completely retain the microplastics, so some small plastic particles get into the ___environment___.

Appendix C: Sample Solution

Plastic Detectives – The Search For Plastic

Station 2: Examination of textiles

Task 1:

a) Part A: Carry out the experiment according to the instructions.
b) Part B: Carry out the experiment according to the instructions.
Write down your observations.

From the black fleece fabric, small fibers are released during washing.

These look like short black hair under the microscope.

c) What could be the residue?
Find out about the composition of the substance on the label.
The fabric is 100% Polyester.

Task 2: Are plastic particles in the laundry a problem?

Use the word box and the card to fill in the blanks. Orally explain the effects of plastic particles in the wash.

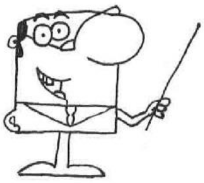
Word box: plastic, lints, sewage treatment plant, wastewater, environment, plastic particles

From the fabric (plastic fibers), which consists of _____plastic____, _____lints______ dissolve. These ______plastic particles______ flow via the washing machine and its ____wastewater_______ into the _____sewage___ ___treatment plant_______. The sewage treatment plant cannot completely retain the microplastics, so some small plastic particles get into the ____environment___.

Appendix C: Sample Solution

Plastic Detectives – The Search For Plastic

Station 3: Mr. Experto looking for traces in the drugstore



Task:

Mr. Experto has recently been shopping in the drugstore.

Look at the ingredients of the purchased items and use the plastic list to identify the products that contain plastic. Write down these articles.

Share the work in the group and then exchange it.

Article	Plastic contained?	
Examples of drugstore articles:	YES	NO
Toothpaste (Rossmann: Perlodent med, Sensitiv)		X
Eyeshadow (Catrice: The Fresh Nude Collection Eyeshadow Palette)	X	
Make-Up (Maybelline: Fit me, Matte+Poreless, 120)	X	
Detergent (Ariel: heavy-duty detergent)		X
Washing Gel (Balea: Clarifying wash gel with fruit acid, combination skin)		X
Soap (Balea: Savona Cream Soap: Milk & Honey)		X
Powder (Manhatten: Soft Compact Powder, Natural Look, Naturelle)	X	

Attention, tell a friend!

Look at the ingredients when buying cosmetics. If plastic is included, then do not buy the item better.

Tip: Words that contain "poly" are an indication of plastic.

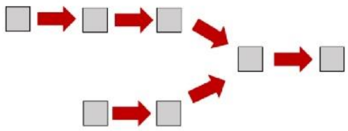
Appendix C: Sample Solution

Plastic Detectives – The Search For Plastic

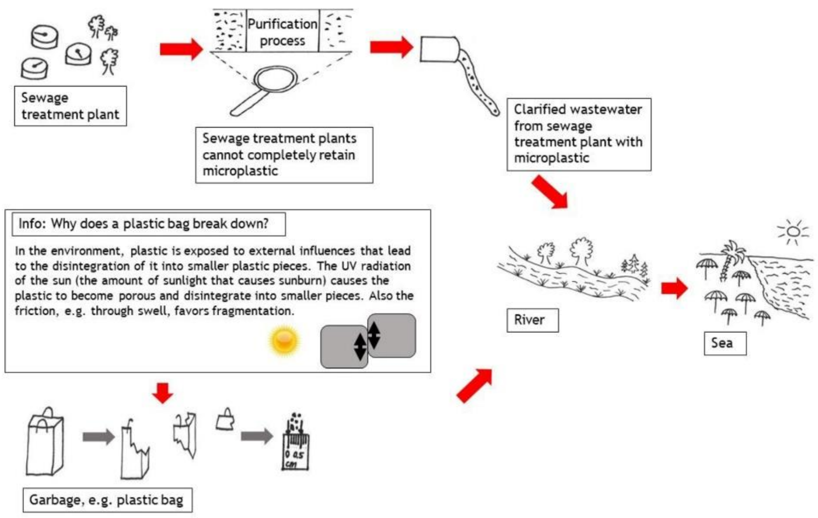
Station 4: How does the microplastic get to the beach?

<u>Task 1:</u> Watch the short information film.

<u>Task 2:</u> Sort the laminated images into a flowchart. The lower scheme will help you.



Paste the sample solution here:



<u>Task 3:</u> After you've laid and checked the pictures, explain each other the question: "How does microplastics get to the beach?".

<u>For experts:</u>

Try to explain the terms **primary microplastics and secondary microplastics** using the graphic.

„primary" = first available, „secondary" = later added

Primary microplastics are fine plastic particles, e.g., for the cosmetics industry. Secondary microplastics are fine plastic particles that result from the disintegration of large pieces of plastic.

Appendix C: Sample Solution

Plastic Detectives – The Search For Plastic

Station 5: Microplastic in the environment – so what?!

Task 1: Take the roles of the animals in "Conference of Animals in the Sea".

Read the text and answer the following questions.

a) Why are the animals meeting for a conference?

The animals are meeting for a conference to talk about their experiences due to the growing plastic pollution in their habitat.

b) What problem of the animals stood out to you?

Personal opinion of the students.

For example: The animals eat microplastic without noticing and probably starve to death because of it.

c) Which animal do you think is struggling the most? Explain why.

Personal opinion of the students.

For example: I think the whale is struggling the most because it is at the end of the food web.

d) What problems do the animals have with the microplastic (plastic particles smaller than 5 mm)? Tick the right sentences.

☒	Plastic can be confused with food.	☒	If an animal dies, it can affect other animals (food web).
☐	Microplastics can be digested by fish.	☒	Humans also consume microplastic via food.
☒	Microplastics can accumulate toxic substances that endanger animals.	☐	Humans protect animals from microplastics.
☐	Animals need microplastics as food.	☒	Plastic is indigestible and does not provide energy.
☒	Animals can get caught in plastic and hurt.	☐	Animals need plastic for swimming.

Appendix C: Sample Solution

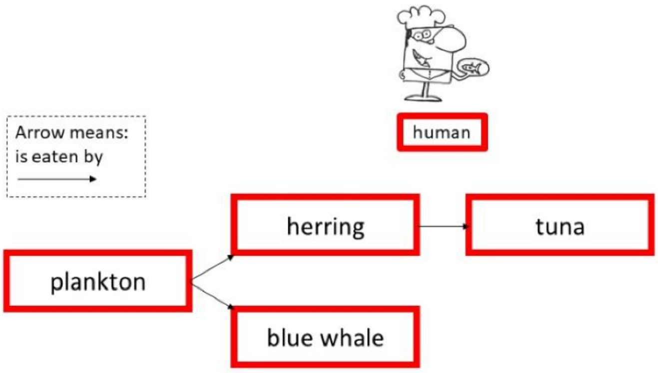
Plastic Detectives – The Search For Plastic

Station 5: Microplastic in the environment – so what?!

Task 2:

a) Write down the food web beginning with plankton (small crustaceans). Take the text as an aid and fill in the boxes below.

Words: blue whale, herring, plankton, tuna



b) If microplastic is present in the plankton, then it can enter the food web. Use a red pencil to surround animals burdened with microplastics.

c) Does it affect humans when microplastics are in the food web? Discuss with your group members which marine animals you like to eat and consider whether humans are also burdened by microplastics (possibly red box).

Yes, it can affect humans.

Personal taste or nutritional habits of the students.

For example: I like to eat fish and mussels. If I eat a mussel, which has filtered microplastic, I also eat microplastic.

Appendix C: Sample Solution

Plastic Detectives – The Search For Plastic

Plastic Detectives

Station 6: Is there an alternative?

Task 1: Play the plastic-memory and match the related single-use, multiple-use and alternative products, respectively the least to the most sustainable products.

Task 2: Paste the sample solution here.

Write down the pros and cons of the products (e.g., concerning price, weight, durability, amount of garbage, single-use/multiple-use).

 **Disposable bottle** light cheap unbreakable single-use a lot of garbage	 **Reusable plastic bottle** light nonrecurring acquisition costs +/- unbreakable multiple-use +/- garbage	 **Glass bottle** heavy nonrecurring acquisition costs fragile multiple-use no garbage
 **Foil** light cheap hygienic leaking single-use a lot of garbage	 **Plastic lunch box** light nonrecurring acquisition costs daily rinsing tight multiple-use +/- garbage	 **Stainless steel lunch box** light nonrecurring acquisition costs daily rinsing leaking multiple-use no garbage

Appendix C: Sample Solution

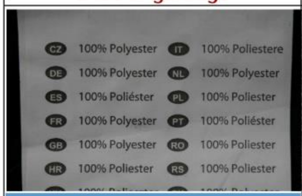
Plastic Detectives

Plastic Detectives – The Search For Plastic

 **Chocolate surprise egg** cheap nondurable a lot of garbage	 **Plastic toy** nonrecurring acquisition costs durable +/- garbage	 **Wooden toy** nonrecurring acquisition costs durable no garbage
 **Plastic soap dispenser** cheap hygienic plastic packaging a lot of garbage	 **Refillable soap dispenser + refill pack** cheap refill hygienic plastic packaging +/- garbage	 **Bar of soap** cheap hygienic paper packaging no garbage
 **Plastic bag** light free single-use a lot of garbage	 **Reuseable plastic bag** light nonrecurring acquisition costs multiple-use +/- garbage	 **Jute bag** light nonrecurring acquisition costs multiple-use no garbage

Appendix C: Sample Solution

Plastic Detectives – The Search For Plastic

		
Food package light free single-use a lot of garbage	**Plastic string bag** light nonrecurring acquisition costs multiple-use +/- garbage	**Cotton string bag** light nonrecurring acquisition costs multiple-use no garbage
 Synthetic clothes	 Clothes: synthetic/natural blend	 Natural clothes
Synthetic clothes light cheap functional carefree	**Clothes: synthetic/natural blend** +/- light cheap functional carefree	**Natural clothes** +/- heavy +/- expensive functional +/- carefree
		
Cosmetic with microplastic cheap environmentally unfriendly	**Cosmetic without microplastic** cheap +/- environmentally unfriendly	**Natural cosmetics** cheap environmentally friendly

Appendix C: Sample Solution

Plastic Detectives – The Search For Plastic

Station 7: Minimizing the problem

Task 1: Answer the following questions again.

a) Which things that you own or use are made out of plastic?

Personal opinion of the students.

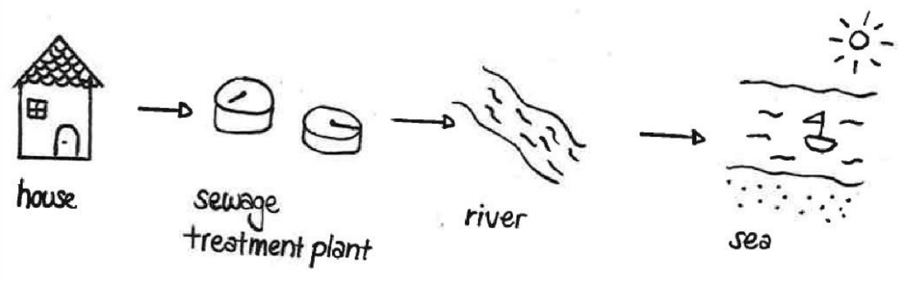
For example: toothbrush, toys, water bottle, lunchbox, pens, ruler, food packaging, exercise book cover, clothes, shoes, laminated handouts, plastic equipment of experiments, shampoo and shower gel packaging, toothpaste tube

b) Where in the environment have you seen plastic or microplastic?

Personal experience of the students.

For example: beach, meadow, forest, river, sea, roadside, park, forest, lakeshore, field, riverbank

c) Diagram how plastic or microplastic might get from your house to the beach.



d) Compare your initial with your final answers. Talk about your newly acquired knowledge with your group. Finally, we will talk about it together in class.

Appendix C: Sample Solution

Plastic Detectives – The Search For Plastic

Station 7: Minimizing the problem

Task 2:

In more and more ecosystems, such as rivers and seas, microplastic is found.

What can you do, so that less plastic/microplastic gets into the environment? Write down your suggestions on the leaflets and keep them until debriefing.

Finally, we will talk about the subject together and create a poster that you can hang in the classroom.

Appendix D: PowerPoint Presentation

Plastic Detectives – The Search For Plastic

Plastic Detectives

Introductory PowerPoint Presentation

Plastic Detectives

The Search For Plastic

UNIVERSITÄT BAYREUTH

Emma and Lenny were on vacation

Plastic Detectives

Fig. 1: Emma and Lenny playing on the beach.

Insert a map or an image of a sea or a lake (ideally with plastic garbage) that students visited in their free time or on vacation. At best, use a lake or sea next to the students‘ hometown. This image will create interest and curiosity.

UNIVERSITÄT BAYREUTH

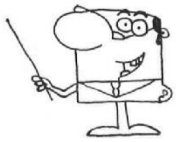
Appendix D: PowerPoint Presentation

Plastic Detectives – The Search For Plastic

Plastic Detectives

Emma and Lenny inquire…

Plastic Detectives



Emma: Good day, Mr. Experto. We were on vacation and made a strange discovery.

Mr. Experto: Hello you two, how can I help you?

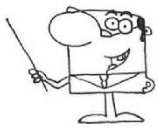
Lenny: We were on the beach and played in the sand. When we were sieving sand for our sandcastle, we found very small plastic particles in the sand. Why is not only sand on the beach?

Mr. Experto: The plastic particles you found are called microplastics by experts because they are smaller than 5 mm. That is a new problem in the environment.

UNIVERSITÄT BAYREUTH

Emma and Lenny inquire…

Plastic Detectives



Lenny: But how can plastic be so small? I only know large plastic, like my drinking bottle.

Mr. Experto: You are right, Lenny, your drinking bottle is made out of plastic. When this bottle breaks down into smaller and smaller parts, until those pieces are smaller than 5 mm, you call it …?

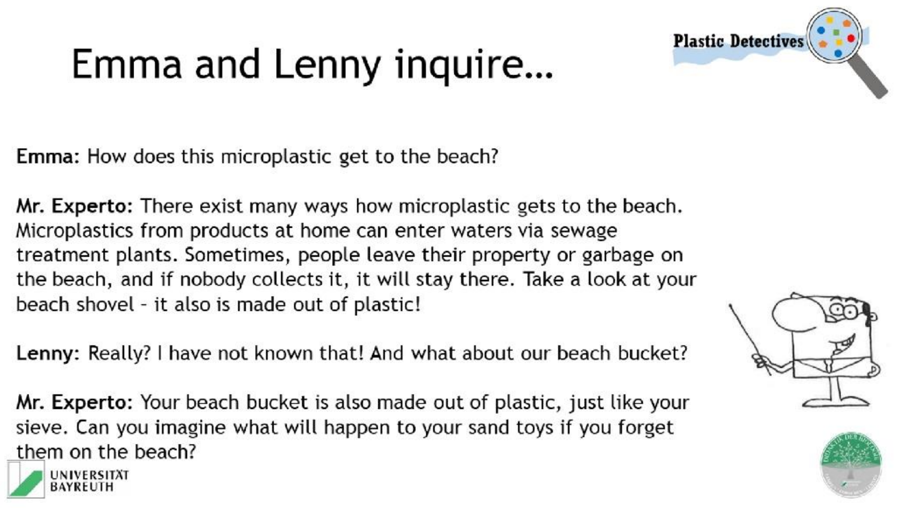
Lenny: Microplastic.

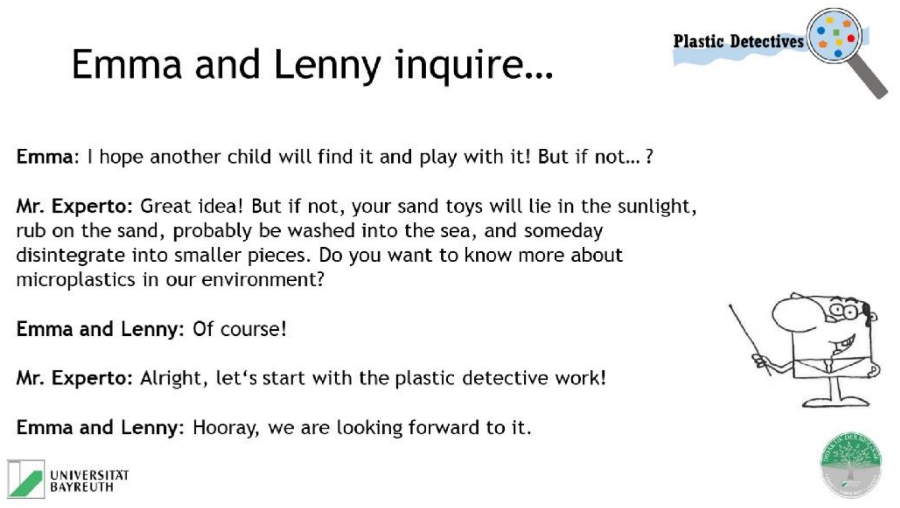
Mr. Experto: Exactly! Next to large plastic that disintegrates, for example due to sunlight, there are many more possible sources of microplastics in our daily routine. Microplastic is also in products that you use in everyday life at home.

UNIVERSITÄT BAYREUTH

Appendix D: PowerPoint Presentation

Plastic Detectives – The Search For Plastic





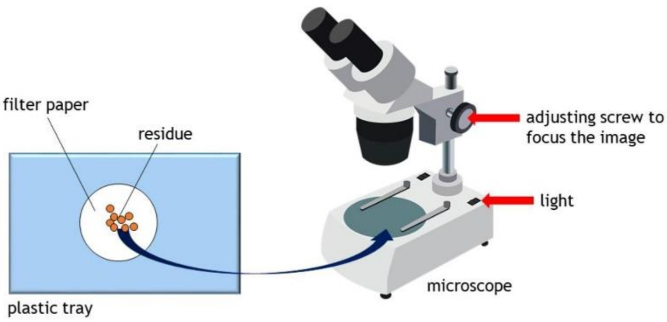
Appendix D: PowerPoint Presentation

Plastic Detectives – The Search For Plastic

Procedure

- Working in groups
- Workbook with tasks
- Scientific work material

Microscope



Appendix D: PowerPoint Presentation

Plastic Detectives – The Search For Plastic

Plastic Detectives

Procedure

Plastic Detectives

- Tables: Tasks from workbook
- Sample solutions
- After processing the stations → clean up!

UNIVERSITÄT BAYREUTH

Sequence of stations

Plastic-Detectives

1 → 2 → 3 → 4 → 5 → 6

7

Together at the end

UNIVERSITÄT BAYREUTH

Appendix D: PowerPoint Presentation

Plastic Detectives – The Search For Plastic

Sources of Illustrations

Fig. 1: Emma and Lenny playing on the beach.
https://pixabay.com/de/photos/kinder-freunde-bengel-h%C3%BCbsch-sand-114624/

5.6. Teilarbeit D

PLOS ONE, 2021, 16(9), e0257734

Conceptions of University Students on Microplastics in Germany

Patricia Raab[1*], Franz X. Bogner[1]

[1]Centre of Math & Science Education (Z-MNU), Department of Biology Education, University of Bayreuth, NW1, 95447 Bayreuth, Germany

*Correspondence: patricia.raab@uni-bayreuth.de

Conceptions of University Students on Microplastics in Germany

Abstract

Microplastics are a global challenge and a frequently studied environmental issue. Hence, the knowledge body about microplastics within the scientific community is growing fast and challenges an elaborated knowledge transfer from science to the general public. Just as well-informed people are the basis for reducing microplastics' impact on the environment, knowledge of the audience's conceptions is the basis for an accurate and successful dissemination of scientific findings. However, insights into the publics' perceptions of microplastics are still rare. The present study aimed to capture students' conceptions about microplastics based on their individual experiences following qualitative inductive, exploratory research. Therefore, 267 students of a state university in Germany responded to a paper-and-pencil questionnaire containing open and closed questions on microplastic-related conceptual understanding, risk perception, information behavior, sources, and sinks. The inductive classifying of all responses by a qualitative content analysis revealed six basic concepts: 1) Microplastics are mainly understood as small plastic particles. 2) Microplastics are closely associated with its negative consequences. 3) The most labeled source in households is plastic packaging. 4) Compared to other water bodies, microplastics are rarely suspected in groundwater. 5) A high threat awareness exists in classifying microplastics as very dangerous and dangerous. 6) Media such as TV or the Internet are the most crucial information sources while the school has less importance in acquiring information. It is precisely this pattern that indicates the need for profound science communication to establish a joint and scientifically sound knowledge base in society. Knowledge about conceptions of potential "customers" allows tailor-made scientific knowledge transfers to shape public awareness, initiate changes in thoughts and prepare the field for collaborative behavior.

Keywords: Microplastics, conceptions, science communication, students

Introduction

Scientific background

The success of plastic materials transformed life and, at the same time, challenged our planet permanently and irrevocably. In 2017, Geyer et al. [1] estimate the number of plastics ever manufactured at 30%, which is still in use since the beginning of production in 1950. The rest (70%) is classified as waste and was either incinerated, recycled, or, representing the largest share, with 79%, accumulated in landfills or the environment [1]. Consequently, not surprisingly, plastic pollution is one of our generation's critical environmental challenges [2]. In addition to the anesthetic and easily visible plastic debris, smaller plastic fragments, namely microplastics, contribute to worldwide environmental pollution. Microplastics are defined as plastic particles smaller than 5 mm [3] and are classified into primary and secondary microplastics [4]. Primary microplastics are intentionally manufactured in a micro-size range to find use in plastic production as plastic resin pellets, industrial abrasives, and cosmetic products [5]. Secondary microplastics are fragmented larger-sized plastic materials caused, for instance, due to exposure to UV light and mechanical forces [6]. However, microplastics are a very diverse group: they differ greatly according to their color, shape, size, chemical composition, and specific density [7, 8].

Duis & Coors [7] meta-analyzed primary and secondary microplastic source studies, compiling an overview of potential sources, which we allocated to the different sectors (see Table 1). Sources such as building materials [9] or sewage sludge in agricultural sites [10] are still missing. The chosen structure to apportion the sources in different sectors offers one possible classification: building materials, road paints, and automobile tire wear may likewise summarize the urban run-off [11].

Table 1. Listing of primary and secondary microplastic sources.

	Primary Microplastic Sources	Secondary Microplastic Sources
Household	- Personal care products containing microplastics as exfoliants/abrasives	- Abrasion/release of fibers from synthetic textiles - Release of fibers from hygiene products - Abrasion from other plastic materials (*e.g.*, household plastics) - Plastic items in organic waste
Industry	- Drilling fluids for oil and gas exploration - Industrial abrasives - Pre-production plastics, production scrap, plastic regranulate: accidental losses, run-off from processing facilities	- Paints based on synthetic polymers (ship paints, other protective paints, house paint, road paint): abrasion during use and paint removal, spills, illegal dumping - Plastic coated or laminated paper: losses in paper recycling facilities
Agriculture		- Plastic mulching - Synthetic polymer particles used to improve soil quality and as composting additive
Maritime Activity		- Material lost or discarded from fishing vessels and aquaculture facilities - Material lost or discarded from merchant ships (including lost cargo), recreational boats, oil and gas platforms

Traffic		- Abrasion from car tires
Plastic Litter		- General littering, dumping of plastic waste - Losses of waste during waste collection, from landfill sites and recycling facilities
Medicines	- Medical applications (*e.g.*, dentist tooth polish)	
Weather		- Losses of plastic materials during natural disasters

Modified after Duis & Coors [7].

The respective share of primary and secondary microplastics to the total contamination of microplastics in the environment lacks reliable quantification [12]. A view widely held expects large plastics as a major source of microplastics in the environment, which consequently disintegrates into secondary microplastics through external influences.

Plastics inevitably enter the three environmental compartments water, atmosphere, and soil [9]. First reports on microplastics in the oceans date back to the 1970s [13]. In the sea, many studies reported microplastics from the surface [14, 15] to the sediments [14, 16] down to the deep sea [17]. Zbyszewski & Corcoran [18] documented microplastics in the Lake Huron in the US. Imhof et al. [19] did it for the Lake Garda in Europe. Expectedly, also the terrestrial system is charged with microplastics. Microplastics are present in cities in the form of tire abrasion [20, 21], agricultural sites, with fibers having the largest share [10], as well as in remote regions like the French Pyrenees [2], the arctic [22], and groundwater [23, 24]. Finally, atmospheric transport distributes microplastics worldwide, even in regions with no or sparse human population, by wet and dry deposition [2].

Regarding the consequences, Laist [25] estimated 267 marine species to be affected by plastic debris. Plastic ingestion was also reported for other marine animals such as turtles [26–28], fish [29], and marine birds [30, 31]. Next to plastics, also the already investigated effects of microplastics in the different ecosystems appear far-reaching. Microplastics' small size raises its accessibility to a broader range of organisms [6, 32]. Many researchers reported the ingestion of microplastics by marine animals like zooplankton [33, 34] and mollusks [35] as well as by crabs [36, 37], fish [38, 39], birds [40], and whales [41]. Moreover, microplastics have also been detected in freshwater animals like water flea [42], fish [43, 44], and worms [45].

After ingestion, microplastics can translocate from the gut to the circulatory system and tissues [46], from tissues to cells [47], and organs [37]. Chemicals adsorbed on the surface of microplastics may accumulate in the body after ingestion and may have health implications (*e.g.*, lead to liver toxicity and pathology in fish) [48]. After uptake, microplastics could be transferred to higher trophic levels [49]. Beginning with zooplankton, microplastics may accumulate in the marine food web [50], wherefore, it comes as no surprise to assume microplastics also in the human food chain [51]. Vinay Kumar et al. [52] detected microplastics in mussels sold in supermarkets for human consumption.

Next to marine organisms, contamination of food during production or packaging is a possible microplastic source for human consumption, *e.g.*, in bottled water [53] or salt [54].

Besides ingestion, further consequences start from the presence of microplastics in the environment. Organisms, *e.g.*, bacteria, use microplastics for settlement and hitchhike through the waters [55]. Microplastics can change soil properties like their structure and water dynamics in the terrestrial ecosystem, thereby possibly affecting plant performance, *e.g.*, its biomass or root traits [56]. Moreover, microplastics are in the air we breathe [57, 58], travel on the wind, and drift down the skies to remote regions [22].

Students' conceptions

Despite the growing research body, only a few social science studies address microplastics' social perception [59]. Therefore, there is a need to understand which and how much scientific knowledge arrives in the general public. This may help offer target-oriented awareness campaigns on the responsible handling of plastic and microplastics. To generate insights into individual conceptions about microplastics, we chose university students who had successfully passed secondary school education. Consequently, their conceptions may provide crucial implications for science communication.

The application of qualitative content analysis allows the categorization of a great variety of individual conceptions. This method follows the theory of constructivism, which evolved from Piaget's studies of cognitive development [60]. Every person holds particular conceptions about the world, which may differ from those others have and are used to orientate themselves in the world and explain natural phenomena. They are formed in the early years of life and are stable in the face of change [61]. In this regard, the demarcation of knowledge and conceptions is not entirely unambiguous. Basically, conceptions differ from knowledge in that they have no claim to truth and are more subjective [62]. For many years, research focused on the differences between scientific conceptions and the so-called misconceptions that education should replace. Today, everyday (naïve) students' conceptions are labeled as alternative conceptions, a term introduced by Wandersee et al. [63], indicating their lifeworld reference separated from professional conceptions. Gathering insight into students' conceptions shows their individual conceptions based on personal experience, often differing from scientific ones [64]. Already in 1994, Smith et al. ([65], p. 151) labeled prior knowledge as "primary resource for acquiring new knowledge." Hence, conceptions represent good starting points for awareness campaigns to develop scientific comprehension [60]. Successful science education rests on, among other things, the consideration and inclusion of individual conceptions [66], which may slowly refine and transform. Therefore, communicational efforts, tailor-made to conceptions and experiences, may result in better outcomes.

Research lines on conceptions exist as a convenient tool for successful teaching in science classes [64]. Several studies uncovered diverse conceptions of university students [67] and pupils on scientific topics [68–70]. Fröhlich et al. [71] reported a change of perceptions during the school career. Following the constructivist view of learning, new knowledge is constructed by rearranging the existing cognitive basis through experience [65]. For enlightenment, initiatives must give students a chance to promote their effort in combining existing with new information [72]. Thereby, learning itself can be a very individual process [73]. Knowledge of students' conceptions and incorporation of them into the process of learning may lead to more advanced and comprehensive learning [60], possibly overcoming alternative conceptions [74]. Franke & Bogner [75] applied alternative conceptions in their gene technology laboratory intervention. Divided into two treatment groups, one was confronted with alternative conceptions on the underlying topic during the lesson, while the other was not. The pupils who dealt with the alternative conceptions showed higher interest and well-being as well as a better cognitive achievement proving the relevance of conceptions' recognition [75]. Finally, conceptions indicate neglected topics in the curriculum and give suggestions for an integration in the future [71].

As already mentioned, currently, little is known about the general public's comprehension of microplastics. We have chosen a student sample representing the final stage of school education, giving insights into the conceptions students hold at the very end of their school careers. Thereby, university students provide school and university education implications in particular and science communication implications in general. Educators and scientists get an impression of topics surrounding microplastics that need to be deepened, put into a different context, or become part of the curriculum in the first place. Additionally, in the context of science communication, scientists may get an idea of the level of general understanding to communicate their knowledge at an appropriate level. Consequently, our study monitors different topics surrounding microplastics which give valuable starting points for a variety of awareness campaigns. The overall aim of the study was to receive first insights into the conceptions university students hold on microplastics to make science communication of any kind more precise and adequate. The study's objectives were five-fold: (1) What do German university students understand by the term microplastics? (2) Where do students get their information about microplastics from? (3) Which microplastic sources in the household do students know? (4) Which water ecosystems in Germany do students consider contaminated with microplastics? (5) How dangerous do students consider microplastics, and how do they justify their classification?

Materials and methods

In this study, we followed the exploratory research [76], aiming to provide meaningful first insights into students' conceptions on microplastics in Germany. We decided on combining the exploratory research with a qualitative inductive research method [77], using the individual conceptions as the basis for all analyses.

In 2020, there are 108 universities distributed throughout Germany, with nearly 1.8 million students enrolled [78]. In Bavaria, there are about 246,000 university students [78], 13,000 of whom study at the University of Bayreuth [79]. At the time of data collection, the University of Bayreuth consisted of six faculties, which we all covered in this study.

Especially in Germany, a country with high educational standards, a change in the way plastics and microplastics are handled must be achieved. Accounting for 24% of the total demand, the German demand for plastics is by far the highest in Europe [80]. In 2018, less than 40% of the plastic post-consumer waste was recycled, and up to 60% were used for energy recovery, with a total waste volume of 5 million tonnes [80]. However, with 50%, the recycling rate for the 3 million tonnes of plastic packaging lay above the European average of 42% [80]. Although waste recycling shows a positive trend, Germany's total volume of plastics remains comparatively high. A rethinking towards more reduction, recycling, reusing, and repairing is necessary to minimize the publics' impact on the environment.

Our convenience sample consisted of 267 university students. The average age was 20.3 (*SD* = ± 2.56) years, and 56.6% were female. The sample comprised exclusively of on-campus students of the University of Bayreuth (Bavaria, Germany), representing the university's six faculties. They belonged to the following scientific disciplines: Natural sciences, humanities, engineering, economics, and cultural sciences. We have included all surveyed students in the analyses as no indications existed to exclude certain respondents.

Participation was voluntary. The students could reject study participation at any time. Due to pseudo-anonymous data collection, it is not possible to assign the questionnaires to individual students. All participating students completed a 15-minute paper-and-pencil questionnaire (approved by the ethics committee of the University of Bayreuth) under the same conditions. At the beginning of the academic term, the students independently answered the questions based on their conceptions and experiences during one of their university courses. All students were given the same questionnaire containing open and closed questions (see Table 2), which allowed a comprehensive assessment their conceptions on topics related to microplastics. More precisely, the questionnaire comprised three open (Q1, Q2, Q3), one closed question (Q4), and a combination of an open and a closed question (Q5a and Q5b). The questions were created explicitly for this study to assess general ideas on microplastics based on topics relevant to fundamental enlightenment. To keep the survey duration as short as possible, we focused on crucial issues for individual's handling with plastics and microplastics.

Table 2. Questionnaire questions.

Question	Wording
Q1	What do you understand by the term microplastics?
Q2	Where do you get your information about microplastics from?
Q3	Name sources of microplastics in the household.
Q4	In which ecosystems are microplastics in Germany? (a) sea (b) rivers (c) lakes (d) groundwater
Q5a	Assess the potential danger posed by microplastics. (a) very dangerous (b) dangerous (c) hardly dangerous (d) not dangerous
Q5b	Justify your decision.

Q1, Q2, Q3, and Q5b are open questions. Q4 is a multiple-choice question. Q5a is a single-choice question.

The closed questions Q4 and Q5b were used consciously. In Q4, the classification of groundwater as an ecosystem may not be familiar to the non-specialist and may lead to an incomplete mapping of students' conception of the topic. Regarding question 5a, the risk evaluation, a precise classification along a gradation was beneficial for the validity. For the two closed questions, we determined the number of students who agreed to each answer choice and illustrated them with percentages in the results.

In contrast to the closed questions, the open-ended questions allowed students to describe their personal ideas and thoughts without being guided by predetermined answer choices. Hence, the students' individual responses to the open-ended questions were the starting point of the evaluation following the qualitative content analysis by Mayring [77]. Within the qualitative content analysis, students' mentioned terms or explanations formed the basis of a categorical framework, which we constructed independently for each question [81]. This inductive categorization enabled a detailed and accurate recording as well as a homogeneous bundling of the students' diverse ideas. The category system was progressively refined so that the introduction of gradual subcategories enabled an even more detailed analysis of the responses. The developed coding guidelines included a clear category definition and an anchor example from the student responses for each question to ensure transparent categorization. Table 3 shows an excerpt of the coding guideline of Q1. Since the students' conceptions about a topic were quite multidimensional and partly conceptually multilayered, a student's answer could be assigned to several categories simultaneously. After determining and setting all statements to the appropriate categories, the category assignments were quantified. This quantification allowed an accurate determination of the number of students holding a particular conception about every single topic concerning microplastics. Hence, also the students' conceptions on the open questions are given in percent in the results.

Table 3. Exemplary coding guideline of Q1.

Category	Definition	Anchor Example
Small plastic particles	Microplastic is described as small plastic. These include terms such as *small/microscopic plastic particles*, *plastic particles not visible to the eye*, and general references to the small size of plastics.	ID 230: "**Small plastic particles.**"
Plastic	Microplastic is described as *plastic* or *small amounts of plastic*. No reference is made to the size of the plastic.	ID 211: "**Plastic** in waters that pollute waters and are taken up by animals."
Primary MP	In the description of the term, reference is implicitly made to primary microplastics, *e.g.*, by mentioning the direct production of small plastics or their presence in personal care products.	ID 207: "Smallest plastic particles such as **peeling grains.**"
Secondary MP	The term's description implicitly refers to secondary microplastics, for example, by addressing the defragmentation of plastic into microplastics.	ID 232: "Microscopic plastic particles that are **created when plastic disintegrates**. This is extremely harmful to organisms."
Effects	In the description of the term, the effects of microplastics on the environment and humans are mentioned. Among the listed topics are environmental damage, damage to health, presence in the environment, in living beings and in food, indigestibility, and the difficulty of removing microplastics from the environment.	ID 4: "Tiny little particles of plastic. **Harmful to the environment.**"

Relevant statement parts for categorization in bold.

The first author categorized all data of the open questions. To validate the categories, a randomly selected 20% subsample of the data was reanalyzed after one year by the first author to estimate intra-rater reliability and by another independent, nonpartisan person to receive inter-rater reliability statistics. The intra- and inter-rater Cohen's kappa coefficients were calculated for all four open questions (see Table 4) [82]. Cohen's kappa coefficients indicate the measure of agreement between different people, also called raters, on identical rating systems [83]. The higher the calculated score, the higher the agreement on the category system for the individual answers. Cohen's kappa value was calculated by examining the percentual accordance of raters' categorization of data input [84]. Thereby the measurement considers the statistical probability of random agreements, reducing the weight of the value systematically [84]. Cohen's kappa scores ranged between .86 and .97, indicating an 'almost perfect' agreement between the raters, which is, following Landis & Koch [85], reached above the value of .81.

Table 4. Cohen's kappa scores for intra- and inter-rater reliability of questions Q1, Q2, Q3, and Q5b.

	Cohen's Kappa Score	
Questions	**Intra-Rater Reliability**	**Inter-Rater Reliability**
Q1	0.96	0.86
Q2	0.94	0.96
Q3	0.93	0.95
Q5b	0.97	0.94

Results

First, we show the results of the two closed questions on microplastic the sinks in German waters and the risk evaluation. Afterward, we explain the results of the open questions, which we quantified by using the categories we created from the students' answers. For the open questions, we summarized all answers belonging to the category 'expression of ignorance' and 'inadequate answer' as 'no answer'. Single conceptions held by less than 3% of the students were conflated in 'other'. We omitted the categories 'no answer' and 'other' in the Figures for a better overview. The frequencies in the Figures refer to the number of students whose answers can be assigned to the respective category.

Students' conceptions of microplastic sinks in German waters

In this multiple-choice question, the closed response format offered students four aquatic ecosystems for selection (see Table 2). 86% of the students thought that the German sea contained microplastics. 81% of those surveyed considered German rivers to be polluted. 74% of the students regarded lakes as burdened, and for groundwater, 34% of the students indicated a microplastic load (see Fig 1).

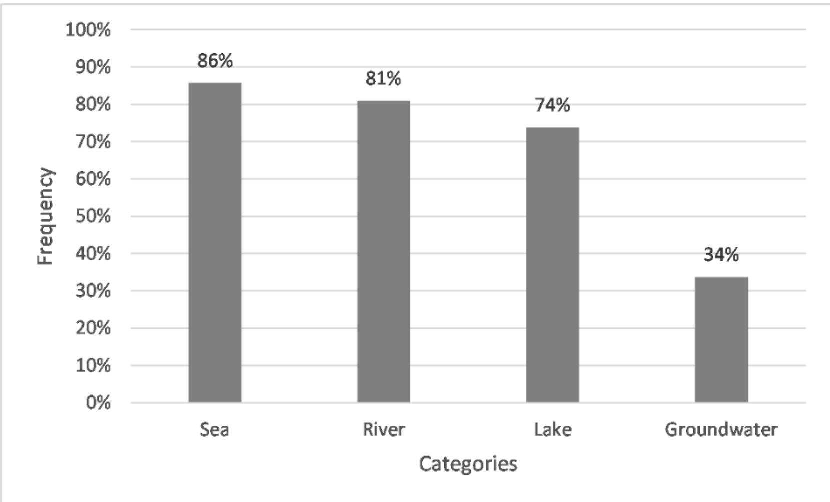


Fig 1. Frequencies of students whose answers assigned to the corresponding categories for the closed Q4: "In which water ecosystems is microplastics in Germany? (a) sea, (b) rivers, (c) lakes, (d) groundwater." $N = 267$. Closed question with pre-determined answers.

Students' risk evaluation and justification

The closed question on risk evaluation (for response options, see Table 2) showed that 36% of the students classified microplastics as very dangerous, and 55% considered microplastics as dangerous. Solely 3% sorted microplastics as hardly dangerous, and nobody ranked it as not dangerous (see Fig 2).

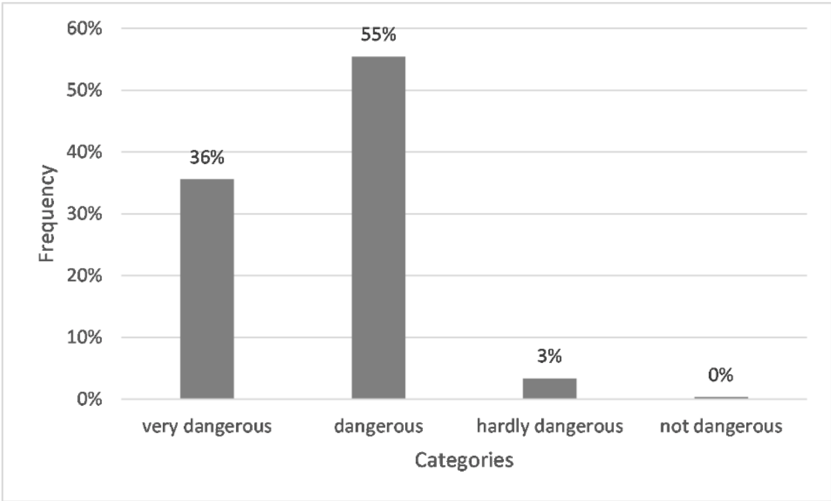


Fig 2. Frequencies of students whose answers assigned to the corresponding categories for Q5a: "Assess the potential danger posed by microplastics. (a) very dangerous, (b) dangerous, (c) hardly dangerous, (d) not dangerous." *N* = 267. Closed question with pre-determined answers.

The following open-ended question was designed to capture the student's rationale for their risk evaluation. The justification of the stated risk evaluation provided diverse explanations. 36% of the students indicated general health hazards for all living organisms (*e.g.*, resulting in the accumulation in tissues). 34% named environmental damage like ecosystem contamination (*e.g.*, water pollution) or negative influences on plants. 25% stated ingestion by animals (especially by marine life like fish), 18% described uptake as food by humans, and 12% listed stress of the whole food web to explain their risk evaluation of microplastics. Moreover, 30% of the students named microplastics' properties (*e.g.*, characteristics stemming from additives or adsorbed substances, small size, indigestibility, non-degradable) to justify their risk evaluation, like student ID 98 did: "Plastic is not biodegradable. Therefore a lot of plastic will accumulate over a long period of time. Especially if the plastic parts are very small, hardly visible, they will probably be ingested quickly without intention, which is probably more harmful than healthy." Finally, 5% claimed a need for further research as an explanation for their risk evaluation. Regarding the need for research, it was noted that more research is required in this area to weigh up the consequences and risks. Students' responses often contained serval categories simultaneously, as was the case of student ID 155: "Plankton stores plastic, which is passed on in the food web and in the end it also affects humans. Furthermore, medical and biological consequences are not foreseeable, and there is no way to remove the garbage." This student's justification comprised the categories 'ingestion by animals', 'ingestion by humans', 'food web', and 'need for research'. Besides these detailed answers, 19% left their risk estimation unfounded (see Fig 3).

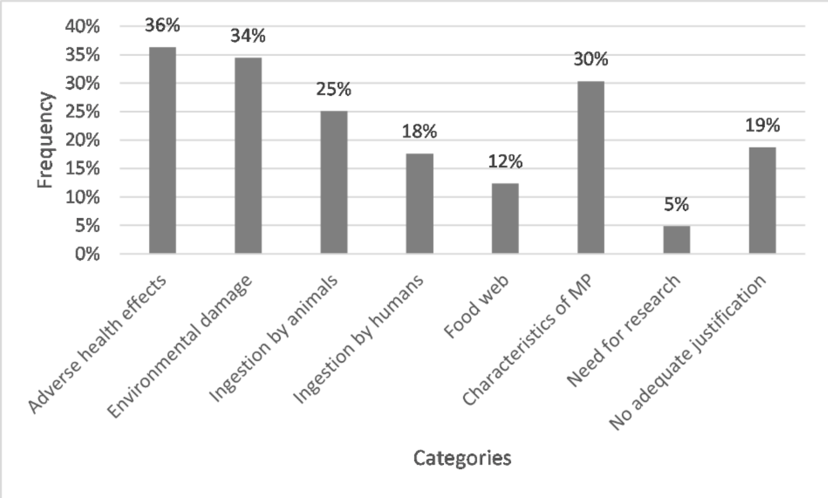


Fig 3. Frequencies of students' answers assigned to the corresponding categories for Q5b: "Justify your decision [of Q5a]." *N* = 267. Open question with categories formed from students' answers.

Students' conceptions of the term microplastics

78% of respondents classified the term microplastics with reference to small plastic particles (see Fig 4). 5% of the students ranked microplastics as plastic. In addition to a basic classification, some students included more profound information in their definitions. 8% respectively, 12% explained primary and secondary microplastics, as the answer of student ID 194 shows: "Very small plastic particles. These can already be present as such, *e.g.*, in cosmetics, and thus get into the environment or the human organism during or after use, or plastic waste, especially in the oceans, is broken down by mechanical action and thus becomes microplastic." This answer also demonstrates that a student's response to one question can contain several categories simultaneously. In this case, the categories 'small plastic particles', 'primary microplastics', and 'secondary microplastics'.

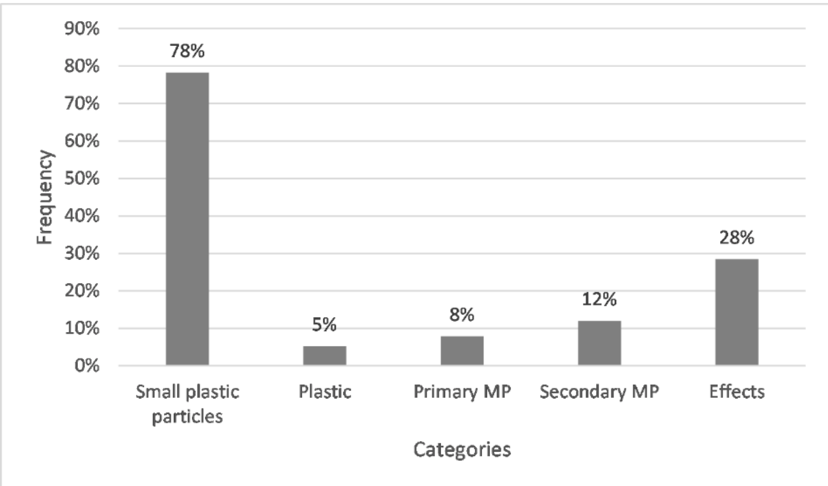


Fig 4. Frequencies of students whose answers assigned to the corresponding categories for Q1: "What do you understand by the term microplastics?" *N* = 267. Open question with categories formed from students' answers.

Furthermore, almost every third student (28%) discussed effects, although these were not asked. In some cases, the students only briefly addressed the consequences, as student ID 4 did: "Tiny little particles of plastic. Environmentally harmful", who pointed out the environmental damage. Others discussed the adverse effects of microplastics in more detail, like student ID 145: "Small plastic parts which [...] can be found everywhere (food, water, sand). It is speculated that this, *i.e.*, the ingestion of microplastics, can cause health risks." Hence, the addressed negative consequences included topics like pollution, ingestion by organisms, accumulation in organisms, indigestibility, durability and lack of degradation.

Students' sources of information

52% of the respondents indicated the media as their source of information. Another 21% named educational institutions, and 4% projects and nature conservation organizations as their source of information. 3% of the respondents considered it part of their general education (see Fig 5).

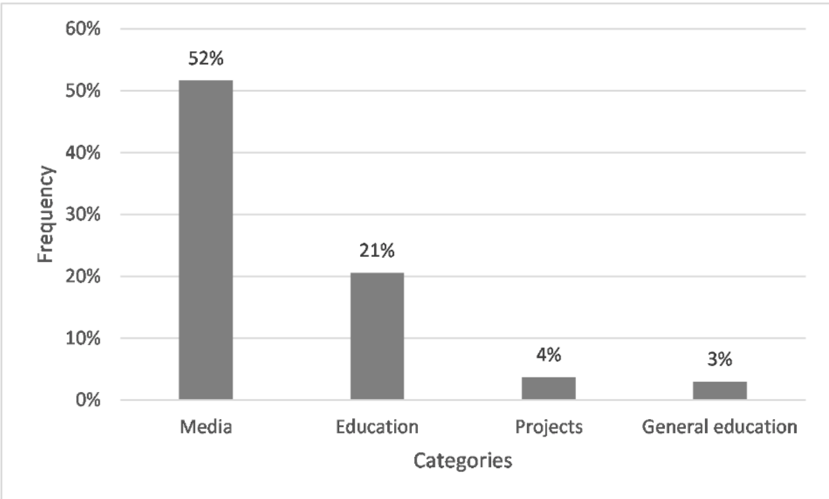


Fig 5. Frequencies of students whose answers assigned to the corresponding categories for Q2: "Where do you get your information about microplastics from?" *N* = 267. Open question with categories formed from students' answers.

85% of those who listed media further specified this category by naming television, Internet, and print media (see Fig 6). Television (76%) proved to be the essential source of information in the media field. Within the television subcategory, respondents stated documentaries and news as sources of information. On the Internet (57%), social media and individual information retrieval via google were relevant. Newspapers were the basis for information for the print media (18%).

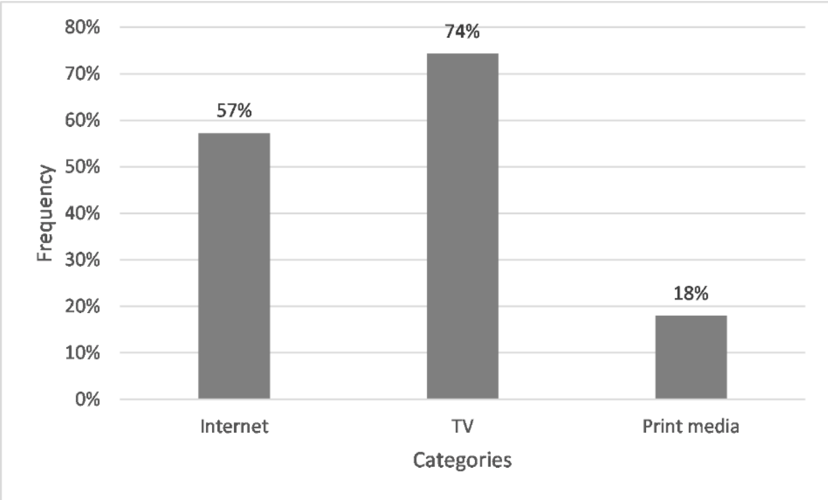


Fig 6. Frequencies of students whose answers specified the term `media` in Q2: "Where do you get your knowledge about microplastics from?" *n* = 117. Open question with categories formed from students' answers.

When taking a closer look at the subcategories of education, schools (73%) were the most important source of information, ahead of universities (29%). It should be noted here, however, that merely 21% of the students in total named educational institutions as a source (see Fig 7).

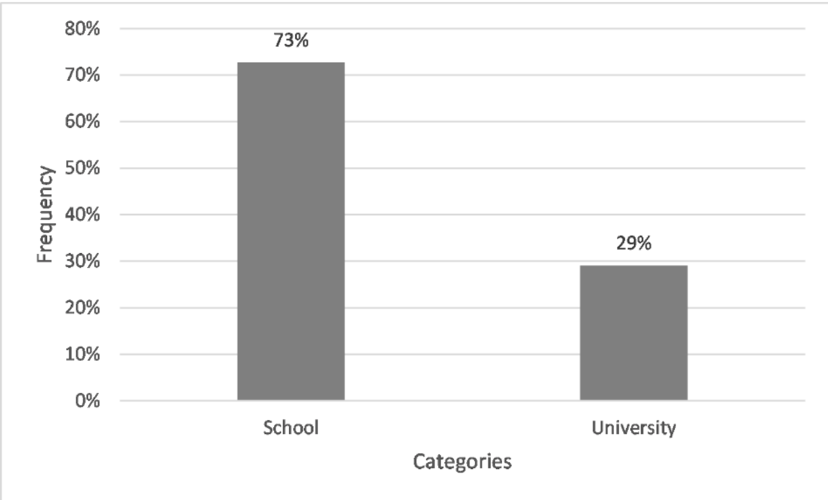


Fig 7. Frequencies of students whose answers specified the term `education` in Q2: "Where do you get your knowledge about microplastics from?" *n* = 55. Open question with categories formed from students' answers.

Students' conception of microplastic sources in the household

As a possible source of microplastics in the household, plastic packaging (*e.g.*, plastic bags, plastic bottles) was mentioned by 43% of the students. Almost one in three (28%) named various cosmetic products (*e.g.*, make-up, shower gel), 19% mentioned diverse plastic objects (*e.g.*, kitchen utensils, toys). A smaller number of students (10%) listed plastic waste (containing references to inadequate waste disposal), 6% of the respondents named detergents and textiles, and 4% food in their answers (see Fig 8).

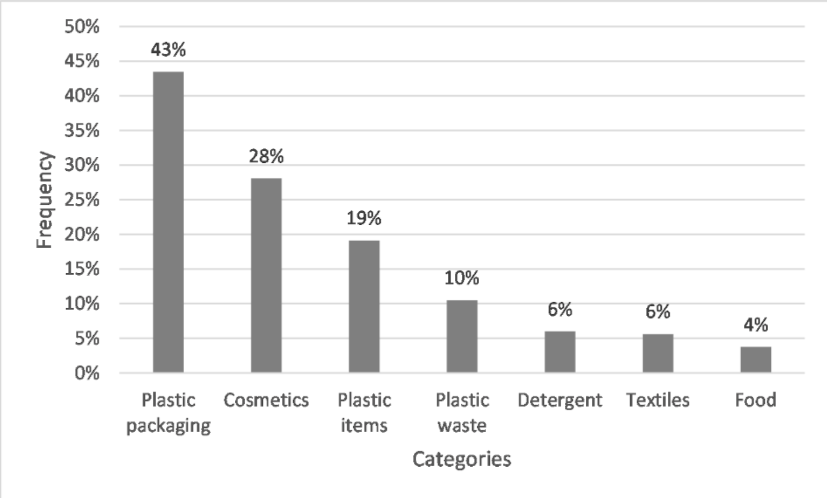


Fig 8. Frequencies of students whose answers assigned to the corresponding categories for Q3: "Name sources of microplastics in the household?" *N* = 267. Open question with categories formed from students' answers.

Discussion

The students' input on microplastics revealed expected as well as surprising denominations. In general, the students were familiar with the broad outlines of microplastics, and the majority understood the term microplastic to mean small plastic particles. Surprisingly, conceptions strongly associated microplastics with adverse effects, consequently classifying them as dangerous. This evaluation may stem from their primary source of information, which is not educational institutions but the media, where simplification of scientific findings or interpretative frames might influence the perception of danger [86]. The risk estimation revealed a diverse picture of justifications, including scientifically sound statements and explanations that have not yet been thoroughly scientifically explored. Hence, the conceptions uncovered some superficial understandings of the topic. The study also revealed results, which were quite in line with our expectations: Many students mentioned plastic packaging, and even cosmetics, despite its small proportion of the overall problem, as household sources [87]. Other sources, *e.g.*, fibers from hygiene products and plastics in organic waste, were ignored. Concerning sinks in German waters, compared to the ocean, lakes, and rivers, relatively few students suspected microplastic contamination of groundwater. In the following, we discuss the major outcomes of conceptions, beginning from proposed blind spots to the role of media and recommendations for action in science communication. Since the present study was conducted among students, the results can only draw a conclusion about this special study group. The results do not permit any generalization to students as such or to society in general. Thus, the following discussion on students' conceptions about microplastics should be read accordingly.

Blind spots in the household and unawareness about groundwater pollution

Some conceptions indicate a need for action concerning education. Taking Table 1 into consideration, there are starting points for imparting microplastic sources in the household, which are not yet in the students' consciousness. Only a few students mentioned plastic items, plastic waste, detergents, textiles, or food products. Similar results were obtained in the study by Deng et al. [88], in which the respondents were familiar with conventional plastic products such as plastic bottles but less familiar with paints or textile fibers. Also, in this study, none of the students was aware of the release of fibers from hygiene products (*e.g.*, feminine hygiene products or cotton swabs) or plastic items in organic waste. Insufficient cleaning processes in sewage treatment plants [10] allow hygiene products' components to enter waterways after improper disposal in the toilet. Hence, correctly disposed hygiene products pose less of a problem for the environment. Similarly, household plastics in organic waste, predominantly packaging, may enter the environment on agricultural sites and gardens as organic fertilizer from biowaste fermentation and composting [89]. In both cases, education on proper disposal could achieve a reduction of microplastic inputs.

Moreover, answers to the closed question on microplastic polluted water ecosystems revealed another blind spot of the students. While they seem to be familiar with microplastics in the sea (ticked off by 86%), lakes (74%), and rivers (81%), comparatively few students stated microplastic pollution of groundwater (34%). This result is in accordance with Re [90], who argued that microplastics in groundwater sparsely get scientific and political consideration. Rivers [91], lakes [19], and especially the sea [14] gained a lot of scientific and thus media attention.

Different studies have already found results in water's thematic context, giving impulses for approaching the topics through education. Fremerey et al. [92] surveyed 10th graders and undergraduates' conceptions about drinking water. They found some unexpected, persistent alternative conceptions: Both pupils and students believed drinking water to be purified in sewage treatment plants. Obviously, fundamental understandings of sewage treatment plants and waterworks processes were confused, leading to persistent alternative conceptions on the purification process of drinking water. Furthermore, studies can reveal blind spots like it was the case for the term 'virtual water' [92]. In a study on Ecuadorian students, Liefländer et al. [93] detected unfamiliar terms concluding that education about these terms is necessary to avoid overgeneralization. Hence, those gaps are subject areas that need to be explained in very basic terms to prevent students from explaining these concepts based on their own experiences, leading to superficial approaches and interpretations that differ from scientific perspectives. Schmid's & Bogner's [94] study on students' conceptions on water reuse supports this claim. Although knowledge about new technologies of water reuse was missing, students expressed concern about water quality. Schmid & Bogner [94] concluded well-thought outreach activities as necessary to create acceptance. Alternative or missing conceptions on special topics are essential clues for educators and experts in the field. Education on these contents must be handled in a particularly sensitive and skillful way to enlighten students about unknown topics and approximate their conceptions to scientific ones.

Reasonable conceptions about what microplastics are

The students classified microplastics as small plastics. Hence, the thematic area concerning microplastics is quite common among them. Our result contrasts with Deng et al. [88], finding this term mostly unknown among the participants. Microplastics' division into primary and secondary microplastics succeeded only implicitly, *i.e.*, without mentioning the terms primary and secondary. Although the subcategories were not explicitly named, it is still clear that they are aware of different origins of microplastics, namely those that were intentionally produced for usage (primary) and those that arise through degradation (secondary). This comprehension also becomes evident in the question of microplastic sources in the household. Even though only a small number of the students implicitly mentioned primary and secondary microplastics in Q1, the answers in Q3 show that a larger part is aware that these two types of microplastics exist. In their responses, the students mentioned cosmetics (belonging to primary microplastics; [5]) and plastic packaging or plastic objects, which are merely a microplastic source when used or otherwise disintegrate into tiny pieces smaller than 5 mm (secondary microplastics; [6]). All answers that fall into the categories 'plastic packaging', 'plastic objects', 'plastic waste' and 'textiles' indicate students' awareness for microplastics' creation from plastic, hence secondary microplastics. The results suggest that the concepts of primary and secondary microplastics are known among the students; however, they lack the corresponding technical term. Here, a term clarification would be appropriate to enable students to title the concepts they already have.

Plastic packaging as the main source in households

With 43%, plastic packaging was the most frequently mentioned source in the household. Plastic packaging can, of course, be attributed to plastic waste (10%). However, at this point, it was explicitly categorized individually because of the high number of responses that explicitly addressed plastic packaging. A level of detail that we did not want to lose. Estimations on the origin of plastic (debris) in oceans show roughly 80% as land-based, while approximately 20% deriving from maritime activities like fishing [95, 96]. Especially in Germany, the demand for plastics is not reducing but remains high compared to the other European countries [80]. Students' focus on plastic packaging is hardly surprising, given that it represents the majority (namely 39.6%) of European plastic demand [80]. Hence, packaging material presents a substantial part of plastic litter and, accordingly, plastics in the environment. In light of these numbers, the abundant mentions of plastic packaging are justified and a crucial starting point for reducing plastics and microplastics' entry into the environment.

The apparent understanding of plastic packaging as a microplastic source in private households among the students can be an anchor point in the process of behavioral change. Leire & Thidell [97] described in their study missing mindfulness as responsible for consumers' lacking connection between purchasing decisions and environmental consequences due to a lack of awareness. A study by Hartley et al. [98] reported that participation in a classroom module on marine litter led to improved students' self-reported environmentally friendly behaviors, which were also passed on to friends and family. Hence, education on environmentally relevant topics possesses a great potential to increase pro-environmental behavior concerning plastics and microplastics. In line with these findings, the central goal in the future is to make learners aware of how their chewing choices and plastic consumption directly impact plastic and microplastic pollution in nature [99].

Since the plastic waste problem is a problem of human behavior and not solely of plastics' characteristics [100], these results underline educational initiatives' fruitfulness and the necessity for additional programs on everyone's responsibility.

Overrepresentation of cosmetics

Also unsurprising, personal care products (especially cosmetics) were the second most cited microplastic source in households. In a study of 2016, the topic was still unknown among students [101]. The relatively strong focus on personal care products among the students we surveyed can be explained by the increased attention in scientific studies [87], the large media presence [86], or the targeted advertising measures of the cosmetics industry. Although care products are currently attributed a relatively low relevance to the overall problem of microplastics [87], an awareness of this source in one's household is nevertheless valuable.

Perception of microplastics as dangerous hazard

Students perceive microplastics as very dangerous or dangerous. The proportion of those who considered microplastics to be barely dangerous was vanishingly small. No one considered them to be harmless. Reasons were diverse, ranging from effects on humans, animals, and ecosystems to microplastics' characteristics and the demand for more research. In contrast to the surveyed students, the respondents of Deng et al. [88] showed a more pronounced anthropocentric view of plastic pollution. From a selection of negative effects of plastics, the respondents felt most affected by the city's pollution, *i.e.*, their personal, man-made environment. Some justifications were scientifically sound and well-studied; others included topics on which scientists themselves still disagree or are not yet researched. While scientists agree on the ingestion of microplastics by many organisms [25], the consumption's health consequences are still being investigated and not yet thoroughly understood. Some studies point to negative consequences like inflammation [102], while other studies cannot show measurable effects [103]. Further eco-toxicological studies need to broaden the assessment of the extent of microplastics' impact on health.

The probably most critical point to note was the missing response rate of 19% of the students when they were asked to justify their risk evaluation. Given that only 3% considered microplastics as hardly dangerous and no one saw any danger coming from it, the question arises whether the students are eventually oversensitized by the topic without thoroughly understandying why. Almost one-third of the students depicted microplastics' effects in their definition, although these were not required in the question. This rate indicates a strong thematic link between the topic of microplastics and its effects. The fact that the characterized consequences were purely negative signals a strong negative association of the respondents with microplastics, especially since none of the respondents named even one positive property or influence. Such a negative connotation of microplastics in connection with the lack of benefits was also reported by Kramm et al. [104]. The observed high sensitivity to microplastics' hazards possibly arises from the representation of risk in the primary information source, the media [105]. In this context, the framing in media reports may play an important role [86]. Framing emphasizes individual, selected aspects within a communication process, which the sender chooses to color the facts in a manner intended by him [106]. Scientific uncertainties are often omitted in the media due to simplifying scientific findings or biased reporting, suggesting a higher probability of risks stemming from microplastics than objectively surveyed [86]. Different risk conceptions may lead to an overestimation of risks by the public. While scientists classify risk as "the probability of a negative outcome", the public understands risk as "the uncertainty of a negative outcome itself" ([86], p. 1). Thereby a different evaluation of scientific findings on potential risks dominates the public mind. Due to the strongly negative attitude towards microplastics, education should also address plastics' positive properties as problem solvers in modern society, *e.g.*, for food safety or application in the medical field [107], to avoid a one-sided view of plastics.

Media as the primary source of information: School is falling behind

As media can inform many people uncomplicatedly and directly, non-surprisingly media perceived a great relevance (named by 52%), which is in accordance with Deng et al. [88]. In contrast, the education sector as a source of information was scored by just 21% of respondents, while the university even played a minor role than schools. Although the media landscape has changed a lot and media use has undoubtedly grown since then, already in 1987, Blum [108] reported schools as less critical than mass media (TV, radio, private reading) as sources of students' knowledge and beliefs. Nelkin ([109], p. 2) concluded that science is understood "less through direct experience or past education than through the filter of journalistic language and imagery". Several other studies on student conceptions already found media as an essential source [110, 111]. Our results confirmed these results, which is of concern, as the topic should be given an important place in schools and at university (especially in science courses) due to its topicality and global impact. The low number of university mentions may lie in the young semester and in the large number of study programs surveyed, covering not solely science classes. Hence, the numbers of pure science majors might look different.

Looking at the students' information in more detail, the high proportion of TV in media can be seen as positive, as they cited news, reports, etc., as a source. According to Brossard [112], the Internet has a growing relevance in procuring information, which is also reflected in our results. The Internet can be a reliable source if it is used for research on high-quality sites. The growth in the usage of social media has undoubtedly proceeded in the last two years. This trend must be regarded with caution since content, as long as it does not come from official organizations or scientists, is hardly checked and quickly distributed.

Media have the potential to form scientific knowledge and thereby shape public conceptions [113]. This is also the case for topics on plastics and microplastics. Therefore, the way information about plastic pollution is presented through the media can influence society's understanding [114]. Next to positive aspects such as speed, timeliness, and range, the media reporting also holds disadvantages, *e.g.*, when the coverage quality suffers from exaggeration, oversimplification, or misrepresentation [115]. Hence, media can also contribute to disseminating and perpetuating alternative conceptions [116], which possibly become entrenched in the public's mind by repeated reporting. An example of a persistent alternative conception in connection with plastic pollution is the Great Pacific Garbage Patch, which is anchored in the public's mind as a closed garbage patch [114, 117] and most likely derived from multiple media reports on the subject, which often used images of plastic-flooded rivers to illustrate the point. Contrary to this popular notion of a carpet or island of plastics, the Great Pacific Garbage Patch is instead a collection of individual plastic items in the North Pacific Ocean [117]. Science communication to the public with appropriate tools is needed to clarify that the Great Pacific Garbage Patch is rather a matter of individual plastic fragments accumulating than a plastic island. Next to the Great Pacific Garbage Patch, various issues related to microplastics exist for which alternative conceptions have been formed in public. Hahladakis [117] attempts to educate and clarify these alternative conceptions concluding education on the topic essential.

Also teachers are not immune to alternative conceptions [116]. Before lessons, teachers should reflect on their own perceptions and check them with the help of several high-quality sources to identify deviations [118]. Holding alternative (non-scientific) conceptions, teachers possibly may not recognize them in their classroom [111] or even impart their own to their students. Thus, students and teachers might benefit from reliable information from first-hand sources other than the media. Against this background, schools and universities should much more become places that provide up-to-date information on topics relevant to the day and opportunities for students to exchange ideas with teachers, scientists, and fellow students, questioning their own perceptions and discussing divergent views. Strengthening the educational sector would facilitate young adults' responsibility as a well-informed part of society.

Science communication desired

The demand for professional science communication on different media channels and educational institutions is apparent: Transferring the knowledge directly from the scientific community to the general society is vital but needs a language that both sides understand and decode similarly. Burns et al. ([119], p. 191) consider the "use of appropriate skills, media, activities, and dialogue" as a prerequisite for successful science communication. Science education is conceived as the foundation for science communication: The greater people's familiarity with science, the better the understanding of the communicated content will be [120]. To render scientific ideas intelligible, a layperson's perspective may help recognize the gap between both knowledge levels [120]. This is where our study results come in. Knowledge of students' conceptions on microplastics can be valuable starting points for tailor-made science communication initiatives addressing pertinent ideas and excluding already well-established and understood topics. Subsequently, contextual and conceptual adjustments on the subject matter, which scientists aim to convey, have to be performed. Thereby, among other things, the adaptation of vocabulary and jargon is fundamental to creating effective communication with the public [115]. Obviously, the term microplastics has arrived in everyday lives and natural language use. However, special attention to vocabulary and framing in microplastics' consequences and risks is delicate. Furthermore, media and actions have to be tailored to the target audience [119]. Scientists should much more enter the relevant media channels like TV and the Internet to reach a broad audience. This also includes close cooperation with journalists by sufficiently informing them about the main statements, misunderstandings, and misinterpretations. As successful science communication is based on a two-way dialogue that facilitates communicative interaction [119], disseminating knowledge and exchanging opinions via social media without intermediary journalists may be a suitable tool. Indeed, successful science communication is beneficial for researchers and the general public [121], helping people make informed decisions concerning public and private lives [109, 122]. If scientists succeed in this challenging and vital task, a science-literate person will possess profound knowledge to participate in scientific discussions and act wisely.

Need for action

Research on microplastics enlarges continuously, which accordingly changes the knowledge levels of scientists [9]. There is agreement among scientists that plastic debris is everywhere in the world [123]. Furthermore, scientific findings revealed that the ubiquitous occurrence definitely has impacts, *e.g.*, by entangling organisms [25], by changing soil properties [56], by the colonization on its surface [124], or by the ingestion of it [50]. Although potential consequences need further research [125], the question remains how much knowledge is necessary to initiate changes. Knowing that a human-made substance is and will be strictly speaking everywhere should be enough to rethink society, public policies, and industry towards a circular economy and a reduction in consumption. The constant expansion of knowledge about microplastics also indicates the need for action in the educational sector.

The speed of new scientific findings shows that the public's current state of knowledge is never satisfactory but should steadily be expanded [126]. Efficient science communication provides the general public with information "that they need in a form they can use" ([120], p. 14038) while guaranteeing that society is not left behind at an outdated state of knowledge but continuously kept informed about new developments. Dissemination through modern media channels by experts in the field can transport scientifically correct information to a broad audience [127]. Next, scientists' outreach activities would be appropriate methods to impart scientific knowledge directly to students [121]. If the responsibility is handed over to educators in different educational institutions, it must be ensured that they also have up-to-date scientifically sound conceptions about the subject matter, *e.g.*, through participation in training by experts or examination of reliable literature [118]. As conceptions on microplastics are mainly media-driven, teachers should regularly survey their students' and their own conceptions [110]. In general, schools are lagging behind concerning microplastics. Although microplastics can be integrated into some ecological topics, they are not yet a fixed part of the curriculum, leaving a great need for action.

Conclusions

Microplastics are one of our generation's critical environmental challenges. A potential pathway for successful reduction of exposure may lie in recognizing and building upon individual conceptions, which often contain alternative (non-scientific) conceptions [64]. Consequently, knowledge about individual conceptions provides valuable starting points for successful awareness campaigns aiming to educate [60]. A key to bridge the "ivory tower" of expert knowledge to the general public is appropriate science communication (jointly initiated by teams of scientists and educators). For reaching this aim, the communication must be tailored to the audience, be understandable and straightforward in content and language, create a connection to the audiences' lifeworld and take (alternative) conceptions into account [119, 128]. In acknowledging these major domains of science communication, scientists can share their expertise with the public, and educators can support the most promising channels to shape the public's awareness sustainably. As humans are the cause, they are also the solution [59].

Limitations

The present study was conducted among students. Within this sample, we aimed to cover different study fields by collecting data at the six different faculties of the University of Bayreuth. However, the sample does not represent the overall German population, wherefore the results cannot be generalized. The study must be read accordingly. The open questions are a suitable and well-established method to collect data on individual conceptions; however, due to the time restrictions and the artificial situation reminiscent of an exam, students may not have written down every experience and idea they hold on the specific topics in connection with microplastics. Finally, the study allowed to capture only selected issues related to microplastics. Further studies are needed to receive a more comprehensive understanding of students' conceptions of microplastics.

Author Contributions: Writing – original draft: Patricia Raab. Writing – review & editing: Patricia Raab, Franz X. Bogner.

Financial Disclosure: This research was funded by PLAWES (BMBF-Grant: 03F0789A). The APC was funded by the German Research Foundation (DFG) and the University of Bayreuth in the funding program Open Access Publishing (Grant: LA 2159/8-6). This article reflects only the authors' views. The BMBF and the DFG are not liable for any use that might be made of the information contained herein.

Acknowledgments: The authors would like to thank all participating students for their time and effort. The authors are very grateful to Tabea Loermann-Knöchel for initiating the study and conducting the data collection.

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

References

1. Geyer R, Jambeck JR, Law KL. Production, use, and fate of all plastics ever made. Sci. Adv. 2017; 3: e1700782. https://doi.org/10.1126/sciadv.1700782 PMID: 28776036
2. Allen S, Allen D, Phoenix VR, Le Roux G, Durántez Jiménez P, Simonneau A, et al. Atmospheric transport and deposition of microplastics in a remote mountain catchment. Nat. Geosci. 2019; 12: 339–44. https://doi.org/10.1038/s41561-019-0335-5
3. GESAMP. Sources, fate and effects of microplastics in the marine environment: part two of a global assessment: IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection; 2016.
4. Wright SL, Thompson RC, Galloway TS. The physical impacts of microplastics on marine organisms: a review. Environ Pollut. 2013; 178: 483–92. https://doi.org/10.1016/j.envpol.2013.02.031 PMID: 23545014
5. Galgani F, Hanke G, Maes T. Global Distribution, Composition and Abundance of Marine Litter. In: Bergmann M, Gutow L, Klages M, editors. Marine Anthropogenic Litter: Springer International Publishing; 2015. p. 29–56.
6. Browne MA, Galloway T, Thompson R. Microplastic—an emerging contaminant of potential concern? Integr. Environ. Assess. Manag. 2007; 3: 559–61. https://doi.org/10.1002/ieam.5630030412 PMID: 18046805
7. Duis K, Coors A. Microplastics in the aquatic and terrestrial environment: sources (with a specific focus on personal care products), fate and effects. Environ. Sci. Eur. 2016; 28: 1–25.
8. Hidalgo-Ruz V, Gutow L, Thompson RC, Thiel M. Microplastics in the marine environment: a review of the methods used for identification and quantification. Environ Sci Technol. 2012; 46: 3060–75. https://doi.org/10.1021/es2031505 PMID: 22321064

9. Dris R, Imhof HK, Löder MGJ, Gasperi J, Laforsch C, Tassin B. Microplastic Contamination in Freshwater Systems: Methodological Challenges, Occurrence and Sources. In: Zeng EY, editor. Microplastic Contamination in Aquatic Environments: An Emerging Matter of Environmental Urgency. San Diego, CA, USA: Elsevier Science; 2018. p. 51–93. https://doi.org/10.1016/B978-0-12-813747-5.00003-5
10. Corradini F, Meza P, Eguiluz R, Casado F, Huerta-Lwanga E, Geissen V. Evidence of microplastic accumulation in agricultural soils from sewage sludge disposal. Sci Total Environ. 2019; 671: 411–20. https://doi.org/10.1016/j.scitotenv.2019.03.368 PMID: 30933797
11. Norwegian Environment Agency. Sources of Microplastic Pollution to the Marine Environment; 2014.
12. Koelmans AA, Gouin T, Thompson R, Wallace N, Arthur C. Plastics in the marine environment. Environ. Toxicol. Chem. 2014; 33: 5–10. https://doi.org/10.1002/etc.2426 PMID: 24357031
13. Carpenter EJ, Smith KL. Plastics on the Sargasso sea surface. Science. 1972; 175: 1240–1. https://doi.org/10.1126/science.175.4027.1240 PMID: 5061243
14. Thompson RC, Olsen Y, Mitchell RP, Davis A, Rowland SJ, John AWG, et al. Lost at sea: where is all the plastic? Science. 2004; 304: 838. https://doi.org/10.1126/science.1094559 PMID: 15131299
15. Zhang W, Zhang S, Wang J, Wang Y, Mu J, Wang P, et al. Microplastic pollution in the surface waters of the Bohai Sea, China. Environ Pollut. 2017; 231: 541–8. https://doi.org/10.1016/j.envpol.2017.08.058 PMID: 28843202
16. Claessens M, Meester S de, van Landuyt L, Clerck K de, Janssen CR. Occurrence and distribution of microplastics in marine sediments along the Belgian coast. Mar Pollut Bull. 2011; 62: 2199–204. https://doi.org/10.1016/j.marpolbul.2011.06.030 PMID: 21802098
17. van Cauwenberghe L, Vanreusel A, Mees J, Janssen CR. Microplastic pollution in deep-sea sediments. Environ Pollut. 2013; 182: 495–9. https://doi.org/10.1016/j.envpol.2013.08.013 PMID: 24035457
18. Zbyszewski M, Corcoran PL. Distribution and Degradation of Fresh Water Plastic Particles Along the Beaches of Lake Huron, Canada. Water Air Soil Pollut. 2011; 220: 365–72. https://doi.org/10.1007/s11270-011-0760-6
19. Imhof HK, Ivleva NP, Schmid J, Niessner R, Laforsch C. Contamination of beach sediments of a subalpine lake with microplastic particles. Curr. Biol. 2013; 23:R867–8. https://doi.org/10.1016/j.cub.2013.09.001 PMID: 24112978
20. Sommer F, Dietze V, Baum A, Sauer J, Gilge S, Maschowski C, et al. Tire Abrasion as a Major Source of Microplastics in the Environment. Aerosol Air Qual. Res. 2018; 18: 2014–28. https://doi.org/10.4209/aaqr.2018.03.0099
21. Järlskog I, Strömvall A-M, Magnusson K, Gustafsson M, Polukarova M, Galfi H, et al. Occurrence of tire and bitumen wear microplastics on urban streets and in sweepsand and washwater. Sci Total Environ. 2020; 729: 138950. https://doi.org/10.1016/j.scitotenv.2020.138950 PMID: 32371211
22. Bergmann M, Mützel S, Primpke S, Tekman MB, Trachsel J, Gerdts G. White and wonderful? Microplastics prevail in snow from the Alps to the Arctic. Sci. Adv. 2019; 5:eaax1157. https://doi.org/10.1126/sciadv.aax1157 PMID: 31453336
23. Mintenig SM, Löder MGJ, Primpke S, Gerdts G. Low numbers of microplastics detected in drinking water from ground water sources. Sci Total Environ. 2019; 648: 631–5. https://doi.org/10.1016/j.scitotenv.2018.08.178 PMID: 30121540
24. Panno SV, Kelly WR, Scott J, Zheng W, McNeish RE, Holm N, et al. Microplastic Contamination in Karst Groundwater Systems. Ground Water. 2019; 57: 189–96. https://doi.org/10.1111/gwat.12862 PMID: 30675731
25. Laist DW. Impacts of Marine Debris: Entanglement of Marine Life in Marine Debris Including a Comprehensive List of Species with Entanglement and Ingestion Records. In: Coe JM, Rogers DB, editors. Marine Debris: Sources, Impacts, and Solutions. New York, NY: Springer; 1997. p. 99–139.
26. Bugoni L, Krause L, Virgínia Petry M. Marine Debris and Human Impacts on Sea Turtles in Southern Brazil. Mar Pollut Bull. 2001; 42: 1330–4. https://doi.org/10.1016/s0025-326x(01)00147-3 PMID: 11827120
27. Tomás J, Guitart R, Mateo R, Raga JA. Marine debris ingestion in loggerhead sea turtles, Caretta caretta, from the Western Mediterranean. Mar Pollut Bull. 2002; 44: 211–6. https://doi.org/10.1016/s0025-326x(01)00236-3 PMID: 11954737

28. Mascarenhas R, Santos R, Zeppelini D. Plastic debris ingestion by sea turtle in Paraíba, Brazil. Mar Pollut Bull. 2004; 49: 354–5. https://doi.org/10.1016/j.marpolbul.2004.05.006 PMID: 15341830
29. Romeo T, Pietro B, Pedà C, Consoli P, Andaloro F, Fossi MC. First evidence of presence of plastic debris in stomach of large pelagic fish in the Mediterranean Sea. Mar Pollut Bull. 2015; 95: 358–61. https://doi.org/10.1016/j.marpolbul.2015.04.048 PMID: 25936574
30. Tanaka K, Takada H, Yamashita R, Mizukawa K, Fukuwaka M-a, Watanuki Y. Accumulation of plastic-derived chemicals in tissues of seabirds ingesting marine plastics. Mar Pollut Bull. 2013; 69: 219–22. https://doi.org/10.1016/j.marpolbul.2012.12.010 PMID: 23298431
31. Moser ML, Lee DS. A Fourteen-Year Survey of Plastic Ingestion by Western North Atlantic Seabirds. Col. Waterbirds. 1992; 15: 83. https://doi.org/10.2307/1521357
32. Cole M, Lindeque P, Halsband C, Galloway TS. Microplastics as contaminants in the marine environment: a review. Mar Pollut Bull. 2011; 62: 2588–97. https://doi.org/10.1016/j.marpolbul.2011.09.025 PMID: 22001295
33. Cole M, Lindeque P, Fileman E, Halsband C, Goodhead R, Moger J, et al. Microplastic ingestion by zooplankton. Environ Sci Technol. 2013; 47: 6646–55. https://doi.org/10.1021/es400663f PMID:23692270
34. Cole M, Webb H, Lindeque PK, Fileman ES, Halsband C, Galloway TS. Isolation of microplastics in biota-rich seawater samples and marine organisms. Sci Rep. 2014; 4: 4528. https://doi.org/10.1038/srep04528 PMID: 24681661
35. van Cauwenberghe L, Janssen CR. Microplastics in bivalves cultured for human consumption. Environ Pollut. 2014; 193: 65–70. https://doi.org/10.1016/j.envpol.2014.06.010 PMID: 25005888
36. Watts AJR, Lewis C, Goodhead RM, Beckett SJ, Moger J, Tyler CR, et al. Uptake and retention of microplastics by the shore crab Carcinus maenas. Environ Sci Technol. 2014; 48: 8823–30. https://doi.org/10.1021/es501090e PMID: 24972075
37. Brennecke D, Ferreira EC, Costa TMM, Appel D, da Gama BAP, Lenz M. Ingested microplastics (100 μm) are translocated to organs of the tropical fiddler crab Uca rapax. Mar Pollut Bull. 2015; 96: 491–5. https://doi.org/10.1016/j.marpolbul.2015.05.001 PMID: 26013589
38. Boerger CM, Lattin GL, Moore SL, Moore CJ. Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre. Mar Pollut Bull. 2010; 60: 2275–8. https://doi.org/10.1016/j.marpolbul.2010.08.007 PMID: 21067782
39. Foekema EM, Gruijter C de, Mergia MT, van Franeker JA, Murk AJ, Koelmans AA. Plastic in north sea fish. Environ Sci Technol. 2013; 47: 8818–24. https://doi.org/10.1021/es400931b PMID: 23777286
40. Carlin J, Craig C, Little S, Donnelly M, Fox D, Zhai L, et al. Microplastic accumulation in the gastrointestinal tracts in birds of prey in central Florida, USA. Environ Pollut. 2020; 264: 114633. https://doi.org/10.1016/j.envpol.2020.114633 PMID: 32388295
41. Besseling E, Foekema EM, van Franeker JA, Leopold MF, Kühn S, Bravo Rebolledo EL, et al. Microplastic in a macro filter feeder: Humpback whale Megaptera novaeangliae. Mar Pollut Bull. 2015; 95: 248–52. https://doi.org/10.1016/j.marpolbul.2015.04.007 PMID: 25916197
42. Rosenkranz P, Chaudhry Q, Stone V, Fernandes TF. A comparison of nanoparticle and fine particle uptake by Daphnia magna. Environ. Toxicol. Chem. 2009; 28: 2142–9. https://doi.org/10.1897/08-559.1 PMID: 19588999
43. Tanaka K, Takada H. Microplastic fragments and microbeads in digestive tracts of planktivorous fish from urban coastal waters. Sci Rep. 2016; 6: 34351. https://doi.org/10.1038/srep34351 PMID: 27686984
44. Sanchez W, Bender C, Porcher J-M. Wild gudgeons (Gobio gobio) from French rivers are contaminated by microplastics: preliminary study and first evidence. Environ. Res. 2014; 128: 98–100. https://doi.org/10.1016/j.envres.2013.11.004 PMID: 24295902
45. Hurley RR, Woodward JC, Rothwell JJ. Ingestion of Microplastics by Freshwater Tubifex Worms. Environ Sci Technol. 2017; 51: 12844–51. https://doi.org/10.1021/acs.est.7b03567 PMID: 29019399
46. Browne MA, Dissanayake A, Galloway TS, Lowe DM, Thompson RC. Ingested microscopic plastic translocates to the circulatory system of the mussel, Mytilus edulis (L). Environ Sci Technol. 2008; 42: 5026–31. https://doi.org/10.1021/es800249a PMID: 18678044

47. Sendra M, Saco A, Yeste MP, Romero A, Novoa B, Figueras A. Nanoplastics: From tissue accumulation to cell translocation into Mytilus galloprovincialis hemocytes. resilience of immune cells exposed to nanoplastics and nanoplastics plus Vibrio splendidus combination. J. Hazard. Mater. 2020; 388: 121788. https://doi.org/10.1016/j.jhazmat.2019.121788 PMID: 31813690
48. Rochman CM, Hoh E, Kurobe T, Teh SJ. Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. Sci Rep. 2013; 3: 3263. https://doi.org/10.1038/srep03263 PMID: 24263561
49. Farrell P, Nelson K. Trophic level transfer of microplastic: Mytilus edulis (L.) to Carcinus maenas (L.). Environ Pollut. 2013; 177: 1–3. https://doi.org/10.1016/j.envpol.2013.01.046 PMID: 23434827
50. Setälä O, Fleming-Lehtinen V, Lehtiniemi M. Ingestion and transfer of microplastics in the planktonic food web. Environ Pollut. 2014; 185: 77–83. https://doi.org/10.1016/j.envpol.2013.10.013 PMID: 24220023
51. Murray F, Cowie PR. Plastic contamination in the decapod crustacean Nephrops norvegicus (Linnaeus, 1758). Mar Pollut Bull 2011. https://doi.org/10.1016/j.marpolbul.2011.03.032 PMID: 21497854
52. Vinay Kumar BN, Löschel LA, Imhof HK, Löder MGJ, Laforsch C. Analysis of microplastics of a broad size range in commercially important mussels by combining FTIR and Raman spectroscopy approaches. Environ Pollut. 2021; 269: 116147. https://doi.org/10.1016/j.envpol.2020.116147 PMID: 33280916
53. Mason SA, Welch VG, Neratko J. Synthetic Polymer Contamination in Bottled Water. Front. Chem. 2018; 6: 407. https://doi.org/10.3389/fchem.2018.00407 PMID: 30255015
54. Karami A, Golieskardi A, Keong Choo C, Larat V, Galloway TS, Salamatinia B. The presence of microplastics in commercial salts from different countries. Sci Rep. 2017; 7: 46173. https://doi.org/10.1038/srep46173 PMID: 28383020
55. Kirstein IV, Kirmizi S, Wichels A, Garin-Fernandez A, Erler R, Löder M, et al. Dangerous hitchhikers? Evidence for potentially pathogenic Vibrio spp. on microplastic particles. Mar. Environ. Res. 2016; 120: 1–8. https://doi.org/10.1016/j.marenvres.2016.07.004 PMID: 27411093
56. de Souza Machado AA, Lau CW, Kloas W, Bergmann J, Bachelier JB, Faltin E, et al. Microplastics Can Change Soil Properties and Affect Plant Performance. Environ Sci Technol. 2019; 53: 6044–52. https://doi.org/10.1021/acs.est.9b01339 PMID: 31021077
57. Vianello A, Jensen RL, Liu L, Vollertsen J. Simulating human exposure to indoor airborne microplastics using a Breathing Thermal Manikin. Sci Rep. 2019; 9: 8670. https://doi.org/10.1038/s41598-019-45054-w PMID: 31209244
58. Cox KD, Covernton GA, Davies HL, Dower JF, Juanes F, Dudas SE. Human Consumption of Microplastics. Environ Sci Technol. 2019; 53: 7068–74. https://doi.org/10.1021/acs.est.9b01517 PMID: 31184127
59. Pahl S, Wyles KJ. The human dimension: how social and behavioural research methods can help address microplastics in the environment. Anal. Methods. 2017; 9: 1404–11. https://doi.org/10.1039/C6AY02647H
60. Maskiewicz AC, Lineback JE. Misconceptions are "so yesterday!". CBE Life Sci. Educ. 2013; 12: 352–6. https://doi.org/10.1187/cbe.13-01-0014 PMID: 24006383
61. Novak JD. Learning Science and the Science of Learning. Stud. Sci. Educ. 1988; 15: 77–101. https://doi.org/10.1080/03057268808559949
62. Southerland SA, Sinatra GM, Matthews MR. Belief, Knowledge, and Science Education. Educ. Psychol. Rev. 2001; 13: 325–51. https://doi.org/10.1023/A:1011913813847
63. Wandersee JH, Mintzes JJ, Novak JD. Research on alternative conceptions. In: Gabel DL, editor. Handbook of research on science teaching and learning: A project of the National Science Teachers Association. New York, NY: Macmillan; 1994. p. 177–210.
64. Duit R, Treagust DF. Conceptual change: A powerful framework for improving science teaching and learning. Int J Sci Educ. 2003; 25: 671–88. https://doi.org/10.1080/09500690305016
65. Smith JP, diSessa AA, Roschelle J. Misconceptions Reconceived: A Constructivist Analysis of Knowledge in Transition. J. Learn. Sci. 1994; 3: 115–63. https://doi.org/10.1207/s15327809jls0302_1
66. Langheinrich J, Bogner FX. Student conceptions about the DNA structure within a hierarchical organizational level: improvement by experiment- and computer-based outreach learning. Biochem. Mol. Biol. Educ. 2015; 43: 393–402. https://doi.org/10.1002/bmb.20888 PMID: 26481196

67. Maurer M, Bogner FX. First steps towards sustainability? University freshmen perceptions on nature versus environment. PLOS ONE. 2020; 15:e0234560. https://doi.org/10.1371/journal.pone.0234560 PMID: 32542054
68. Schneiderhan-Opel J, Bogner FX. Between Environmental Utilization and Protection: Adolescent Conceptions of Biodiversity. Sustainability. 2019; 11: 4517. https://doi.org/10.3390/su11174517
69. Schönfelder ML, Bogner FX. Individual perception of bees: Between perceived danger and willingness to protect. PLOS ONE 2017. https://doi.org/10.1371/journal.pone.0180168 PMID: 28662124
70. Thorn CJ, Bissinger K, Thorn S, Bogner FX. "Trees Live on Soil and Sunshine!": Coexistence of Scientific and Alternative Conception of Tree Assimilation. PLOS ONE. 2016; 11:e0147802. https://doi.org/10.1371/journal.pone.0147802 PMID: 26807974
71. Fröhlich G, Goldschmidt M, Bogner FX. The effect of age on students’ conceptions of agriculture. Stud. Agric. Econ. 2013; 115: 61–7.
72. Novak JD. Meaningful learning: The essential factor for conceptual change in limited or inappropriate propositional hierarchies leading to empowerment of learners. Sci. Ed. 2002; 86: 548–71. https://doi.org/10.1002/sce.10032
73. Zabel J, Gropengiesser H. Learning progress in evolution theory: climbing a ladder or roaming a landscape? J. Biol. Educ. 2011; 45: 143–9. https://doi.org/10.1080/00219266.2011.586714
74. Asshoff R, Düsing K, Winkelmann T, Hammann M. Considering the levels of biological organisation when teaching carbon flows in a terrestrial ecosystem. J. Biol. Educ. 2020; 54: 287–99. https://doi.org/10.1080/00219266.2019.1575263
75. Franke G, Bogner FX. How does integrating alternative conceptions into lessons influence pupils’ situational emotions and learning achievement? J. Biol. Educ. 2013; 47: 1–11. https://doi.org/10.1080/00219266.2012.716777
76. Stebbins R. Exploratory Research in the Social Sciences. Thousand Oaks, CA, USA: SAGE Publications, Inc; 2001.
77. Mayring P. Qualitative Content Analysis. Forum Qualitative Sozialforschung / Forum: Qualitative Social Research 2000. https://doi.org/10.17169/FQS-1.2.1089
78. Statistisches Bundesamt (Destatis). Bildung, Forschung und Kultur. 2021. https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Bildung-Forschung-Kultur/Hochschulen/_inhalt.html.
79. Universität Bayreuth. Die Universität Bayreuth in Zahlen. 2021. https://www.uni-bayreuth.de/de/universitaet/ubt-in-zahlen/index.html.
80. PlasticsEurope. Plastics—the Facts 2020: An analysis of European plastics production, demand and waste data. Brussels; 2020.
81. Cho J, Lee E-H. Reducing Confusion about Grounded Theory and Qualitative Content Analysis: Similarities and Differences. TQR 2014. https://doi.org/10.46743/2160-3715/2014.1028
82. Cohen J. A Coefficient of Agreement for Nominal Scales. Educ. Psychol. Meas. 1960; 20: 37–46. https://doi.org/10.1177/001316446002000104
83. Bortz J, Döring N. Forschungsmethoden und Evaluation: Für Human- und Sozialwissenschaftler. 4th ed. Heidelberg: Springer; 2009.
84. McHugh ML. Interrater reliabiliy: the kappa statistic. Biochem Med. 2012; 22.
85. Landis JR, Koch GG. The Measurement of Observer Agreement for Categorical Data. Biometrics. 1977; 33: 159–74. https://doi.org/10.2307/2529310 PMID: 843571
86. Völker C, Kramm J, Wagner M. On the Creation of Risk: Framing of Microplastics Risks in Science and Media. Glob Chall. 2019: 1900010. https://doi.org/10.1002/gch2.201900010
87. Hann S, Sherrington C, Jamieson O, Hickman M, Kershaw P, Bapasola A, et al. Investigating options for reducing releases in the aquatic environment of microplastics emitted by (but not intentionally added in) products. Final Report. London/Bristol; 2018.
88. Deng L, Cai L, Sun F, Li G, Che Y. Public attitudes towards microplastics: Perceptions, behaviors and policy implications. Resour. Conserv. Recy. 2020; 163: 105096. https://doi.org/10.1016/j.resconrec.2020.105096

89. Weithmann N, Möller JN, Löder MGJ, Piehl S, Laforsch C, Freitag R. Organic fertilizer as a vehicle for the entry of microplastic into the environment. Sci. Adv. 2018; 4:eaap8060. https://doi.org/10.1126/sciadv.aap8060 PMID: 29632891
90. Re V. Shedding light on the invisible: addressing the potential for groundwater contamination by plastic microfibers. Hydrogeol. J. 2019; 27: 2719–27. https://doi.org/10.1007/s10040-019-01998-x
91. McCormick A, Hoellein TJ, Mason SA, Schluep J, Kelly JJ. Microplastic is an abundant and distinct microbial habitat in an urban river. Environ Sci Technol. 2014; 48: 11863–71. https://doi.org/10.1021/es503610r PMID: 25230146
92. Fremerey C, Liefländer AK, Bogner FX. Conceptions about Drinking Water of 10th Graders and Undergraduates. J. Water Resource Prot. 2014; 06: 1112–23. https://doi.org/10.4236/jwarp.2014.612104
93. Liefländer AK, Fremerey C, Bogner FX. Ecuadorian students' conceptions and personal experience regarding water management issues / Concepciones y experiencias personales de los estudiantes ecuatorianos sobre la gestión del agua. Psyecology. 2016; 7: 25–63. https://doi.org/10.1080/21711976.2015.1114216
94. Schmid S, Bogner FX. What Germany's University Beginners Think about Water Reuse. Water. 2018; 10: 731. https://doi.org/10.3390/w10060731
95. Andrady AL. Microplastics in the marine environment. Mar Pollut Bull. 2011; 62: 1596–605. https://doi.org/10.1016/j.marpolbul.2011.05.030 PMID: 21742351
96. Mehlhart G, Blepp M. Study on land-sourced litter (LSL) in the marine environment: Review of sources and literature. Darmstadt/Freiburg; 2012.
97. Leire C, Thidell Å. Product-related environmental information to guide consumer purchases–a review and analysis of research on perceptions, understanding and use among Nordic consumers. J. Clean. Prod. 2005; 13: 1061–70. https://doi.org/10.1016/j.jclepro.2004.12.004
98. Hartley BL, Thompson RC, Pahl S. Marine litter education boosts children's understanding and selfreported actions. Mar Pollut Bull. 2015; 90: 209–17. https://doi.org/10.1016/j.marpolbul.2014.10.049 PMID: 25467869
99. Stanton T, Kay P, Johnson M, Chan FKS, Gomes RL, Hughes J, et al. It's the product not the polymer: Rethinking plastic pollution. Wiley Interdisciplinary Reviews: Water 2020. https://doi.org/10.1002/wat2.1490
100. Dris R, Agarwal S, Laforsch C. Plastics: From a Success Story to an Environmental Problem and a Global Challenge. Glob Chall. 2020; 4: 2000026. https://doi.org/10.1002/gch2.202000026 PMID: 32685196
101. Anderson AG, Grose J, Pahl S, Thompson RC, Wyles KJ. Microplastics in personal care products: Exploring perceptions of environmentalists, beauticians and students. Mar Pollut Bull. 2016; 113: 454–60. https://doi.org/10.1016/j.marpolbul.2016.10.048 PMID: 27836135
102. Moos N von, Burkhardt-Holm P, Köhler A. Uptake and effects of microplastics on cells and tissue of the blue mussel Mytilus edulis L. after an experimental exposure. Environ Sci Technol. 2012; 46: 11327–35. https://doi.org/10.1021/es302332w PMID: 22963286
103. Hämer J, Gutow L, Köhler A, Saborowski R. Fate of Microplastics in the Marine Isopod Idotea emarginata. Environ Sci Technol. 2014; 48: 13451–8. https://doi.org/10.1021/es501385y PMID: 25289587
104. Kramm J, Völker C, Wagner M. Superficial or Substantial: Why Care about Microplastics in the Anthropocene? Environ Sci Technol. 2018; 52: 3336–7. https://doi.org/10.1021/acs.est.8b00790 PMID: 29494144
105. Koelmans AA, Besseling E, Foekema E, Kooi M, Mintenig S, Ossendorp BC, et al. Risks of Plastic Debris: Unravelling Fact, Opinion, Perception, and Belief. Environ Sci Technol. 2017; 51: 11513–9. https://doi.org/10.1021/acs.est.7b02219 PMID: 28971682
106. Entman RM. Framing: Toward Clarification of a Fractured Paradigm. Journal of Communication. 1993; 43: 51–8. https://doi.org/10.1111/j.1460-2466.1993.tb01304.x
107. Mitrano DM, Wohlleben W. Microplastic regulation should be more precise to incentivize both innovation and environmental safety. Nat Commun. 2020; 11: 5324. https://doi.org/10.1038/s41467-020-19069-1 PMID: 33087714
108. Blum A. Students' Knowledge and Beliefs concerning Environmental Issues in Four Countries. J. Environ. Educ. 1987; 18: 7–13. https://doi.org/10.1080/00958964.1987.9942734
109. Nelkin D. Selling science: How the press covers science and technology. New York, NY: Freeman; 1995.

110. Schmid S, Bogner FX. Is there more than the sewage plant? University freshmen's conceptions of the urban water cycle. PLOS ONE. 2018; 13:e0200928. https://doi.org/10.1371/journal.pone.0200928 PMID: 30024937
111. Shaw KRM, van Horne K, Zhang H, Boughman J. Essay contest reveals misconceptions of high school students in genetics content. Genetics. 2008; 178: 1157–68. https://doi.org/10.1534/genetics.107.084194 PMID: 18245328
112. Brossard D. New media landscapes and the science information consumer. PNAS. 2013; 110: 14096–101. https://doi.org/10.1073/pnas.1212744110 PMID: 23940316
113. Antilla L. Self-censorship and science: a geographical review of media coverage of climate tipping points. Public Underst. Sci. 2010; 19: 240–56. https://doi.org/10.1177/0963662508094099
114. Henderson L, Green C. Making sense of microplastics? Public understandings of plastic pollution. Mar Pollut Bull. 2020; 152: 110908. https://doi.org/10.1016/j.marpolbul.2020.110908 PMID: 32479284
115. Brownell SE, Price JV, Steinman L. Science Communication to the General Public: Why We Need to Teach Undergraduate and Graduate Students this Skill as Part of Their Formal Scientific Training. J. Undergrad. Neurosci. Educ. 2013; 12:E6–E10. PMID: 24319399
116. Dekker S, Lee NC, Howard-Jones P, Jolles J. Neuromyths in Education: Prevalence and Predictors of Misconceptions among Teachers. Front. Psychol. 2012; 3: 429. https://doi.org/10.3389/fpsyg.2012.00429 PMID: 23087664
117. Hahladakis JN. Delineating the global plastic marine litter challenge: clarifying the misconceptions. Environ. Monit. Assess. 2020; 192: 267. https://doi.org/10.1007/s10661-020-8202-9 PMID: 32248299
118. Azevedo M-M, Duarte S. Continuous Enhancement of Science Teachers' Knowledge and Skills through Scientific Lecturing. Front Public Health. 2018; 6: 41. https://doi.org/10.3389/fpubh.2018.00041 PMID: 29535996
119. Burns TW, O'Connor DJ, Stocklmayer SM. Science Communication: A Contemporary Definition. Public Underst. Sci. 2003; 12: 183–202. https://doi.org/10.1177/09636625030122004
120. Fischhoff B. The sciences of science communication. Proc Natl Acad Sci U S A. 2013; 110: 14033–9. https://doi.org/10.1073/pnas.1213273110 PMID: 23942125
121. Clark G, Russell J, Enyeart P, Gracia B, Wessel A, Jarmoskaite I, et al. Science Educational Outreach Programs That Benefit Students and Scientists. PLoS Biol. 2016; 14:e1002368. https://doi.org/10.1371/journal.pbio.1002368 PMID: 26844991
122. Treise D, Weigold MF. Advancing Science Communication. Sci. Commun. 2002; 23: 310–22. https://doi.org/10.1177/107554700202300306
123. Rochman CM. Microplastics research-from sink to source. Science. 2018; 360: 28–9. https://doi.org/10.1126/science.aar7734 PMID: 29622640
124. Bergmann M, Klages M. Increase of litter at the Arctic deep-sea observatory HAUSGARTEN. Mar Pollut Bull. 2012; 64: 2734–41. https://doi.org/10.1016/j.marpolbul.2012.09.018 PMID: 23083926
125. Bucci K, Tulio M, Rochman CM. What is known and unknown about the effects of plastic pollution: A meta-analysis and systematic review. Ecol. Appl. 2020. https://doi.org/10.1002/eap.2044 PMID: 31758826
126. Miller JD. Adult Science Learning in the Internet Era. Curator. 2010; 53: 191–208. https://doi.org/10.1111/j.2151-6952.2010.00019.x
127. Hunter P. The communications gap between scientists and public: More scientists and their institutions feel a need to communicate the results and nature of research with the public. EMBO Rep. 2016; 17: 1513–5. https://doi.org/10.15252/embr.201643379 PMID: 27807059
128. Stocklmayer SM. The Background to Effective Science Communication by the Public. In: Stocklmayer SM, Gore MM, Bryant C, editors. Science Communication in Theory and Practice. Dordrecht: Springer; 2001. p. 3–22.

ANHANG

Eingesetzte Skalen

Im Anhang befinden sich die in den Teilarbeiten eingesetzten Skalen.

Teilarbeit A:

Umwelteinstellungen nach Bogner (2018)

Tageszeitpräferenz nach Carskadon et al. (1993)

Teilarbeit B:

Wissen

Umwelteinstellungen nach Bogner (2018)

Teilarbeit D:

Studierendenvorstellungen

Teilarbeit A

Please value the following statements and tick the corresponding answer!

Mark only with 1 cross!

	Totally agree ☺☺	Agree ☺	Undecided 😐	Disagree ☹	Totally disagree ☹☹
1.) Humankind will die out if we don't live in tune with nature	☐	☐	☐	☐	☐
2.) We must build more roads so people can travel to the countryside	☐	☐	☐	☐	☐
3.) I personally take care of plants	☐	☐	☐	☐	☐
4.) We need to clear forests in order to grow crops	☐	☐	☐	☐	☐
5.) We do not need to set aside areas to protect endangered species	☐	☐	☐	☐	☐
6.) I deliberately take time to watch stars at night	☐	☐	☐	☐	☐
7.) I save water by taking a shower instead of a bath (in order to spare water)	☐	☐	☐	☐	☐
8.) I take time to watch the clouds pass by	☐	☐	☐	☐	☐
9.) Dirty industrial smoke from chimneys makes me angry	☐	☐	☐	☐	☐
10.) Human beings are not more important than other creatures	☐	☐	☐	☐	☐
11.) I enjoy gardening	☐	☐	☐	☐	☐
12.) Humans don't have the right to change nature as they see fit	☐	☐	☐	☐	☐
13.) Not only plants and animals of economic importance need to be protected	☐	☐	☐	☐	☐
14.) I take time to consciously smell flowers	☐	☐	☐	☐	☐
15.) People worry too much about pollution	☐	☐	☐	☐	☐
16.) Our planet has unlimited resources	☐	☐	☐	☐	☐
17.) Listening to the sounds of nature makes me relax	☐	☐	☐	☐	☐
18.) Nature is always able to restore itself	☐	☐	☐	☐	☐
19.) I consciously watch or listen to birds	☐	☐	☐	☐	☐
20.) The quiet nature outdoors makes me anxious	☐	☐	☐	☐	☐

Teilarbeit A

Please value the following statements and tick the corresponding answer!

Mark only with 1 cross!

1.) Imagine: School is canceled! You can get up whenever you want to. When would you get out of bed? Between…

- ☐ 5:00 and 6:30 am
- ☐ 6:30 and 7:45 am
- ☐ 7:45 and 9:45 am
- ☐ 9:45 and 11:00 am
- ☐ 11:00 am and noon

2.) Is it easy for you to get up in the morning?

- ☐ No way!
- ☐ Sort of
- ☐ Pretty easy
- ☐ It's a cinch

3.) Gym class is set for 7:00 in the morning. How do you think you'll do?

- ☐ My best!
- ☐ Okay
- ☐ Worse than usual
- ☐ Awful

4.) The bad news: You have to take a two-hour test. The good news: You can take it when you think you'll do your best. What time is that?

- ☐ 8:00 to 10:00 am
- ☐ 11:00 am to 1:00 pm
- ☐ 3:00 to 5:00 pm
- ☐ 7:00 to 9:00 pm

5.) When do you have the most energy to do your favorite things?

- ☐ Morning! I'm tired in the evening
- ☐ Morning more than evening
- ☐ Evening more than morning
- ☐ Evening! I'm tired in the morning

6.) Guess what? Your parents have decided to let you set your own bedtime. What time would you pick? Between…

- ☐ 8:00 and 9:00 pm
- ☐ 9:00 and 10:15 pm
- ☐ 10:15 pm and 12:30 am
- ☐ 12:30 and 1:45 am
- ☐ 1:45 and 3:00 am

7.) How alert are you in the first half hour you're up?

- ☐ Out of it
- ☐ A little dazed
- ☐ Okay
- ☐ Ready to take on the world

8.) When does your body start to tell you it's time for bed (even if you ignore it)? Between…

- ☐ 8:00 and 9:00 pm
- ☐ 9:00 and 10:15 pm
- ☐ 10:15 pm and 12:30 am
- ☐ 12:30 and 1:45 am
- ☐ 1:45 and 3:00 am

9.) Say you had to get up at 6:00 am every morning: What would it be like?

- ☐ Awful!
- ☐ Not so great
- ☐ Okay (if I have to)
- ☐ Fine, no problem

10.) When you wake up in the morning how long does it take for you to be totally "with it?"

- ☐ 0 to 10 minutes
- ☐ 11 to 20 minutes
- ☐ 21 to 40 minutes
- ☐ More than 40 minutes

Teilarbeit B

A) Beantworte die folgenden Fragen zu Deinem Wissen.
Es gibt immer nur eine richtige Antwort, deshalb setze bitte nur ein Kreuz pro Frage. Wenn Du eine Antwort nicht weißt, kreuze die Frage nicht an.

1. Was ist Mikroplastik?

- ☐ Ein kleines Kunststoffteil, kleiner als 10 cm.
- ☐ Ein Kunststoffteil, welches kleiner als 5 mm ist.
- ☐ Ein großes Kunststoffteil.
- ☐ Ein Klumpen Kunststoff.

2. Welche Kleidung kann Mikroplastik produzieren?

- ☐ Kleidung aus Wolle.
- ☐ Kleidung aus Seide.
- ☐ Kleidung aus Baumwolle.
- ☐ Kleidung aus Fleece.

3. Wie gelangt Mikroplastik von der Kleidung an den Strand?

- ☐ Abwasser → Kläranlage → Fluss → Meer
- ☐ Abwasser → Fluss → Meer
- ☐ See → Fluss → Meer
- ☐ Meer → Fluss → See

4. Was stimmt?
Mikroplastik…

- ☐ … ist eine gute Nahrungsergänzung.
- ☐ … ist gut für die Umwelt.
- ☐ … lagert sich in Tieren z.B. der Muschel an.
- ☐ … ist gesund.

Teilarbeit B

A) Beantworte die folgenden Fragen zu Deinem Wissen.
Es gibt immer <u>nur eine richtige Antwort</u>, deshalb setze bitte <u>nur ein Kreuz pro Frage</u>. Wenn Du eine Antwort nicht weißt, kreuze die Frage <u>nicht</u> an.

5. Die Schäden bei Tieren durch Mikroplastik sind immens und können sich wiederrum auf andere Tiere auswirken.
Wenn ein Tier z.B. eine Meeresschnecke an den Folgen von Mikroplastik stirbt, dann …

- ☐ … stört es andere Tiere nicht, da es genug anderes Futter gibt.
- ☐ … können auch andere Tiere z.B. Fische sterben, die dieses Tier als Nahrungsquelle nutzen.
- ☐ … entstehen einfach neue Tiere.
- ☐ … können andere Tiere das tote Tier essen.

6. Wie erkennt man Produkte mit Mikroplastik?

- ☐ Man liest sich die Inhaltsstoffe des Produktes durch und identifiziert somit Plastik.
- ☐ Es gibt ein Mikroplastik-Siegel, woran man Produkte mit Mikroplastik erkennt.
- ☐ Die Information steht immer vorne auf der Verpackung.
- ☐ Bei den Inhaltsstoffen eines Produktes ist immer Plastik rot markiert.

7. Wie kann die Bildung von Mikroplastik vermieden werden?

- ☐ Plastik in den Garten legen.
- ☐ Dusch-Peelings mit Plastik-Peeling kaufen.
- ☐ Keine Plastikabfälle bzw. -teile in die Natur schmeißen.
- ☐ Möglichst viele Plastikteile z.B. Spielzeug benutzen.

Teilarbeit B

B) Bewerte die folgenden Aussagen, indem Du im entsprechenden Kästchen 1 Kreuz setzt.

	Folgender Aussage stimme ich …	**gar nicht zu**	**eher nicht zu**	**teilweise zu**	**eher zu**	**voll zu**
		- -	**-**	**+/-**	**+**	**++**
		☹ ☹	☹	☹ /☺	☺	☺ ☺
1.	Wir müssen mehr Straßen bauen, damit die Menschen aufs Land fahren können.	☐	☐	☐	☐	☐
2.	Die Natur ist immer in der Lage, sich aus eigener Kraft wiederherzustellen.	☐	☐	☐	☐	☐
3.	Unser Planet hat unbegrenzte Ressourcen.	☐	☐	☐	☐	☐
4.	Wir müssen **keine** Gebiete schützen, um bedrohte Tierarten zu bewahren.	☐	☐	☐	☐	☐
5.	Die Menschen machen sich zu viele Gedanken über Umweltverschmutzung.	☐	☐	☐	☐	☐
6.	Die stille Natur draußen macht mich ängstlich.	☐	☐	☐	☐	☐
7.	Wir müssen Wälder abholzen, um Nutzpflanzen (z.B. Getreide) anzubauen.	☐	☐	☐	☐	☐
8.	Menschen haben **nicht** das Recht, die Natur zu ändern, wie sie es für richtig halten.	☐	☐	☐	☐	☐
9.	Menschen sind **nicht** wichtiger als andere Lebewesen.	☐	☐	☐	☐	☐
10.	Um Wasser zu sparen, dusche ich anstatt zu baden.	☐	☐	☐	☐	☐
11.	Schmutziger Industrierauch aus Kaminen macht mich wütend.	☐	☐	☐	☐	☐
12.	Die Menschheit wird aussterben, wenn wir nicht im Einklang mit der Natur leben.	☐	☐	☐	☐	☐
13.	**Nicht** nur Pflanzen und Tiere von wirtschaftlicher Bedeutung sollten geschützt werden.	☐	☐	☐	☐	☐

Teilarbeit B

B) Bewerte die folgenden Aussagen, indem Du im entsprechenden Kästchen 1 Kreuz setzt.

	Wie häufig führst Du die folgenden Aktivitäten außerhalb der Schule aus?	**nie**	**selten**	**manchmal**	**oft**	**sehr oft**
1.	Ich beobachte bewusst Vögel oder höre ihnen zu.	☐	☐	☐	☐	☐
2.	Ich nehme mir Zeit, den Wolken beim Vorüberziehen zuzusehen.	☐	☐	☐	☐	☐
3.	Ich nehme mir Zeit, um bewusst an Blumen zu riechen.	☐	☐	☐	☐	☐
4.	Ich nehme mir bewusst Zeit, nachts die Sterne zu beobachten.	☐	☐	☐	☐	☐
5.	Ich arbeite gerne im Garten.	☐	☐	☐	☐	☐
6.	Ich kümmere mich persönlich um Pflanzen.	☐	☐	☐	☐	☐
7.	Naturgeräuschen zuzuhören entspannt mich.	☐	☐	☐	☐	☐

Teilarbeit D

Bitte bearbeiten Sie alle Fragen **alleine**, **sorgfältig** und **wahrheitsgemäß**.

1) Was verstehen Sie unter dem Begriff Mikroplastik?

2) Woher haben Sie Ihr Wissen über Mikroplastik?

3) Nennen Sie Quellen von Mikroplastik im Haushalt.

Teilarbeit D

4) In welchen Ökosystemen befindet sich Mikroplastik in Deutschland?
Kreuzen Sie an (mehrere Kreuze sind möglich).

☐	☐	☐	☐
Meere	Flüsse	Seen	Grundwasser

5 a) Schätzen Sie die potentielle Gefahr ein, die von Mikroplastik ausgeht.

☐	☐	☐	☐
sehr gefährlich	gefährlich	kaum gefährlich	nicht gefährlich

5 b) Begründen Sie Ihre Entscheidung, die Sie unter 5a getroffen haben.

____
____
____
____
____
____
____
____
____

Danksagung

An dieser Stelle möchte ich mich bei den Personen bedanken, die mich die vergangenen drei Jahre begleitet und unterstützt haben.

An erster Stelle möchte ich mich bei meinem Doktorvater, Herrn Prof. Dr. Franz X. Bogner, bedanken, der mir die Promotion am Lehrstuhl Didaktik der Biologie an der Universität Bayreuth ermöglicht hat. Vielen Dank für das mir entgegengebrachte Vertrauen und die Möglichkeit, Verantwortung zu übernehmen und dabei eigene Erfahrungen zu sammeln. Weiterhin danke ich Ihnen herzlich für Ihren Rückhalt bei allen Angelegenheiten, Ihre Unterstützung bei offenen Fragen, Ihr Feedback im Schreibprozess sowie den Besuch von Konferenzen.

Frau Petra Feuerstein danke ich für die schnelle und unkomplizierte Unterstützung bei allen organisatorischen und bürokratischen Fragen. Weiterhin gilt mein Dank Herrn Dr. Franz-Josef Scharfenberg für seine kompetente Unterstützung und Hilfsbereitschaft bei jeder Angelegenheit.

Ganz herzlich möchte ich mich bei Frau Sabine Hübner für ihre beständige Hilfe bedanken. Danke für Ihr offenes Ohr, Ihre Zeit, Ihre Ratschläge sowie die gemeinsame Gestaltung von Lehrveranstaltungen. Dank Ihnen habe ich in den vergangenen Jahren viel fürs Leben gelernt.

Ein großes Dankeschön möchte ich auch an meine ehemaligen und derzeitigen Kolleginnen richten. Danke für Eure fachliche Unterstützung sowie die schönen, kurzweiligen Mittagspausen und Lehrstuhltreffen am Abend, die Euch Kolleginnen auch zu meinen Freundinnen gemacht haben.

Ein ganz besonderer Dank gilt meinem Mann, meiner Familie und meinen engsten Freunden. Danke, dass Ihr immer an mich glaubt und für mich da seid. Ich danke Euch für Eure immerwährende Unterstützung, Euren Zuspruch und die Selbstverständlichkeit mit der Ihr mich bei allen Herausforderungen begleitet und mir Kraft schenkt. Ich danke Euch.

(Eidesstattliche) Versicherungen und Erklärungen

(§ 8 Satz 2 Nr. 3 PromO Fakultät)

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

(§ 8 Satz 2 Nr. 3 PromO Fakultät)

Hiermit erkläre ich, dass ich die Dissertation nicht bereits zur Erlangung eines akademischen Grades eingereicht habe und dass ich nicht bereits diese oder eine gleichartige Doktorprüfung endgültig nicht bestanden habe.

(§ 8 Satz 2 Nr. 4 PromO Fakultät)

Hiermit erkläre ich, dass ich Hilfe von gewerblichen Promotionsberatern bzw. –vermittlern oder ähnlichen Dienstleistern weder bisher in Anspruch genommen habe noch künftig in Anspruch nehmen werde.

(§ 8 Satz 2 Nr. 7 PromO Fakultät)

Hiermit erkläre ich mein Einverständnis, dass die elektronische Fassung der Dissertation unter Wahrung meiner Urheberrechte und des Datenschutzes einer gesonderten Überprüfung unterzogen werden kann.

(§ 8 Satz 2 Nr. 8 PromO Fakultät)

Hiermit erkläre ich mein Einverständnis, dass bei Verdacht wissenschaftlichen Fehlverhaltens Ermittlungen durch universitätsinterne Organe der wissenschaftlichen Selbstkontrolle stattfinden können.

……………………………………………………………………………………………
Ort, Datum, Unterschrift