UNIVERSITÄT BAYREUTH

Fakultät für Biologie, Chemie und Geowissenschaften

Lehrstuhl Didaktik der Biologie

Kann kompetenzorientierter Natur und Technik-Unterricht individuell nachhaltiges Handeln beeinflussen?

Wie Umwelteinstellungen, Motivation und Technikbegeisterung kognitives Lernen über Müllverwertung/-vermeidung beeinflussen

Dissertation

zur Erlangung des akademischen Grades einer

Doktorin der Naturwissenschaften

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Hinweis auf diversitätsgerechten Sprachgebrauch:

Aus Gründen der besseren Lesbarkeit wird in der vorliegenden Arbeit für personenbezogene Bezeichnungen das generische Maskulinum verwendet. Wann immer möglich, werden geschlechterübergreifende Pluralformen verwendet. Es wird an dieser Stelle ausdrücklich darauf hingewiesen, dass die ausschließliche Verwendung der männlichen Form geschlechtsunabhängig verstanden werden und alle Geschlechteridentitäten einbeziehen soll. In Abschnitten, in denen explizit auf Geschlechterunterschiede eingegangen wird, werden die geschlechterspezifischen Bezeichnungen verwendet.

1. SUMMARY

Environmental and climate protection are widely discussed alongside technologies that could contribute to tackling climate change. While technological advancements have initially been considered the root of all climate problems, they may now be key to successfully navigating a looming climate crisis. Waste management is, thereby, a particularly salient topic since it combines a change in attitudes towards environmentally friendly and sustainable behaviors with modern and sustainable technologies. In the otherwise rather mobility-focused public debate, waste management, however, seems to get lost although it affects all human beings regardless of nationality, age or wealth.

Thus, we developed a student-centered teaching module for fifth graders to address the topics of sustainable waste management and recycling. Relevant knowledge about waste production and energy generation from waste, was expected to raise awareness and foster sustainable action.

In a first step, the pilot study A with 264 university freshmen should provide an overview of attitudes towards technologies and the environment after having completed their A-Levels. We identified that positive attitudes towards technologies correlated with tendencies to exploit nature and vice versa. Technologies were also more appealing to male students as compared to female students, who were more inclined with environmental protection and appreciation of nature. Likewise, the field of study appeared to influence individual attitudes: For instance, those who studied natural sciences were more protective and appreciative of nature than economics and law students. Natural science and law students, however, also consider and accept technologies as important drivers of social advancements, whereas cultural studies students deny their impact.

Sub-study B outlines our teaching module developed for fostering "Scientific Work" (curriculumPLUS of the Bavarian Gymnasium) within the scope of "Nature and Technology”, which focused on waste avoidance and recycling. The module encompassed three sections with individual stations and considered curricular basic concepts of biology and competency requirements. Due the age of students, processes underlying the"4Rs" (reduce, reuse, recycle, recover), which describe the generation of energy from waste, were significantly simplified. Throughout the entire module, students worked independently in groups to discuss and compare their results with previously prepared solutions. Students were also asked to build a functional model of a waste-to-energy plant and name its functional parts. This model could later be experienced in either a virtual or a real-life visit to a waste-to-energy plant.

For our studies C and D, 276 students participated two module variants: completely in the classroom or on-site at the waste-to-energy plant. Knowledge pre-, post-, and retention scores were collected to

analyze knowledge acquisition across both module variants. We also assessed respective learning emotions. In Sub-study D, scientific motivation, technology preferences and environmental attitudes were measured alongside knowledge acquisition, to evaluate the influence of these variables on knowledge acquisition and to identify possible interrelations.

In study C, we, moreover, piloted and verified our questionnaire for performance measurement. Results indicated a short- and medium-term increase in knowledge as compared to prior knowledge. Correlations could be obtained between learning emotions, for instance relevance and interest as components of motivation, with knowledge retention scores after six weeks. We identified the following pattern: The more relevant and interesting students considered a waste-to-energy plant, the better were knowledge retention scores.

Study D showed that students with a greater tendency to protect nature have a greater increase in knowledge and vice versa. The appreciation of nature and the attitude towards technology had no influence on learning results. Surprisingly, the intrinsic motivation for science also showed only a small influence on prior knowledge. We, however, identified strong positive correlations between scientific motivation and protective environmental attitudes, whereas the utilization of nature correlated negatively with science motivation. Furthermore, male students received higher technology and motivational self-efficacy scores, while girls achieved higher scores for appreciation of nature.

To conclude, our teaching module successfully combined nature and technology for classroom teaching. It proved that professional knowledge can be imparted in a gender-neutral way. The involvement of a local company also added to the understanding of students of how relevant sustainable waste management is for everyday life. The visit to a waste-to-energy plant did, contrary to expectations, not contribute to continuously better extracurricular learning outcomes for students. Motivational and interest-related factors of such outreach learning locations should, however, not be neglected, since the aim was not to ensure better learning results but to develop didactically valuable teaching modules that combine several STEM subjects and address as many competencies as possible.

2. ZUSAMMENFASSUNG

Themen wie Umwelt- und Klimaschutz kommen aktuell täglich in den Medien vor, ebenso moderne Technik und Technologien. Während Letzteres meist negativ behaftet als vermeintlicher Zerstörer der Umwelt gilt, wird der Schutz der Umwelt in der Gesellschaft hoch angesehen. Die Müllproblematik scheint beide Aspekte miteinander zu verbinden, denn hier gilt es nachhaltige, ressourcenschonende Verfahren zu entwickeln, um Schaden an der Natur möglichst klein zu halten und dabei moderne umweltfreundliche Technik einzusetzen, denn jeder trägt im täglichen Leben zur Entstehung von Müll bei.

In der vorliegenden Studie wurde ein schülerzentriertes Unterrichtsmodul für die fünfte Jahrgangsstufe entwickelt, das die Thematik Müllvermeidung und –verwertung aufgreift. So soll früh für die Problematik sensibilisiert, umweltrelevantes Wissen vermittelt und technische Prozesse zur Energiegewinnung greifbar gemacht werden.

Um einen umfassenden Überblick über die Technik- und Umwelteinstellungen nach erfolgreich durchlaufener Schullaufbahn zu erfassen, wurden in **Teilstudie A** zunächst entsprechende Einstellungen von 264 Studierenden im ersten Semester verschiedener Studienrichtungen erfasst. Hierbei zeigten Personen mit positiver Zuwendung zur Technik klare Tendenzen die Natur auszubeuten und umgekehrt. Männliche Studierende waren dabei der Technik positiver zugeneigt als weibliche, die eher höhere Werte in Bezug auf Umweltschutz und Wertschätzung der Natur vorwiesen. Zudem zeigte die Spezialisierung, also die Wahl eines Studiengangs, eine gute Korrelation mit individuellen Einstellungen: Beispielsweise zeigte sich, dass Studierende der Naturwissenschaften eher dazu tendieren die Natur zu schützen und wertzuschätzen als Studierende der Wirtschafts- und Rechtswissenschaften. Rechts- und Naturwissenschaftler hingegen finden Technik in der Gesellschaft wichtiger und nehmen diese eher an als Kulturwissenschaftler.

Teilstudie B beschreibt das Unterrichtsmodul, das für das Fach „Natur und Technik", genauer dem Schwerpunkt „Naturwissenschaftlichen Arbeiten" (LehrplanPLUS des bayerischen Gymnasiums) entwickelt wurde. Inhaltlich stand die Thematik Müllvermeidung und -verwertung im Vordergrund. Bei der Entwicklung der drei Module mit ihren Stationen wurde auf eine kompetenzorientierte Aufbereitung des Stoffes und die Anwendung der Basiskonzepte Biologie geachtet. Zum einen wurden die „4R" (engl. *reduce, reuse, recycel, recover*) behandelt, zum anderen wurde die Energierückgewinnung aus Müll in einem Müllkraftwerk mit seinen Fachbegriffen und Arbeitsschritten altersgerecht thematisiert. Hier sollten die Schüler in Kleingruppen selbstständig arbeiten und ihre Ergebnisse mit Lösungen abgleichen. Weiter sollten sie ein Funktionsmodell eines Müllkraftwerkes im

Kleinen nachbauen und die Funktionsteile benennen können. Abschließend fand entweder eine Führung durch das Müllkraftwerk statt oder es wurde ein Film als Führung aus demselben Müllkraftwerk gezeigt.

In den **Teilstudien C** und **D** nahmen 276 Schülerinnen und Schüler entweder im Müllkraftwerk oder im Klassenzimmer teil. Es wurde das Vorwissen und der Wissenserwerb, sowie Lernemotionen in **Teilstudie C** erhoben, um den Wissenszuwachs durch die Teilnahme am Unterrichtsmodul zu evaluieren. Weiter sollte der Wissenserwerb in Abhängigkeit vom Lernort und die Rolle der Lernemotionen erfasst werden. In **Teilstudie D** wurden neben dem Wissenserwerb auch die naturwissenschaftliche Motivation, Technikpräferenzen und Umwelteinstellungen erhoben. Ziel war es die Rolle dieser Komponenten beim Wissenserwerb zu evaluieren und mögliche Wechselbeziehungen festzustellen.

Dabei konnte in **Teilstudie C** der selbst entwickelte Fragebogen zur Leistungsmessung des Fachwissens bestätigt werden. Damit wurde ein kurz- und mittelfristiger Wissenszuwachs im Vergleich zum Vorwissen festgestellt. Weiter konnte der Zusammenhang mit den Lernemotionen von Relevanz und Interesse als Komponenten von Motivation mit der Behaltensleistung nach sechs Wochen belegt werden. Je relevanter und interessanter Schüler ein Müllkraftwerk fanden, desto besser war die Behaltensleistung nach sechs Wochen.

Teilstudie D zeigte, dass Schüler mit größerer Tendenz zum Schutz der Natur einen höheren Wissenszuwachs haben und umgekehrt. Die Wertschätzung der Natur sowie die Einstellung zum Thema Technik hatten keinen Einfluss auf den Lernerfolg. Erstaunlicherweise zeigte auch die intrinsische Motivation für Naturwissenschaft, nur einen kleinen Einfluss auf das Vorwissen. Die naturwissenschaftliche Motivation wies jedoch einen starken positiven Zusammenhang zwischen naturwissenschaftlicher Motivation und schützenden Umwelteinstellungen auf, wohingegen die Ausnutzung der Natur negativ mit der naturwissenschaftlichen Motivation korrelierte. Des Weiteren zeigten männliche Schüler höhere Werte in Bezug auf Technik und der motivationalen Komponente Selbstwirksamkeit, wohingegen Mädchen höhere Werte im Bereich der Wertschätzung der Natur erzielten.

Zusammenfassend ist das hier entwickelte Unterrichtsmodul ein gelungenes Beispiel für die Verknüpfung von Natur und Technik im Unterricht. Zum einen konnte das Fachwissen vermittelt sowie geschlechtsneutral unterrichtet werden. Den Schülern konnte ein Industriebetrieb aus der Region vorgestellt und seine Relevanz für die Gesellschaft verdeutlicht werden. Weiter konnte gezeigt werden, dass ein außerschulischer Lernort nicht immer bessere Lernergebnisse bei den Schülern hervorbringt. Ausschlaggebend ist, dass der Unterricht Interesse und Motivation weckt und den

Schülern sinnvoll für ihren Lebensalltag erscheint. Es sollte Ziel sein, didaktisch wertvolle Unterrichtsmodule zu entwickeln, die mehrere MINT-Fächer miteinander verbinden und möglichst viele Kompetenzen ansprechen.

3. SYNOPSIS

3.1. Einleitung

„Bei allem, was man tut, das Ende zu bedenken, das ist Nachhaltigkeit.“
*(Eric Schweitzer *24.07.1965, deutscher Unternehmer)*

Der Verpackungsmüll stieg im Jahr 2018 auf ein Rekordhoch von 227,5 kg pro Kopf. Trotz Einführung des Verpackungsgesetzes 2019, das Teil des Abfallvermeidungsprogrammes von 2013 ist, ist die anfallende Menge an Müll immer noch zu hoch. Dieses Programm sieht Bürgerinnen und Bürger in der Pflicht zur Reduzierung von Abfall beizutragen. Weiter wird der Einsatz von technisch modernen Entsorgungsanlagen unumgänglich sein (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit, 2020).

Das bedeutet, dass jeder deutsche Bürger in seinem täglichen Leben an der Entstehung von Müll beteiligt ist. So ist es an Jedem von uns daran zu arbeiten, möglichst wenige Ressourcen zu verschwenden und nachhaltig zu denken und zu handeln. Auch die „Fridays for Future“ Bewegung zeigt, dass sich bereits junge Menschen mit diesem Thema aktiv auseinandersetzen wollen und dies auch tun. Wie persönlich und gesellschaftlich mit dem anfallenden Müll umgegangen wird, scheint von sozialen Normen und Selbstvertrauen abzuhängen (Cialdini, Reno, & Kallgren, 1990; Kort, Mccalley, & Midden, 2008). Verhaltensnormen sind wichtig in einer Gesellschaft, um ein stabiles Umfeld zu schaffen, das sozial akzeptable Verhaltensweisen unterstützt. Viele Studien zeigten, dass Menschen eher Müll an öffentlichen Plätzen ordnungsgemäß entsorgen, wenn es gute Vorbilder gibt (Cialdini, 2003; Schultz, Bator, Large, Bruni, & Tabanico, 2013). Die Ausbildung von Lehrkräften in den USA im Bereich Abfallvermeidung und Recycling, gekoppelt an die Entwicklung eines entsprechenden Curriculums, hatte positive Auswirkungen auf das öffentliche Verhalten der breiten Gesellschaft (Hasan, 2004). Dadurch konnte ein aktives Abfallmanagement unter Einbezug und Sensibilisierung der Öffentlichkeit als Schlüssel zur Lösung des Müllproblems identifiziert werden. In einer polnischen Studie konnte belegt werden, dass Schüler, wenn sie an einer gezielten Bildungsmaßnahme zum Abfallmanagement teilgenommen haben, als Multiplikatoren in ihrem Umfeld (z.B. der Familie) fungieren können (Grodzińska-Jurczak, Bartosiewicz, Twardowska, & Ballantyne, 2003). Diese Beobachtungen konnten auch durch weitere Studien (Ballantyne, Fien, & Packer, 2001; Evans, Gill, & Marchant, 1996; Gallagher, Wheeler, McDonough, & Namfa, 2000) untermauert werden.

Zu bedenken gilt es jedoch, dass die Gesamtheit aller Müllvermeidungsstrategien nur einen Bruchteil zur Ressourcenschonung beitragen können, da Müll auch in der modernen Gesellschaft nicht komplett vermeidbar ist. Hier ist es wichtig moderne Technologien einzusetzen, um diesen möglichst effizient und umweltschonend aufzubereiten. Jedoch verbinden viele Menschen den Begriff Technik mit Gefahren und Risiken (Ardies, De Maeyer, & Gijbels, 2013). Daher muss es Ziel von Bildungsmaßnahmen sein, die verschiedenen Aspekte Umwelt, Technik und Nachhaltigkeit zusammenzuführen.

Im LehrplanPLUS des bayerischen Gymnasiums ist mit dem Fach „Natur und Technik“ schon ein erster Schritt gelungen, den negativ assoziierten Technikbegriff mit dem positiv konnotierten Naturbegriff zu verbinden (Merzyn, 2008).

Aufgrund der Alltagsrelevanz und der Kopplung von Umwelt- und Technikaspekten wurde in dieser Studie das Thema Abfallvermeidung und –verwertung ausgewählt und ein Bildungsprogramm für die Unterstufe entworfen. Des Weiteren lassen sich die ausgewählten Lerninhalte im Curriculum der fünften Jahrgangsstufe verorten. Hier werden umweltschützende Aspekte und technische Prozesse gleichermaßen behandelt und sinnvoll zusammengeführt, mit dem Ziel kompetenzorientiert inhaltsbezogenes Wissen zu vermitteln (LehrplanPLUS, 2020).

Der Schwerpunkt dieser Arbeit liegt zum einen auf der Erfassung des Status quo von Umwelt und Technikeinstellungen von Studierenden im ersten Studiensemester nach Abschluss der Schullaufbahn. Zum anderen auf der Evaluation der entwickelten Bildungsmaßnahme zur Abfallvermeidung und –verwertung. Dabei sollen insbesondere die Umwelteinstellungen, Technikpräferenzen und die naturwissenschaftliche Motivation von Schülern erfasst und in Relation zum Lernerfolg gesetzt werden. Des Weiteren sollen die Schüler durch die Bildungsmaßnahme für das Thema sensibilisiert und zum nachhaltigen Handeln angeregt werden.

3.2. Theoretischer Hintergrund

3.2.1 Kompetenzorientierung und Unterrichtsmethoden

Guter Unterricht ist ein sehr komplexes Gefüge aus verschiedenen Komponenten, die im Vorfeld durchdacht und aufeinander abgestimmt werden müssen. Zunächst stellen sich die Fragen, wer, was, wann, wo, von wem, wie unterrichtet werden soll (Meyer, 1983). Mishra und Koehler (2006) beschreiben Unterricht als vielschichtiges Konstrukt aus pädagogischem, inhaltlichem und technischem Wissen. Hauptkomponente ist dabei das Fachwissen der Lehrkraft (Shulman, 1986), die in der Lage sein muss, das Wissen zu organisieren, den jeweiligen Altersgruppen anzupassen und adressatengerecht wiederzugeben. Daher sind gut vorbereitete Lehrkräfte essenziell, um praktische Fertigkeiten und Wissen gleichermaßen zu fördern. Um dies zu konkretisieren und zu vereinheitlichen, wurden in Deutschland durch die Kultusministerkonferenz (Bildungsrat, 2004) vier Kompetenzbereiche für den Biologieunterricht festgelegt: (1) Fachwissen (konkrete Fachinhalte); (2) Erkenntnisgewinn (im Entwickeln von Fragen zu einem Phänomen oder Problem, im Finden von Lösungen und deren experimenteller Erprobung); (3) Kommunikation (Zugang zu und Austausch von Informationen in fachbezogener Weise); und (4) Bewertung (d.h. wie man biologische Sachverhalte in verschiedenen Kontexten erkennt und bewertet), die 2012 nochmals an den LehrplanPLUS angepasst und konkretisiert wurden (KMK, 2012). Ziel ist es den Unterricht auf anwendbares Wissen auszurichten und zu verbessern, sich auf den „Output“ der Schüler zu konzentrieren und sich von der „Input“-Orientierung abzuwenden und somit einen Perspektivenwechsel zu vollziehen. Dabei spielen in der Biologie immer wiederkehrende Basiskonzepte eine wichtige Rolle. Unter Berücksichtigung dieser Vorgaben vereint die forschungsbasierte Wissenschaftsbildung (*inquiry-based science education,* IBSE) verschiedene Aspekte des wissenschaftlichen Wissenserwerbs (Bybee, 2007). Die Beobachtung von Phänomenen, die Generierung von Hypothesen und die Formulierung von Forschungsfragen, die Planung und Durchführung geeigneter Experimente, die Interpretation von Daten und die Argumentation über mögliche Ergebnisse sowie deren Präsentation vor Gleichaltrigen werden in dieser Unterrichtsmethodik vereint (Anderson, 2002).

Jedoch gilt es trotz Beachtung der verschiedensten Unterrichtsmethoden zu bedenken, dass Schüler nicht nur in der Schule mit Naturwissenschaften in Berührung kommen und lernen. Sowohl inner- als auch außerschulische Erfahrungen prägen die Entwicklungen, Einstellungen, Motivation und das soziale Leben von jungen Menschen (Resnick, 1987).

3.2.2 Naturwissenschaftliche Motivation und Emotionen im Unterricht

Der Motivationsbegriff wurde in der Literatur mit mehr als 100 Definitionsmöglichkeiten erklärt (Kleinginna & Kleinginna, 1981). Für den Unterricht in den MINT-Fächern definiert Glynn, Brickman, Armstrong, und Taasoobshirazi, (2011, S. 1160) Motivation als „inneren Zustand, der das Verhalten Naturwissenschaften zu erlernen weckt, richtet und aufrechterhält." Dies bedeutet, dass guter Unterricht bei Schülern Interesse erwecken soll, um diesen Zustand zu erreichen. Interesse beschreibt Palmer (2009) weiter als eine Form von Motivation, die in besonderen Situationen auftritt und als Initiator für den Lernprozess dienen kann. Weiter kann Interesse die Aufmerksamkeit auf einen Lerngegenstand lenken und bei der Zielfindung helfen (Hidi & Renninger, 2006), genauer wird Interesse als eine Person-Objekt-Beziehung angesehen (Faulstich & Grotlüschen, 2009). Zwei Formen von Interesse können unterschieden werden: „Individuelles Interesse", was auch als Langzeitinteresse beschrieben wird (Renninger, Hidi, & Krapp, 1994), und „Situatives Interesse", das kurzzeitig aus der Situation heraus entsteht (Hidi, 1990; Renninger & Wozniak, 1985). Eine weitere Differenzierung von Interesse in eine erste „*catch*"- und zweite „*hold*"-Phase durch Mitchell (1993) bedeutet, dass in der ersten Phase Interesse z.B. durch die Sozialform oder eine Unterrichtsmethode geweckt wird, wohingegen dieses geweckte Interesse in der zweiten Phase stabilisiert werden muss. Im Unterricht ist es also wichtig eine Form von „situativem Interesse" zu erzeugen, um wertvolles „langfristiges Interesse" zu erreichen, welches für den Lernprozess von Nutzen ist (Randler & Bogner, 2007). Auch persönliche Relevanz spielt eine wichtige Rolle. Unter Relevanz wird das Ausmaß verstanden, in dem ein Urteil erhebliche Konsequenzen für persönliche Ziele, Bedürfnisse oder die persönliche Karriere hat (Rohrbeck, Ginsburg-Block, Fantuzzo, & Miller, 2003; Vygotsky, 1978). Auf den schulischen Kontext übertragen, ist ein für die persönliche Karriere wichtiger Lerninhalt relevant (Frymier & Shulman, 1995). Weitere Studien postulieren darüber hinaus, dass es wichtig sei, das Curriculum auf die Interessen der Zielgruppe anzupassen, um einen optimalen Lernprozess zu sichern (Gilman & Anderman, 2006). So ist es für die Schüler entscheidend, den Nutzen des Unterrichts im betreffenden Fach für sich oder die gesellschaftliche Relevanz zu erkennen (Albrecht & Karabenick, 2018). Weiter zu berücksichtigen ist einerseits die intrinsische Motivation, die eine Aktivität bedeutet, die Vergnügen in ihrer Ausführung bringt und dadurch selbstständig aufrechterhalten wird und andererseits die extrinsische Motivation, die von der Ergebnisorientierung erzeugt und aufrechterhalten wird (Ryan & Deci, 2000). Es kommt also weniger auf die Wahl des Faches an, sondern eher auf das individuelle Interesse, die Relevanz und die individuellen Einstellungen die den Lernerfolg beeinflussen (Keller, 1983).

3.2.3 Umwelt- und Technikeinstellungen

Die Assoziationen zu Umwelt und Technik können wohl nicht gegensätzlicher sein, da der Einsatz von Technik und Technologien negativ und Umweltaspekte positiv behaftet sind (Merzyn, 2008). Weiter ist jedem nicht erst seit der „Fridays for Future" Bewegung bekannt, dass das Wissen über Umweltprobleme, die individuellen Einstellungen und das eigene Tun in Zusammenhang stehen.

Die Erkenntnis über den Zusammenhang des eigenen Handelns und eigener Werte existiert schon seit den 70er Jahren. Seither gibt es Bemühungen zuverlässige Messinstrumente zu entwickeln, um die Einstellungen von jungen Menschen in Bezug auf Umwelt zu erfassen. Das *„Two Major Environmental Value model“*(2-MEV) von Bogner und Wiseman (1999) ist ein mittlerweile häufig eingesetztes (z.B. Boeve-de Pauw & Van Petegem, 2011; Johnson & Manoli, 2008; Milfont & Duckitt, 2004), reliables und valides Modell zur Messung von Umwelteinstellungen von vor allem jungen Menschen. Dieses Modell enthält zwei Faktoren höherer Ordnung mit einer Skala zur Quantifizierung folgender Präferenzen: "Erhaltung" (PRE) und "Nutzung" (UTL) der Umwelt. Ersterer hebt Präferenzen hervor, die die Erhaltung und den Schutz der Umwelt widerspiegeln, Letzterer misst die anthropozentrische Dimension der Ausnutzung der Natur. Eine mit dem 2-MEV kreuzvalidierte Studie bewies die Beziehung zwischen Umweltwerten und Risikotoleranz. Personen mit Erhaltungspräferenzen waren vorsichtig, während "Nutzer" hoch risikotolerant waren (Bogner, Brengelmann, & Wiseman, 2000). Die Persönlichkeit spielt folglich eine wichtige Rolle. Eine von Wiseman und Bogner (2003) beschriebene Korrelation von "Schutz" (PRE) und "Nutzung" (UTL) mit Psychotizismus, Extraversion und Neurotizismus zeigt den Einfluss der Persönlichkeit. Im Verlauf wurde das Modell 2018 (Bogner, 2018) um eine dritte Dimension "Wertschätzung der Natur" (APR) (Kaiser, Brügger, Hartig, Bogner, & Gutscher, 2014) erweitert, um den wertschätzenden Umgang mit der Natur zu messen.

Auch Technik gewinnt in der modernen Gesellschaft zunehmend an Bedeutung. Technik ist in allen Lebensbereichen präsent, sowohl am Arbeitsplatz, als auch in Freizeit und zur einfachen Kommunikation wird sie von nahezu jedem genutzt. Die Gesellschaft wird immer „smarter“ und auch im Schul- oder Universitätsalltag hält die Technik Einzug. Diese ist für Schüler und Studierende zur Informationsbeschaffung, zum Lernen oder zur schlichten Kommunikation (Lepp, Barkley, & Karpinski, 2015) unverzichtbar geworden. Jedoch werden die Einstellungen und Emotionen gegenüber Technik ganz unterschiedlich beschrieben. McRobbie, Ginns und Stein (2000) z.B. nennen die menschliche und die soziale Dimension der Technik; konkreter wird Technik als ein Prozess beschrieben, der in Kontexten angesiedelt ist und zur Entwicklung von Produkten führt. Jugendliche verbinden mit dem Technikbegriff eher die Anwendung von Computern (Rennie & Jarvis, 1995). Jedoch werden laut Ardies et al. (2013) oft auch schwierige oder langweilige Lerninhalte mit Technik assoziiert. So hat sich gezeigt, dass die Beobachtung des "Interesses" (INT) und der "sozialen Aspekte der Technik" (SOC) repräsentativ für die Erfassung der Technikpräferenzen ist (Rennie & Jarvis, 1995). Beide Aspekte sind Teil des short Technology Questionnaires (Rennie & Treagust, 1989; Rennie & Jarvis, 1995) .

Weiter zeigen Mädchen bereits im Vorschulalter ein geringeres Technikinteresse als Jungen (Rennie & Jarvis, 1995). Daher ist es wichtig, dass mögliche Geschlechterunterschiede, sei es in Umwelteinstellungen oder Technikpräferenzen, im Unterricht berücksichtigt werden (Mayer-Smith, Pedretti, & Woodrow, 2000). Auch haben Studien gezeigt, dass Männer oft mehr Verständnis im MINT

Bereich zeigen als Frauen (Sadler, Sonnert, Hazari, & Tai, 2012). Eine Ursache für diese Entwicklung könnten negative Erfahrungen im Klassenzimmer sein (Simpson & Steve Oliver, 1990), die bis in das Erwachsenenalter und somit das Berufsleben andauern (Dasgupta & Stout, 2014).

3.3. Ziele und Fragestellungen der Teilarbeiten

Diese Arbeit untersucht MINT-Unterricht im Kontext Müllvermeidung und –verwertung und den Bezug auf Umwelt- und Technikeinstellungen sowie Komponenten die zur Motivation beitragen. Mit einem exemplarischen Unterrichtsmodul für die Unterstufe des bayerischen Gymnasiums soll umweltrelevantes Wissen und somit auch positive Umwelteinstellungen sowie nachhaltiges Denken und Handeln gefördert, technische Prozesse erklärt und das Thema Müll ganzheitlich behandelt werden.

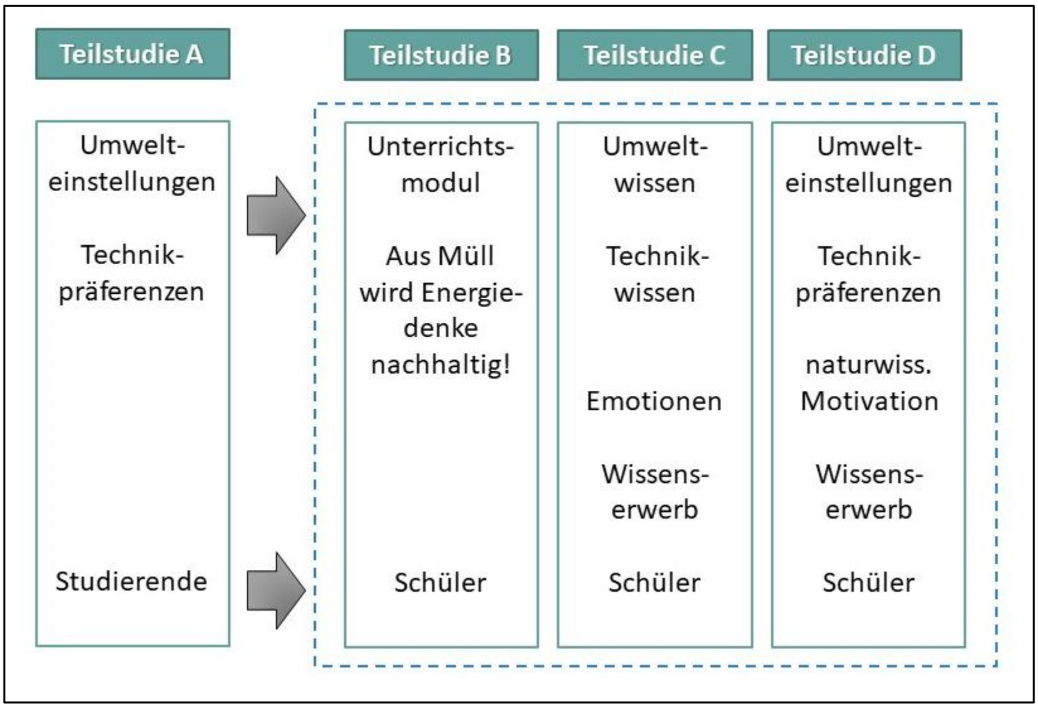

ABBILDUNG 1.: ÜBERSICHT ÜBER DIE TEILSTUDIEN DER GESAMTARBEIT

3.3.1 Teilstudie A – Umwelt- und Technikeinstellungen von Erstsemestern

In **Teilstudie A** werden die Umwelt- und Technikpräferenzen von Studierenden im ersten Semester untersucht, um den Status quo nach durchlaufener Schullaufbahn zu erfassen (Abbildung 1). Dazu werden Studierende verschiedener Fachrichtungen mittels der Literatur entnommenen Fragebögen zu Umwelteinstellungen und ihrem Interesse an Technik und deren soziale Akzeptanz von Technik befragt. Außerdem sollen mögliche geschlechtsspezifische Unterschiede bezüglich dieser Einstellungen detektiert werden.

Die konkreten Forschungsfragen dieser Teilarbeit lauten:

(1) Gibt es einen Zusammenhang zwischen den Umwelteinstellungen und den Technikpräferenzen von Studierenden im ersten Semester?

(2) Beeinflussen individuelle Präferenzen von Studierenden, wie Umwelteinstellungen und Technikpräferenzen die Wahl des Studiengangs?
(3) Existieren Geschlechterunterschiede bezüglich der Einstellungen zu Umwelt und Technik?

3.3.2 Teilstudie B – Das Unterrichtsmodul

Teilstudie B beschreibt ein ganzheitliches, kompetenzorientiertes Unterrichtsmodul zum Thema Müllervermeidung und -verwertung für die Unterstufe des bayerischen Gymnasiums. Ziel des selbst entwickelten Moduls ist es, die Schüler für die Müllproblematik zu sensibilisieren und ihnen verschiedene Verfahren zur Müllreduktion aufzuzeigen (Abbildung 1). Zudem sollen die Schüler den Rückgewinn der Rohstoffe als Option der Nachhaltigkeit sowie Fachbegriffe zum Themenfeld Energie kennenlernen. In beiden Themengebieten sollen Schüler Fachsprache altersgerecht anwenden und Fachbegriffe erklären und nennen können. Außerdem sollen die Schüler die verschiedenen Arbeitsschritte in einem Müllkraftwerk vom Müll hin zur Energieerzeugung unter Berücksichtigung der Basiskonzepte beschreiben. Letztlich sollen die Schüler in der Lage sein aus den gewonnenen Erkenntnissen selbstständig ein Funktionsmodell eines Müllkraftwerkes zu bauen und die Energieumwandlung durch das Leuchten einer LED-Lampe zu visualisieren. Neben fachwissenschaftlichen Aspekten sollen durch die gewählte Unterrichtsmethodik (*„Hands on“*) und die Sozialform (Gruppenarbeit), die Kompetenzbereiche: Bewertung, Kommunikation und Erkenntnisgewinnung gemäß des LehrplanPLUS geschult werden. Konkret bedeutet das, dass durch die Alltagsrelevanz der Müllproblematik auch das Umweltbewusstsein sowie das Technikinteresse der Schülerinnen und Schüler durch die entwickelte Unterrichtseinheit geschult und gefördert werden soll. Ein zusätzlich optionales Ziel ist es (je nach Standort der Schule), einen regionalen Energieerzeuger vorzustellen.

3.3.3 Teilstudie C – Wissenserwerb und der Einfluss von Relevanz und Interesse

Ziel von **Teilstudie C** und **D** ist es, das in Teilarbeit B beschriebene Unterrichtmodul hinsichtlich seiner Effektivität zu evaluieren (Abbildung 1). Der Schwerpunkt in **Teilstudie C** liegt auf der Untersuchung des Erwerbs kognitiven Wissens anhand eines selbst erstellten Messinstrumentes zu drei Testzeitpunkten (Vorwissen, kurzzeitiger Lernerfolg, mittelfristiger Lernerfolg). Weiter soll die Rolle der Emotionen/Assoziationen zu einem Müllkraftwerk untersucht werden und in Bezug zum Wissenserwerb gesetzt werden.

Die konkreten Fragestellungen der **Teilstudie C** lauten:

(1) Eignet sich das selbsterstellte Instrument zur Evaluierung des Wissenserwerbs?

(2) Gibt es nach der Teilnahme an dem Unterrichtsmodul einen zu verzeichnenden Wissenszuwachs?
(3) Gibt es einen messbaren Unterschied im Wissenszuwachs zwischen Gruppen, die vor Ort in einem Müllkraftwerk am Unterrichtsmodul teilgenommen haben und jenen, die im Klassenzimmer unterrichtet wurden?
(4) Ist das angepasste semantische Differenzial ein geeignetes Instrument, um die individuellen Assoziationen (Relevanz und Interesse) bezüglich eines Müllkraftwerkes zu erfassen?
(5) Kann eine Verbindung zwischen Vorwissen/ Wissenszuwachs und persönlicher Relevanz und Interesse hergestellt werden?

3.3.4 Teilstudie D – naturwissenschaftliche Motivation, Umwelteinstellungen und Technikinteresse

Im Zentrum der **Teilstudie D** stehen die Umwelteinstellungen, Technikpräferenzen sowie die naturwissenschaftliche Motivation von Schülern der fünften Jahrgangsstufe des Gymnasiums in Bezug zum Wissenserwerb. Hier soll untersucht werden, ob diese drei Faktoren eine Rolle beim Wissenserwerb in Bezug auf das entwickelte Unterrichtsmodul spielen. Weiter soll der Zusammenhang zwischen Umwelteinstellung und naturwissenschaftlicher Motivation erfasst werden. Schließlich sollen mögliche Geschlechterunterschiede in den einzelnen Bereichen erfasst werden.

Die konkreten Fragestellungen der **Teilstudie D** lauten:

(1) Beeinflussen Einstellungen zu Technik den Wissenserwerb zum Thema Müllvermeidung und –verwertung von Fünftklässlern?
(2) Beeinflussen Einstellungen zur Umwelt den Wissenserwerb zum Thema Müllvermeidung und –verwertung von Fünftklässlern?
(3) Beeinflusst naturwissenschaftliche Motivation den Wissenserwerb zum Thema Müllvermeidung und –verwertung von Fünftklässlern?
(4) Gibt es einen Zusammenhang zwischen naturwissenschaftlicher Motivation und Umwelteinstellungen?
(5) Gibt es geschlechtsspezifische Unterschiede bei den Technikpräferenzen, Umwelteinstellungen und der naturwissenschaftlichen Motivation?

3.4. Methoden

3.4.1 Teilnehmende, Studiendesign, Datenerhebung und -auswertung

Aufgrund der unterschiedlichen Ziele und Fragestellungen der jeweiligen Teilarbeiten variierten die Teilnehmer der Studie sowie das Studiendesign innerhalb der Gesamtstudie. Alle Daten wurden schriftlich mit Fragebögen (*„paper-and-pencil-Tests"*) erhoben. Durch einen individuellen Code wurde die Anonymität und die exakte Zuordnung der Fragen gewährleistet.

In der **Teilstudie A** wurden Daten von 264 (132 weiblich = 50 %, 132 männlich = 50 %) Studierenden im ersten Semester aus fünf Studienrichtungen der Universität Bayreuth im Wintersemester 2018 erhoben. Alle Teilnehmenden haben einmalig am Ende einer Vorlesung einen Fragebogen (*„paper-and-pencil-Test"*) ausgefüllt, nachdem sie vorher über die freiwillige anonyme Teilnahme an der Studie aufgeklärt wurden. Die Codierung bestand aus Geschlecht, Alter, Semester und Studiengang. Die Rücklaufquote betrug 100%. Da die Wahl des Studiengangs eine Spezialisierung der Studierenden im Alter von M = 22,06 bedeutet, wurden diese in die Gruppen Rechtswissenschaften (n =49), Wirtschaftswissenschaften (n =71), Naturwissenschaften (n = 96), Kulturwissenschaften (n = 23) und Pädagogik (n = 25) eingeteilt. Diese Studie beschäftigte sich mit den Einstellungen zur Umwelt und Technik in verschiedenen Studiengängen und etwaigen Geschlechterunterschieden in diesen beiden Bereichen.

Die Studierenden bearbeiteten einen Fragebogen, der zum einen das Instrument 2-MEV (*Two Major Environmental Values)* (Bogner & Wiseman, 1999, 2006) in Kombination mit APR (*Appreciation of Nature Scale*) (Brügger, Kaiser, & Roczen, 2011) enthielt. Hier wurde die gekürzte Form nach Bogner (2018) mit 20 Items verwendet. Das Messinstrument kann in drei Faktoren: *„Preservation"* (misst die Einstellung zum Schutz der Natur (PRE)), *„Appreciation"* (misst die Wertschätzung der Umwelt (APR)) und *„Utilization"* (bewertet die Bereitschaft die Natur im anthropozentrischen Sinn (UTL)), eingeteilt werden. Zum anderen enthielt der Fragebogen das Messinstrument sTQ (*short Technology Questionnaire*), das ursprünglich von Rennie & Treagust (1989) entwickelt wurde und von Marth & Bogner (2019) im schulischen Kontext eingesetzt wurde. Dieser Fragebogen enthält zehn Items, die in zwei Faktoren „Interesse in Technik" (INT) und „soziale Aspekte von Technik" (SOC) unterteilt werden können und beschäftigt sich allgemein mit der Frage: „Was denkst du über Technik?". Alle Items erforderten eine Beantwortung mit einer Bestätigung oder Ablehnung auf einer Fünf-Punkt-Likert-Skala und wurde innerhalb des jeweiligen Instruments zufällig angeordnet.

Die Datensätze (2-MEV mit APR, sTQ) wurden jeweils, zu ihrer Bestätigung einer exploratorischen Faktorenanalyse (Hauptachsenanalyse; Oblimin-Rotation) unterzogen. Da die Stichprobenzahl in diesem Fall groß genug war, wurde der zentrale Grenzwertsatz der Normalverteilung von Daten (Field,

2013) angenommen. Zum Vergleich der fünf Gruppen aus den Studiengängen wurden parametrische Tests herangezogen, da eine Normalverteilung vorausgesetzt wurde. Dazu wurde eine Varianzanalyse (univariate ANOVA) gefolgt von einer post-hoc Bonferroni-Korrektur für die Subskalen von 2-MEV mit APR und sTQ angewendet. Um Geschlechterunterschiede in den jeweiligen Subskalen festzustellen wurden im Anschluss T-Tests durchgeführt.

In **Teilarbeit B** wurde ein Unterrichtsmodul für die fünfte Jahrgangstufe des bayerischen Gymnasiums im Schwerpunkt Naturwissenschaftliches Arbeiten entworfen. Es ist die Grundlage für die **Teilarbeiten C und D**. Die Studie (Fragebögen und Unterrichtsmodul) wurde vom Bayerischen Staatsministerium für Unterricht und Kultus (KMS: IV.8-BO5106/171/9) genehmigt. Lehrkräfte konnten ihre Klassen für das Modul anmelden und die Eltern wurden über die anonymisierte, freiwillige Teilnahme sowie die Dauer der Datenspeicherung informiert und konnten dieser zustimmen oder diese ablehnen. Aus Alter, Klasse, den ersten zwei Buchstaben des Vornamens der Mutter und den Anfangsbuchstaben des Geburtsortes wurde ein Code zur Anonymisierung und Zuordenbarkeit der Fragebögen erstellt.

In **Teilarbeit C** erfolgte die Befragung von 276 Schülern der fünften Jahrgangsstufe im Alter von $M \pm SD$: 10,2 ± 0,42 aus städtischen und ländlichen Regionen. Je nach Auswahl durch die Schulleitung fand die Durchführung des Moduls im Klassenzimmer (N = 229) oder in einem Müllkraftwerk (N =47) statt. Ziel dieser Studie war es, den erzeugten Wissenszuwachs, der durch das Unterrichtsmodul erlangt wurde, zu erfassen und mögliche Einflussfaktoren festzustellen.

Um den Wissensstand festzustellen wurde ein Multiple-Choice Test entwickelt. Bei diesem Wissensfragebogen gab es vier verschiedene Antwortmöglichkeiten, wovon jedoch nur eine Antwort die Richtige war. Dieser Fragebogen enthielt 13 Wissensfragen zum Aufgabenfeld Müll-Management und die technische Funktionsweise eines Müllkraftwerkes. Dieser wurde zu drei Testzeitpunkten erhoben. T0 zu Erfassung des Vorwissens, fand zwei Wochen vor der Durchführung des Unterrichtsmoduls statt. Der zweite Testzeitpunkt T1 fand direkt nach der Intervention am jeweiligen Schulungsort statt, T2 sechs Wochen nach der Intervention. Die Fragen wurden für jeden Testzeitpunkt zufällig gemischt und angeordnet. Die Evaluation der Wissenstests basierte auf Summenwerten wobei die Antwort „richtig“ = 1 bedeutet und eine falsche Antwort mit 0. Weiter wurde eine Test-Retest-Gruppe N=52 im Alter von $M \pm SD$: 11,08 ± 0,12 befragt, die nicht an der Interventionsstudie teilnahm, sie erhielt den Fragebogen zweimal im Abstand von zwei Wochen.

Zur Feststellung der Trennschärfe des Instrumentes wurde eine Schwierigkeitsanalyse durchgeführt. Um die Schwierigkeitsindizes zu erhalten wurden die Summenwerte der Antworten (1 = richtig, 0 = falsch) der Teilnehmer analysiert. Dazu wurde die Zahl der richtigen Antworten addiert und abschließend durch die Gesamtzahl der Teilnehmer dividiert. Wegen der Stichprobengröße wurde auch hier der zentrale Grenzwertsatz (Field, 2013) angewendet und mit parametrischen Tests gerechnet. Die Analyse der drei Testzeitpunkte erfolgte mit den errechneten Summenwerten und der Testvariante ANOVA mit post-hoc Bonferroni-Korrektur.

Um zu überprüfen, ob es einen Zusammenhang zwischen dem Wissenserwerb und individuellen Einstellungen gibt, wurde zum Zeitpunkt T2 ein semantisches Differential nach Osgood (1964) eingesetzt und an den schulischen Kontext angepasst. Dieses erfasst die individuelle Einstellung einer Person, indem es eine Entscheidung zwischen zwei antithetischen Entscheidungsmöglichkeiten einfordert (Hill, 1958). Die eingesetzten bipolaren Adjektive wurden nach Schönfelder und Bogner (2017) (z.B. „langweilig-faszinierend“; „überflüssig-nötig“) und im Original nach Drissner et al. (2013) angepasst. Die Schülerinnen und Schüler mussten sich nach dem Leitsatz: „ich finde ein Müllkraftwerk ist:“ auf einer Fünf-Punkt-Likert-Skala, zwischen den Adjektiven entscheiden. Um die sieben bipolaren Wortpaare den Faktoren *Relevanz* (drei Items) und *Interesse* (vier Items) zuordnen zu können, wurde eine explorative Faktorenanalyse (Hauptachsenanalyse mit Oblimin Rotation) durchgeführt. Die so errechneten Faktorenwerte wurden als Grundlage zur Berechnung der zweiseitigen Korrelation in Bezug auf die verschiedenen Wissenszeitpunkte herangezogen.

Teilarbeit D beschäftigte sich mit den Umwelteinstellungen, dem Technikinteresse und der naturwissenschaftlichen Motivation in Verbindung mit dem Wissenserwerb der Schüler sowie möglichen Geschlechtsunterschieden. Dazu wurden 276 Schüler der fünften Jahrgangsstufe im Alter von $M \pm SD$: 10,2 ± 0,42 zum Zeitpunkt T0 mit Hilfe des 2-MEV mit APR (Bogner, 2018) bestehend aus 20 Items mit den Faktoren *Schutz der Natur (PRE), Ausbeutung der Natur (UTL)* und *Wertschätzung der Natur (APR)* und dem Science Motivation Questionnaire II (SMOT) nach Glynn et al. (2011) bestehend aus 12 Items befragt. Bei diesem Instrument wurden - da die Schüler noch jünger waren, als in der Vollversion vorgesehen – nur drei der fünf Subskalen (intrinsische Motivation (IM), Selbstwirksamkeit (SE) und Selbstbestimmtheit (SD)) ausgewählt. Um eine Beziehung zwischen diesen beiden Instrumenten zu finden wurden diese beiden Fragebögen mit ihren Subskalen korreliert. Das Technikinteresse wurde zum Zeitpunkt T2 mittels sTQ (Rennie & Treagust, 1989) bestehend aus 10 Items erhoben.

Um die Struktur der drei Messinstrumente zu bestätigen wurden jeweils exploratorische Faktorenanalysen (Hauptachsenanalyse) mit Oblimin- (2-MEV mit APR / SMOT) oder Varimax Rotation (sTQ) durchgeführt. Wegen der Stichprobengröße wurde auch hier der zentrale Grenzwertsatz (Field, 2013) angenommen. Für die Feststellung des Wissenserwerbs wurden die Summenwerte aus Teilarbeit B verwendet. Für die Analyse des Zusammenhangs von Wissenserwerb und Umwelteinstellungen sowie naturwissenschaftlicher Motivation erfolgte für die jeweiligen einzelnen Subskalen eine Varianzanalyse (ANOVA) mit post hoc Test und Bonferroni-Korrektur. Ebenso wurde für die Berechnung der Korrelation von Umwelteinstellungen und naturwissenschaftlicher Motivation verfahren. Zur Berechnung von Geschlechterunterschieden wurde ein T-Test verwendet.

3.4.2 Darstellung des Unterrichtsmoduls

Der inhaltliche Schwerpunkt des Moduls „Müllverwertung und Müllvermeidung im Unterricht“ lag auf der Vermittlung von kognitiven Lerninhalten rund um das Thema „Müllvermeidung und -verwertung“ sowie den verschiedenen Formen der Energieumwandlung. Es soll eine Steigerung der Wertschätzung von Natur und Umwelt bewirkt werden und die Aufgabe der „Schadensbegrenzung“, in Form von Energierückgewinnung und -umwandlung, als eine Aufgabe eines Müllkraftwerks als Grobziel in den Vordergrund rücken.

Der außerschulische Lernort Müllkraftwerk sollte als Bindeglied zwischen dem Lernen am Original und der Verfügbarkeit im Klassenzimmer in Form von Funktionsmodellen dienen. Deshalb fand die Studie auch in einem Müllkraftwerk in Schwandorf und nicht nur im Klassenzimmer statt. Die Unterrichtseinheit wurde für drei Schulstunden konzipiert. Der Unterricht wurde immer von derselben Lehrkraft durchgeführt und in einer Pilotstudie mit Grundschülern, Gymnasiasten und Studenten getestet.

Aus Müll wird Energie –denke nachhaltig! (135 min)		
Modul 1: ***R**educe, **R**euse, **R**ecycle (3R)*	*Modul 2:* ***R**ecovering energy*	*Modul 3:* *Exkursion zu einem Müllkraftwerk*
Problemstellung und Einstieg 1A) Muss dieser Berg so hoch sein? Erarbeitungsphase 1B) Der Müllkreislauf	2) Was ist, wenn nicht recycelt werden kann? 3A) Müll rein … Strom raus 3B) Der letzte Weg des Mülls 3C) Modell eines Müllkraftwerks D) Optional: Für Schnelle	4) Das Müllkraftwerk virtuell oder vor Ort

ABBILDUNG 2.: ÜBERSICHT ÜBER DIE STATIONEN DES UNTERRICHTSMODULS

Die Unterrichtseinheit besteht aus drei Modulen (Abbildung 2). Das Erste enthält den Einstieg und die Problematisierung des Themas mit den Optionen Müllvermeidung, -wiederverwendung und –recycling. Im folgenden Modul wird die Müllverwertung besprochen und die Funktionsweise sowie der Aufbau eines Müllkraftwerkes besprochen. Im dritten Modul können die Schüler je nach Gegebenheit ein Müllkraftwerk real oder via Film besuchen.

3.4.2.1 Einstieg

Um den Schülern ein Müllkraftwerk vorzustellen, gibt die Lehrkraft im Klassenzimmer oder ein Experte im Müllkraftwerk eine kurze Einführung über das Einzugsgebiet und die Aufgabe eines Müllkraftwerkes. Um alle Schüler gleich für die Problemstellung zu sensibilisieren und das Vorwissen aus der Grundschule zu aktivieren gibt es in Modul 1, Station 1A eine lehrerzentrierte Vorgruppenphase. Die Schüler bearbeiteten im Plenum die Problemstellung, „wie kann der Müllberg verkleinert werden?“. Sie erarbeiteten Lösungsvorschläge und kategorisieren diese unter den Überschriften „Vermeidung“, „Wiederverwendung“, „Recycling“ (Abbildung 3a & b). Dies dient zur Initialisierung einer Definitionsbildung dieser verschiedenen Begriffe durch die Schüler.

ABBILDUNG 3A & B.: LERNEN IM PLENUM

3.4.2.2 Erarbeitung (Gruppenphase)

ABBILDUNG 4.: DER MÜLLKREISLAUF

In den folgenden Stationen arbeiteten Schüler selbstständig, angeleitet durch ein Arbeitsheft, das alle Aufgabenstellungen und Tipps enthielt. Die Gruppen bestanden aus zwei bis vier Schülern.

Die Gruppenphase startete mit Station 1B im Modul 1. Hier wurden gängige Symbole aus der Abfallwirtschaft vom Stoffkreislauf der Natur und anhand von Produktkennzeichnungen (allgemeines Recycling-Symbol, Grüner Punkt) abgeleitet. Dazu mussten die Schüler einen Wertstoffkreislauf mit vorgegebenen Überschriften dem Stoffkreislauf der Natur nachempfinden und so das Recyclingsymbol ableiten (Abbildung 4). Der Wertstoffbegriff wurde so selbständig erarbeitet, definiert und die Vorteile der Wertstoffrückgewinnung behandelt. Anschließend wurden die selbst erarbeiteten Ergebnisse mit den bereitgestellten Lösungsblättern verglichen.

Modul 2 behandelt die Schritte der Müllverwertung, Station 2 bildet die Überleitung zu diesem Thema. Sie zeigt den Schülern Wege auf, wenn nicht recycelt werden kann, und nennt die Optionen, Ablagerung und Verbrennung. In Station 3A erarbeiteten sich die Schülerinnen und Schüler, anhand eines altersgerechten Informationstextes, die Fachtermini zum Thema Energie und ordneten dem Fachbegriff (Bsp. Bewegungsenergie, Energieüberträger…) die korrekte Definition zu. In der nächsten Station erhielten die Schülerinnen und Schüler einen Überblick über die einzelnen Bereiche (Anlieferung, Müllbunker, Verbrennungsraum, Schlackebunker, Abtransport der Schlacke) eines Müllkraftwerkes und seine einzelnen Arbeitsschritte (Dampferzeugung, Turbine, Generator). In Station 3C konnten die Schüler das theoretische Wissen praktisch anwenden, indem sie ein kleines Müllkraftwerk mit Hilfe eines Bausatzes nachbauten und eine LED zum Leuchten brachten. Ziel war es ein Funktionsmodell eines Müllkraftwerkes (Abbildung 5A & B) im Kleinen nachzubauen und den Bauteilen ihre jeweiligen Aufgaben zuzuordnen.

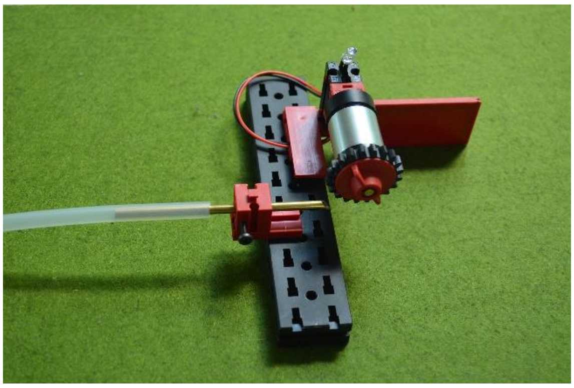

ABBILDUNG 5A & B.: FUNKTIONSMODELL EINES MÜLLKRAFTWERKS

Schnellere Gruppen konnten sich optional überlegen, weshalb Mülltrennung so wichtig ist, und ihre Ergebnisse notieren.

3.4.2.3 Schluss

Das Modul drei stellte die Abschlussphase der Unterrichtseinheit dar. Die Schüler, die im Müllkraftwerk waren, durften dieses mit einem Experten besichtigen und das Funktionsmodell mit dem Realobjekt vergleichen. Die Schüler, die das Unterrichtsmodul im Klassenzimmer absolvierten, erhielten eine altersgerechte Führung via Film, der vom selben Müllkraftwerk bereitgestellt wurde, und konnten so ihre Ergebnisse mit dem Realobjekt vergleichen. Diese Phase diente der Wiederholung und Sicherung des Gelernten.

3.5. Ergebnisse und Diskussion

Die vorliegende Studie fokussiert die Verbesserung des naturwissenschaftlichen Unterrichts unter Berücksichtigung der Kompetenzerwartungen des LehrplanPLUS. Dabei steht der Wissenserwerb in Kombination mit Technikbegeisterung, Umwelteinstellungen und naturwissenschaftlicher Motivation im Vordergrund. Die Vorstudie (**Teilstudie A**) diente zur Feststellung der Interessensbildung in Bezug auf Technik, der Akzeptanz von Technik in der Gesellschaft, Geschlechterunterschieden sowie der gebildeten Umwelteinstellungen nach durchlaufener Schullaufbahn bei Studierenden im ersten Semester. Dies diente als Entwicklungsgrundlage für das Unterrichtsmodul (**Teilstudie B**), das im Anschluss durchgeführt und nach verschiedenen Aspekten evaluiert (**Teilstudien C & D**) wurde. **Teilstudie C** überprüfte die Effizienz des konzipierten Unterrichtsmoduls in Bezug auf Wissenserwerb in Kombination mit persönlichem Interesse. **Teilstudie D** berücksichtigte die Technikeinstellungen von Schülern sowie Umwelteinstellungen, naturwissenschaftliche Motivation und Geschlechterunterschiede.

3.5.1 Teilstudie A – Umwelt- und Technikeinstellungen von Erstsemestern

In dieser Studie wurden die Umwelt- und Technikeinstellungen von Studierenden im ersten Semester erfasst. Des Weiteren wurden diese Präferenzen in Abhängigkeit von einander sowie von der Spezialisierung der Studierenden nach Studiengang und Geschlechterunterschiede betrachtet.

Zunächst wurde die Anwendbarkeit der Instrumente 2-MEV mit APR und sTQ mittels Faktorenanalyse überprüft. Die Kaiser-Meyer-Olkin-Tests (KMO) (Kaiser, 1970) bestätigten die Angemessenheit der Stichprobe mit einem Wert von 0,84 ≤ 0,001. Die 2-MEV mit APR Skala weist akzeptable Reliabilität (Cronbach´s α =0,73) und die sTQ Skala weist hohe Reliabilität (Cronbach´s α = 0,83) auf. Die Faktorenanalyse für den 2-MEV mit APR ergab wie erwartet drei Faktoren (Wertschätzung der Natur, Naturschutz, Ausbeutung der Natur). Für den sTQ konnte die Faktorladung bestätigt werden, die in der Originalarbeit (Rennie & Jarvis, 1995) vorlag.
Die Korrelation der beiden Instrumente mit ihren einzelnen Faktoren ergab, dass es einen Zusammenhang zwischen Faktoren des 2-MEV mit APR und des sTQ gibt. Es bestehen positive Korrelationen zwischen Schutz der Natur und Wertschätzung der Natur, Interesse und sozialen Aspekten von Technik sowie Ausbeutung der Natur und sozialen Aspekten von Technik. Wohingegen negative Korrelationen zwischen Ausbeutung der Natur und Naturschutz, Technikinteresse und Naturschutz, soziale Aspekte von Technik und Naturschutz sowie soziale Aspekte von Technik und Wertschätzung der Natur gefunden werden konnten (Abbildung 6).

Diese Ergebnisse bestätigen die Annahmen, dass Personen, die bereit sind, die Natur zu schützen und sie in ihrer Schönheit zu bewahren, weniger Interesse an Technik haben. Wohingegen Personen, die bereit sind, die Natur und ihre Ressourcen auszubeuten, diese für weniger schützenswert und bewundernswert halten (Kibbe, Bogner, & Kaiser, 2014; Roczen, Kaiser, Bogner, & Wilson, 2014). Des Weiteren wird die Annahme gestützt, dass Studierende, die ein hohes Interesse an Technik haben, diese auch in der Gesellschaft gut akzeptieren.

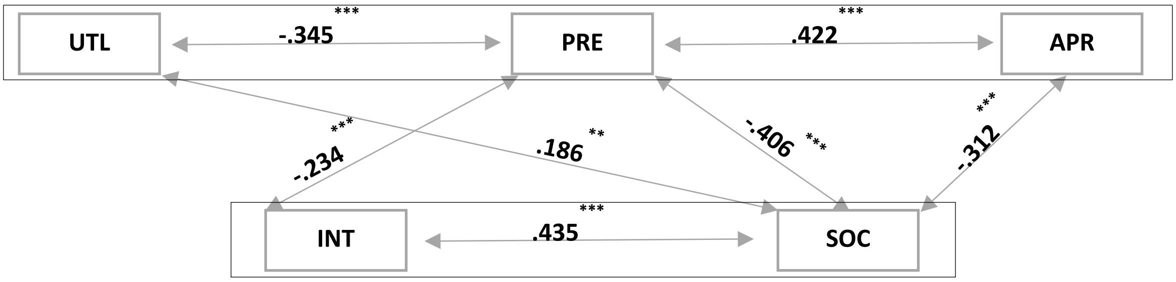

ABBILDUNG 6.: ZUSAMMENHANG ZWISCHEN DEN FAKTOREN DES 2-MEV MIT APR UND DES STQ; MIT UTL (AUSNUTZUNG DER NATUR), PRE (NATURSCHUTZ), APR (WERTSCHÄTZUNG DER NATUR) UND INT (INTERESSE IN TECHNIK), SOC (SOZIALE ASPEKTE VON TECHNIK)

Auch die Betrachtung der Geschlechterunterschiede lieferte signifikante Ergebnisse in jeder Unterskala des jeweiligen Instruments. Dabei zeigten sich weibliche Personen eher dazu bereit die Natur zu schützen und die Schönheit der Natur wertzuschätzen, während männliche Personen eher geneigt sind die Natur auszubeuten. Auch zeigten sich Männer interessierter in Technik und erzielten höhere Werte in sozialen Aspekten von Technik.

Diese Ergebnisse unterstützen die Hypothese, dass soziale Stereotypen im MINT-Bereich existieren und Frauen in diesem Bereich eher unterrepräsentiert sind. Über alle Bevölkerungsschichten hinweg gibt es Grund zur Annahme, dass Frauen sich eher in der protektiven Rolle in der Gesellschaft finden und somit eher altruistisches Verhalten zeigen (Beutel & Mooney, 1995; Eagly, 1987; Zelezny, Chua, & Aldrich, 2000). Männer hingegen sind von Technik begeistert und bereit die Natur auszubeuten, wenn es nützt. Diese Verhaltenstendenzen stellen sich oft schon in der Schulzeit dar und bleiben bis ins Erwachsenenalter bestehen (Dasgupta & Stout, 2014; Eaton, Mitchell, & Jolley, 1991).

Auch die Spezialisierung, wie die Wahl des Studiengangs, kann Aufschluss über die Einstellung einer Person in Bezug auf Umwelt und Technik geben. So zeigten sich signifikante Unterschiede zwischen Studierenden aus dem MINT-Bereich, die eine höhere Bereitschaft zeigten die Natur zu schützen und wertzuschätzen als Personen aus dem Bereich Jura und Wirtschaftswissenschaften. Auch Studierende der Kultur- und Geisteswissenschaften tendieren eher dazu die Natur wertzuschätzen als Pädagogen, Juristen und Wirtschaftswissenschaftler. Auch Naturwissenschaftler erreichten höhere Werte als Pädagogen. Dagegen zeigten Studierende aus dem juristischen und wirtschaftswissenschaftlichen Sektor höhere Werte in sozialen Aspekten von Technologie als Personen aus dem kultur- und geisteswissenschaftlichen Bereich.

Diese Ergebnisse deuten darauf hin, dass ein MINT-Fach eher von Personen gewählt wird, die die Schönheit der Natur wertschätzen und diese für schützenswert halten. Personen, die zu einem ausbeuterischen Nutzen tendieren, spezialisieren sich eher im Bereich Jura und Wirtschaftswissenschaften. Diese Teilstudie gibt Grund zur Annahme, dass sich die Umwelt-Technikeinstellungen im Laufe der Schulzeit bilden und so das spätere Leben (z.B. Berufswahl) nachhaltig beeinflussen. So gilt es bei der Planung von Unterricht möglichst beide Fachbereiche zu berücksichtigen und wenn möglich diese zu verbinden.

3.5.2 Teilstudie B – Das Unterrichtsmodul

Das Unterrichtsmodul Müllvermeidung und –verwertung im Unterricht wurde als kompetenzorientiertes Lernprogramm, abgestimmt auf den LehrplanPLUS des bayerischen Gymnasiums, entwickelt.
Der inhaltliche Schwerpunkt des Projekts „Müllverwertung und Müllvermeidung im Unterricht“ lag auf der Vermittlung von kognitiven Lerninhalten sowie affektiven und psychomotorischen Lernzielen. Dabei wurden die Kompetenzbereiche Fachwissen, Erkenntnisgewinn, Kommunikation und Bewertung gezielt angesprochen.

So sollte wie in den übergreifenden Bildungs- und Erziehungszielen des Gymnasiums unter *„Schulart- und fächerübergreifende Bildungs- und Erziehungsziele sowie Alltagskompetenz und Lebensökonomie“* für den Bereich *„Bildung für Nachhaltige Entwicklung (Umweltbildung, Globales Lernen)“* gefordert, Kompetenzen entwickelt werden, die Schüler in die Lage versetzen nachhaltig zu denken, Lösungen zu erkennen und diese selbstständig zu entwickeln. Des Weiteren erwarben die Schüler Wissen über die Umweltproblematik von Müll, die verschiedenen Aufbereitungsmethoden sowie deren Auswirkungen auf die Umwelt. Sie sollten sich mit gesellschaftlichen Werten und Normen beschäftigen, um ihre Gesellschaft aktiv mitgestallten zu können und die Vorteile technischer Müllverwertung zu erkennen. Durch die Bearbeitung der Müllproblematik und der technischen Prozesse im Müllkraftwerk sollte eine Steigerung der Wertschätzung von Natur und Umwelt erfolgen und die Aufgabe der „Schadensbegrenzung“ in Form von Energierückgewinnung und -umwandlung, als eine technische Aufgabe eines Müllkraftwerks als Grobziel in den Vordergrund rücken. Weiter sollte den Schülern die positiven Aspekte von Technik für die Gesellschaft vermittelt werden.

Das Unterrichtsmodul ist unter 3.4.2 Darstellung des Unterrichtsmoduls genau beschrieben, **Teilarbeiten C & D** dienten der Evaluation dessen. Die Ergebnisse werden nun im Folgenden dargelegt.

3.5.3 Teilstudie C – Wissenserwerb und der Einfluss von Relevanz und Interesse

In **Teilstudie C** wurde das Wissen vor und nach der Teilnahme am Unterrichtsmodul im Klassenzimmer oder in einem Müllkraftwerk erfasst und ausgewertet. Weiter wurde der Einfluss von Relevanz und

Interesse auf den Wissenserwerb evaluiert. Dabei konnte ein Wissenszuwachs für die Gruppe im Klassenzimmer und die Gruppe im Müllkraftwerk im Vergleich zum Vorwissen festgestellt werden. Auch nach sechs Wochen blieb der Wissenszuwachs in beiden Gruppen konstant. Die Schüler der fünften Jahrgangsstufe haben die erlernten Inhalte nach Teilnahme am Unterricht nicht signifikant vergessen. Die Wissensfragen, die zur Untersuchung herangezogen wurden, wiesen Schwierigkeitsindizes von 0,06 (schwere Frage) - 0,84 (leichtere Frage) auf. Der aus dem Vorwissen errechnete Kolmogorov-Smirnov-Test (p = 0,20) zeigte eine Normalverteilung der Schwierigkeit der Fragen. Was bedeutet, dass der Wissenstest auch für leistungsheterogene Lerngruppen gut geeignet ist.

Die Ergebnisse zeigten, dass der Lernort nicht entscheidend für den Wissenserwerb ist. Diese Beobachtungen sind identisch mit denen von Bogner und Fremerey (2017), die ähnliche Ergebnisse bei einer Studie in einem Wasserwerk gemacht haben. Ein weiterer Grund für eine gute Behaltensleistung von Schülern ist, dass der Unterricht nicht nur auf den reinen Wissenserwerb abzielt, sondern eine Methodenvielfalt in der Vermittlung von Inhalten geboten wird (Tennyson & Rasch, 1988). Dadurch lassen sich die konträren Beobachtungen zur Behaltensleistung nach sechs Wochen in anderen Studien (z.B. Sturm & Bogner, 2010) erklären.

Die Auswertung des semantischen Differenzials, zur Feststellung der Assoziationen (Relevanz und Interesse) der Schüler zu einem Müllkraftwerk, hat ergeben, dass Schüler die den Unterricht im Klassenzimmer erhalten haben, ein Müllkraftwerk als etwas weniger, jedoch nicht signifikant, relevanter und interessanter empfunden haben als Schüler, die den Unterricht vor Ort besucht haben. Weiter hat sich gezeigt, dass die Faktoren Relevanz und Interesse mit der Behaltensleistung nach sechs Wochen korrelieren.

Diese Ergebnisse zeigen, dass die persönliche Relevanz und das Interesse in Zusammenhang stehen (Schiefele, 1991) und als Prädiktor für eine gute Retentionsleistung gesehen werden können. Renninger et al. (1994) beobachteten nachhaltiges Wissen, wenn bei den Probanden Interesse vorhanden war. Man könnte sogar noch weiter gehen und Lernbereitschaft mit Interesse gleichsetzten (Palmer, 2009). Die Ursachen für die gute Behaltensleistung liegen auch an der individuellen Wahlmöglichkeit zwischen sozialem Engagement, körperlicher Aktivität in Verknüpfung mit einem neuen Lernobjekt (Palmer, 2009) aus der näheren Lebenswelt der Schüler, was auch die enge Verbindung zwischen Relevanz und Interesse erklären kann. Weiter deuten die Ergebnisse daraufhin, dass Emotionen beim Lernen eine wichtige Rolle spielen (Värlander, 2008). Der wenn auch geringe Unterschied in Bezug auf Relevanz und Interesse in der Klassenzimmer-Gruppe und der Gruppe im Müllkraftwerk, zeigt, dass ein Besuch vor Ort stärkeres Interesse generieren kann. Im Klassenzimmer jedoch sollte immer von einem mittleren Interessenswert ausgegangen werden, wenn der Unterricht entsprechend abwechslungsreich und forschend-entdeckend gestaltet ist (Gibson & Chase, 2002).

Ganzheitlich betrachtet zeigen die Ergebnisse auch, dass der Wissenserwerb nicht von der Länge einer Unterrichtseinheit abhängt (Fremerey & Bogner, 2014; Fröhlich, Sellmann, & Bogner, 2013). Vielmehr scheint es davon abzuhängen, wer unterrichtet und welche Unterrichtsmethoden eingesetzt werden. In unserem Fall schien IBSE (*inquiriy based science education*) (Bybee, 2007) eine gute Methode gewesen zu sein, um Fachwissen zu erlangen (Resnick, 1987), problemlösend zu denken, wissenschaftliche Arbeitsmethoden zu üben und sich in der jeweiligen Altersgruppe auszutauschen (National Research Council, 2000). Zwischenmenschliche Beziehung scheinen im Lernprozess ebenfalls wichtig zu sein, ein gemeinsames Lernziel zu verfolgen scheint sich positiv auf den Wissenserwerb auszuwirken und das Selbstkonzept im MINT-Bereich zu stärken (Johnson & Johnson, 1999).

3.5.4 Teilstudie D – naturwissenschaftliche Motivation, Umwelteinstellungen und Technikinteresse

Teilstudie D untersuchte die Umwelteinstellungen, die naturwissenschaftliche Motivation sowie Einstellungen in Bezug auf Technik und deren Einfluss auf den Wissenserwerb. Die Überprüfung der Anwendbarkeit der jeweiligen Instrumente *Science Motivation Questionaire II* (SMOT), 2-MEV mit APR (*Two Major Environmental Values*) und *short Technology Questionaire* (sTQ) erfolgte mittels Faktorenanalyse. Die KMO-Tests (Kaiser, 1970) erreichten Werte von 0,74 (2-MEV mit APR), 0,79 (sTQ) und 0,85 (SMOT) und bestätigten so die Anwendbarkeit der Instrumente für diese Studie. Alle Skalen (2-MEV mit APR Skala (Cronbach´s α =0,55), sTQ Skala (Cronbach´s α = 0,86) und SMOT (Cronbach´s α = 0,85)) sind reliabel. Die Faktorenanalyse für den 2-MEV mit APR bestätigte wiederum die drei Faktoren (Wertschätzung der Natur, Naturschutz, Ausbeutung der Natur). Auch für den sTQ konnten die beiden Faktoren der Originalarbeit (Rennie & Jarvis, 1995) bestätigt werden. Gleiches gilt für den SMOT, hier konnten die ausgewählten Subskalen mit drei resultierenden Faktoren (intrinsische Motivation, Selbstwirksamkeit, Selbstbestimmtheit) bestätigt werden. Um einen möglichen Zusammenhang zwischen Umwelt-, Technikeinstellungen und naturwissenschaftlicher Motivation zu detektieren, wurden die jeweiligen Subskalen der drei Instrumente mit dem Wissen aller drei Testzeitpunkte (T0, T1, T2) korreliert. Dabei konnte kein Zusammenhang zwischen allen drei Wissenszeitpunkten und dem Technikinteresse und den sozialen Aspekten von Technik hergestellt werden. Für den SMOT konnte lediglich ein signifikanter Zusammenhang zwischen intrinsischer Motivation und dem Vorwissen hergestellt werden. Jedoch konnten signifikante Korrelationen für die Subskalen Schutz/ Ausbeutung der Natur und dem Vorwissen, dem kurzzeit- und dem mittelfristigen Wissen gefunden werden, dabei korreliert die Präferenz zur Ausbeutung der Natur negativ mit den drei Wissenszeitpunkten, während die Naturschutzpräferenz eine positive Korrelation aufweist.

Die Ergebnisse haben gezeigt, dass Schüler, die Interesse an Technik zeigen, auch Technik in der Gesellschaft akzeptieren, ähnlich wie die Studierenden aus **Teilstudie A**. Diese Technikeinstellungen wirkten sich jedoch nicht auf den Wissenserwerb aus, was daran liegen könnte, dass die Schülerinnen und Schüler weder die mentale noch die physische Reife (Gates, 1924) entwickelt haben, um den technischen Zusammenhang zwischen der Rückgewinnung von Rohstoffen und dem Nachhaltigkeitsgedanken herzustellen.

Die naturwissenschaftliche Motivation scheint ebenfalls kaum Einfluss auf den Wissenserwerb und die Behaltensleistung zu haben, es zeigte sich lediglich ein kleiner Zusammenhang zwischen intrinsischer Motivation und dem Vorwissen, das Schüler zum Thema Müllvermeidung und Müllverwertung haben. Dies stand im Gegensatz zu früheren Studien (Marth & Bogner, 2017). Die Ursache könnte darin begründet sein, dass die Schüler gekoppelt an Moralvorstellungen der Gesellschaft die Relevanz von nachhaltigem Ressourcenmanagement und Abfallvermeidung auch ohne explizite Bildungsmaßnahme erkennen, was zu einem soliden Vorwissen und zu respektablen Lernergebnissen führen kann (Alexander, 2018; Rohrbeck et al., 2003; Vygotsky, 1978). Die Ergebnisse zeigten jedoch eine klare Verbindung von Umwelteinstellungen mit dem Wissenserwerb in allen drei Testzeitpunkten. Personen, die dazu tendieren die Natur zu schützen, lernen und wissen mehr und umgekehrt. Die Ursache könnte sein, dass das entwickelte Unterrichtsmodul technische Aspekte erklären und Naturschutz durch nachhaltiges Denken fördern sollte. Das erklärt ebenfalls den fehlenden Zusammenhang zwischen der Wertschätzung der Natur und dem Wissenserwerb, da der rein wertschätzende Aspekt der Natur nicht Teil des Unterrichtsmoduls war.

Weiter konnte ein Zusammenhang zwischen Umwelteinstellungen und naturwissenschaftlicher Motivation gezeigt werden, was im Einklang mit früheren Studien steht (Schönfelder & Bogner, 2020). Dies kann damit erklärt werden, dass ein individuelles Bestreben die Natur zu erhalten auch als Motivator (Deci & Ryan, 1985) in diesem Bereich Wissen zu erlangen fungiert. Selbstbestimmung und Selbstwirksamkeit spielen dabei eine wichtige Rolle, womit auch die besseren Lernergebnisse von Naturschützern erklärt würden.

Auch wurden die jeweiligen Subskalen auf Geschlechterunterschiede untersucht. Im Bereich der Technikpräferenzen zeigten männliche Personen deutlich höhere Werte als weibliche Personen, wohingegen weibliche Personen höhere Werte in der Tendenz zum Naturschutz zeigten. Dies deckte sich mit den Ergebnissen aus **Teilstudie A**. Weiter lagen männliche Personen im Bereich Selbstwirksamkeit leicht vorne, was sich gut mit Ergebnissen aus anderen Studien deckt (Dasgupta & Stout, 2014). Diese ziehen auch das altruistische Verhalten von Frauen als Erklärung heran. Kinder spiegeln meist das Verhalten ihrer Eltern wider (Eccles, Jacobs, & Harold, 1990). Mädchen übernehmen das Bild der sich kümmernden Mutter und Jungen imitieren ihre erfolgreichen Väter oder Wissenschaftler und deren Selbstkonzept (Ceci & Williams, 2007). Das kann wiederum die Ursache sein, weshalb Frauen in den MINT-Fächern immer noch unterrepräsentiert sind (Dasgupta & Stout, 2014).

3.6. Schlussfolgerung und Ausblick

Diese Studie thematisierte die Verbindung von Umwelteinstellungen, Technikpräferenzen und naturwissenschaftlicher Motivation in einem Unterrichtsmodul über Müllvermeidung und –verwertung. Bei der Erfassung des Status quo am Ende der Schullaufbahn zeigte sich, dass Studierende gefestigte Technik- und Umweltpräferenzen aufweisen, die Einfluss auf die Wahl des Studienganges hatten. Weiter zeigte sich in dieser Altersgruppe die Etablierung von sozialen Stereotypen, vor allem bei der Betrachtung der Geschlechterrolle; männliche Studierende sind technikaffin und Frauen zeigen sich aktiv im Umweltschutz.
Diese Stereotypen werden sich vermutlich bis zum Ende des Studiums noch weiter fixieren. Also sollte auch in der Hochschulbildung darauf geachtet werden, ganzheitlich auszubilden. Es sollte bedacht werden, dass nur ganzheitlich ausgebildete Studierende in der Lage sind, Probleme im Hinblick auf Nachhaltigkeit und technologischen Fortschritt zu lösen. Unsere Studie zeigt einen starken Zusammenhang zwischen den individuellen Einstellungen der Studierenden zu Technik und Umwelt. Dies ist also für die Erstellung von Bildungsprogrammen für jede Zielgruppe von Bedeutung. Daraus ergibt sich die Notwendigkeit bereits im Kindesalter beide Aspekte miteinander zu verknüpfen. Bildungsprogramme müssen Chancen und Risiken von Technik aufzeigen aber auch als gewinnbringend für den Umweltschutz dargestellt werden. Zusätzlich sollten soziale Stereotypen die sich im Alter in der Gesellschaft gefestigt haben bei der Planung von Unterricht berücksichtig werden, um beide Geschlechter gleichermaßen zu fördern.

Die Verbindung von Umwelt, Natur und Technik, die durch das entwickelte Unterrichtsmodul verwirklicht wurde, war zentrales Element der Studie, die im Klassenzimmer oder im örtlichen Müllkraftwerk stattfand. Dabei konnte ein Wissenszuwachs festgestellt werden, der nach sechs Wochen immer noch nahezu konstant war. Die Betrachtung von Schülern zu Beginn der Unterstufe zeigte, dass die Umwelteinstellungen den stärksten Einfluss auf den Wissenserwerb im Themenfeld „Natur und Technik“ und auf die naturwissenschaftliche Motivation hatten. Auch hatten sich bereits dieselben sozialen Stereotypen etabliert, die schon bei den Studierenden festzustellen waren.

Zusammenfassend lässt sich sagen, dass forschend-entdeckender Unterricht an einem außerschulischen Lernort, wie ein Müllkraftwerk, einen erheblichen Mehrwert für das Schulleben bringt, jedoch nicht zwangsläufig zum erreichen besserer Wissensergebnisse führt. Dies zeigte der Vergleich der Klassenzimmer und Müllkraftwerk -Gruppe. Wichtiger scheinen dabei die Lernemotionen als motivationale Komponenten zu sein, die helfen, neu erworbenes Wissen horizontal und vertikal zu vernetzen. Auch die Möglichkeit, selbständig zu lernen scheint die Behaltensleistung positiv zu beeinflussen. Natürlich ist diese Intervention nur eine problemorientierte Möglichkeit das

Abfallproblem mit seinen technischen Lösungsmöglichkeiten anzugehen, aber sie bietet einen guten Ansatz, dieses Thema für die Schüler relevant zu machen und in den schulischen Kontext zu integrieren.

Es sollte das Ziel weiterer Forschung sein, zu verstehen, wann und warum sich Präferenzen für Umwelt oder Technik herausbilden. Die Geschlechterkluft ist ein weiterer wichtiger Punkt, da die individuellen Vorlieben der Schülerinnen und Schüler ihre spätere Spezialisierung beeinflussen: so könnten zum Beispiel spezielle technikorientierte Kurse für Mädchen diese davon überzeugen, nicht Stereotypen zu folgen und sie ermuntern im MINT- Bereich tätig zu werden. Technikorientierte Kurse sollten in die regulären Lehrpläne integriert werden und so die stereotype geschlechtsspezifische Sozialisierung in der Kindheit abbauen. Vermutlich wäre es sinnvoll bereits im Vorschulalter bei der frühkindlichen Förderung mit dem Abbau der Geschlechterkluft zu beginnen.

Schließlich ist festzustellen, dass das hier entwickelte Unterrichtsmodul ein sehr gutes Beispiel für die kompetenzorientierte Umsetzung des LehrplanPLUS ist. Es fördert die Handlungsfähigkeit und die Kompetenzen der Schüler, wirkt in den untersuchten Bereichen motivierend und sichert langfristiges Wissen, das im Alltag anwendbar ist. Insgesamt ist festzustellen, dass gezielte kompetenzorientierte Bildungsmaßnahmen das Handeln der Schüler nachhaltig beeinflussen können, es jedoch noch weiterer Studien bedarf um konkretere, langfristige Aussagen zu treffen.

4. Literaturverzeichnis der Synopsis

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5. TEILARBEITEN

5.1 Darstellung des Eigenanteils

Der *short Technology Questionnaire* sowie der 2-MEV mit APR wurden aus der Literatur entnommen und von mir an die thematischen Gegebenheiten für **Teilstudie A** angepasst. Die Befragung der Studierenden, die Auswertung und Interpretation der Daten erfolgte durch mich.

Das in **Teilstudie B** entwickelte Unterrichtsmodul wurde von mir konzipiert, an den LehrplanPLUS des Gymnasiums angepasst und am jeweiligen Lernort durchgeführt. Die Materialien wurden von mir entwickelt, didaktisch reduziert und angepasst. Die Ideen dazu entstammen teilweise aus Quellen oder aus meinen Erfahrungen aus der Unterrichtspraxis. Die Teile für den Modellbausatz können käuflich, bekannt als Fischer Technik®, z.B. über den Lehrmittelvertreiber *LEMO-SOLAR*® erworben werden. Der Film zur Führung wurde vom ZMS Schwandorf entwickelt und bereitgestellt. Er deckt sich mit der Führung die vor Ort von Experten durchgeführt wird.

Der *short Technology Questionnaire*, der 2-MEV mit APR, der *Science Motivation Questionnaire* und das semantische Differential wurden aus der Literatur entnommen und von mir an die thematischen Gegebenheiten für **Teilstudie C** und **D** angepasst. Der Wissens-Fragebogen wurde durch mich erstellt. Die Befragung der Schüler, die Auswertung und Interpretation der Daten erfolgte durch mich.

Alle Teilarbeiten wurden von mir selbstständig als Erstautorin konzipiert, verfasst und mit Hilfe von Herrn Prof. F.X. Bogner überarbeitet.

5.2 Publikationsliste

Teilstudie A:

Stöckert, A; Bogner, F.X. (2020)

Environmental Values and Technology Preferences of First-Year University Students

Sustainability, 12(1), 62, 1-14

doi.org/10.3390/su12010062

Teilstudie B:

Stöckert, A; Bogner, F.X. (2021)

Waste to Energy—Think Sustainably!

Technology and Engineering Teacher, 80 (4), 1-9

www.iteea.org/TETDec20Stockert.aspx

Teilstudie C:

Stöckert, A; Bogner, F.X. (2020)

Cognitive Learning about Waste Management: How Relevance and Interest Influence Long-Term Knowledge

Education Sciences, **10**(4), 102, 1-16

doi:10.3390/educsci10040102

Teilstudie D:

Stöckert, A; Bogner, F.X. (2021)

Learning about waste management: Effects of science motivation, preferences in technology, and environmental attitudes

Sustainable Futures, **3**, 100054,

doi:10.1016/j.sftr.2021.100054

5.3 Teilarbeit A

sustainability

Article

Environmental Values and Technology Preferences of First-Year University Students

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Abstract: Environmental and technological preferences correlate. Both are empirically accessible via established instruments such as the Two Major Environmental Value model (2-MEV) with "preservation" (PRE) and "utilization" (UTL), and the technology questionnaire with "interest in technology" (INT) and "social aspects of technology" (SOC). Additionally, "appreciation of nature" (APR) was monitored with a seven-item scale. We used these instruments to assess the preferences of freshmen in five different areas of study (law, economics, science, pedagogy, cultural studies). All subsequent analyses unveiled positive relations between appreciation and preservation, between the two technology subscales, as well as between utilization and social aspects of technology. Negative relationships appeared between preservation and utilization, preservation and both technology factors, as well as appreciation and social aspects of technology. In all subsamples, preservers (individuals with preservation preferences) showed little interest in technology or its social aspects; utilizers scored high in social aspects of technology, whereas appreciators displayed no interest in it. The freshmen's areas of study seem to predict consistent tendencies to (biocentric) preservation or (anthropocentric) utilization. Moreover, females were more likely to preserve and appreciate nature whereas males preferred utilization along with interest in technology as well as in the social implications of technology. The observed differences can be used to develop new and improve existing educational programs; recommendations are discussed.

Keywords: values; environmental attitudes; technology; gender; university freshmen

1. Introduction

Currently, the "Fridays for Future" movement mobilizes young people around the globe. Pupils stay away from school on Fridays to show their commitment to the fundamental protection of our planet. Most often, only environmental aspects are considered in discussions about sustainability which prevents a consensus between our need to protect the environment and retain technological advances. Therefore, it is necessary to have a wider perspective on how to approach this delicate topic.

Social media and broadcasters, and their underlying technological advances, support the spread of this movement. Although technologies have a poor public reputation, politics and economics encourage a more technically oriented curriculum [1]. This entails the question of whether there is a connection between individual attitudes towards the environment and technology. In the past, instruments have been developed to measure environmental attitudes and preferences in technology, but these attitudes had to be measured independent of each other.

1.1. Measuring Environmental Attitudes

Since the 1970s psychometric efforts, valid and reliable measuring instruments have been developed to empirically assess young people's preferences of environment and technology. Despite being disputed, both the "new ecological paradigm" [2] and the Two Major Environmental Value model (2-MEV) [3–6] are widely used instruments; the latter was specifically developed for younger people. It contains two higher-order factors with one scale quantifying environmental perceptions: "preservation" (PRE) and "utilization" (UTL). The first highlights preferences reflecting conservation and protection of the environment; the latter measures the anthropocentric dimension of utilizing nature. In the following [7], the term "attitudes" is used for first order factors, and "values" for higher order factors. The 2-MEV was initially an instrument among many before independent research groups confirmed and integrated its framework: (i) Milfont and Duckitt [8] based their study on psychology freshmen, (ii) Johnson and Manoli [9,10] assessed earth education activities among 6th graders in the US, (iii) Boeve-de Pauw and Van Petegem [11] used a Flemish sample of secondary school students, (iv) Borchers et al. [12] applied it to a West African student sample, as did, very recently, Braun et al. [13] in Asia. As bi-national studies had also confirmed the battery's structure and validity (e.g., [4,14]), cross-validation studies were conducted, too: In a study cross-validated with the 2-MEV, the relationship between environmental values and risk tolerance proved that people with Preservation-preferences were cautious whereas "utilizers" were high risk tolerant [15]. Regarding the impact of personality, Wiseman and Bogner [5] reported a correlation of "preservation" (PRE) and "utilization" (UTL) with psychoticism, extraversion, and neuroticism [16]: utilizers aspire to self-gratification, whereas preservers prefer different gratifications. Moreover, Wiseman, Wilson, and Bogner, [17] showed PRE to be negatively and UTL to be positively correlated to authoritarianism, further contributing to an understanding of the framework's construction.

Although developed for adolescents, the 2-MEV scale is also applicable to adults such as pre-service and in-service teachers [18]. Both local and international studies used the 2-MEV to evaluate subjects in 16 European and North African countries [19]. Castéra et al. [20] confirmed the scale's suitability comparing teacher preferences of environmental values and Genetically Modified Organisms (GMO) in 30 countries.

The 2-MEV's two-factorial structure, although antithetical to each other, allows for measuring the appreciative use of nature without any destructive psychometric power [21]. The latter added a third dimension, "appreciation of nature" (APR), which extended the 2-MEV, measuring the enjoyable utilization of nature with seven items [21–23]. A previous exploratory factor analysis showed links between APR and PRE [22]. Following Campbell's paradigm [23], which describes connections between individual attitudes and subsequent behavior, a person who appreciates nature is more likely to protect it.

1.2. Measuring Preferences in Technology

Surprisingly, reliable measuring instruments exist for technology, although there is no standardized definition in literature: McRobbie et al. [24] asked teachers regarding their different conceptions of emotions concerning technology (which also is supposed to influence their teaching). Throughout their study, they described five different stances on the concept of technology: (1) The human and (2) social dimension of technology as well as technology described as (3) a process, (4) being situated in contexts, and (5) leading to products being developed. Monitoring "interest" (INT) and "social aspects of technology" (SOC) are relevant to preferences in technology. Initially, two subscales could be identified: "What is technology?" (Part A) is meant to measure "cognitive perceptions about the diversity of technology and technology as design process" [25] and "What do you think about technology?" (Part B) assessing "students' effect in terms of their interest in technology." Based on the Pupils´ Attitudes Towards Technology (PATT)-questionnaire [26], Rennie and Treagust [27] introduced the Attitudes and Perceptions About Technology (APAT)-questionnaire to evaluate technology education modules in primary and secondary schools. They [28] proposed seven subscales: career in technology, diversity of technology, importance of technology, interest, technology as a design process, and technology as problem solving, technology is easy. "Interest in technology" (APAT-questionnaire) and "social aspects of technology" (PATT-questionnaire) were, for instance, applied as subscales by Marth and Bogner [29] to evaluate students from different faculties and science teachers.

1.3. Is There a Relationship between Environmental Attitudes and Preferences in Technology?

The question, therefore, arises if attitudes towards technology and environment are related. In case of a relationship, corresponding recommendations to optimize, e.g., educational programs, could be provided to give the younger generation a comprehensive overview of both environmental protection and sustainability. A combination of both instruments is, thus, useful to examine environmental values and technology together. As technology increasingly dominates our daily lives, regardless of age or gender, it becomes more and more indispensable, significantly changing our lifestyles (eight distinct domains, e.g., learning, energy, and environment) [30]. Lifestyle refers to how we design our daily life, how we dress, or which attitudes we have [31]. Particularly young people use technology in an experience-oriented way, which may affect politics, education, social interaction, and technological advances. There are, however, hardly any research results on this yet [32]. Still, it must be considered that technology may also provide an opportunity to help limit our exploitation of natural resources by supporting efficient ways of sustaining them for future generations. The young, therefore, need the respective know-how to properly use the technologies at hand [28].

1.4. Does the Gender or Subject Sepzification Mater?

However, potential influences such as gender should also be considered as well as career decisions depend on individual attitudes. Since the 1990s, technology and related gender issues have been frequent targets of research [33,34] and are more relevant than ever [35]. In earlier studies regarding science, technology, engineering and mathematics (STEM) with different age groups, gender gaps in interest and social aspects in technology were considered very relevant [29]. Furthermore, science and related subjects (e.g., mathematics, biology, and physics) often appear difficult to understand and are less appealing to women. Thus, men often outnumber females by 2:1 regarding interest in STEM [36]. Possible explanations might be inconvenient experiences in the classroom which often determine preferences until adulthood [37] and maintain gender gaps [38,39]. In addition to gender influences, the question also arises if the choice of a subject specification is also influenced by such preferences. Therefore, it is reasonable to monitor freshmen from different subject areas regarding their attitudes towards technology and the environment.

1.5. Research Questions

In our present paper, we examine different aspects of individual environmental values and technology preferences as well as their mutual interaction. Our research objectives are three-fold: (i) To observe freshmen's preferences in technology in relation to environmental attitudes, (ii) to focus on subsamples of freshmen with different areas of subject (law, economics, science, cultural studies, pedagogy), as well as (iii) to search for potential gender differences in both scales.

2. Materials and Methods

For our study, we collected data from 264 (132 of them were females) freshmen (age $M = 22.06$ years) with five different areas of study: (1) law ($n = 49$), (2) economics ($n = 71$), (3) science ($n = 96$), (4) cultural studies ($n = 23$), and (5) pedagogy ($n = 25$). All participants visited the University of Bayreuth in the north of Bavaria, Germany. Questionnaires were distributed at the end of selected freshman lectures in the respective faculties to all present students at the beginning of the semester 2018. Students were informed about the voluntary and anonymous participation, the response rate was 100%, and the Ethics Committee of the University of Bayreuth approved the study.

All students completed a paper-pencil questionnaire, which included the 2-MEV along with the APR domain [22] as well as a short version of the technology questionnaire [29]. The response pattern followed a five-point Likert scale (1 = completely incorrect, 5 = completely correct) and was randomly mixed.

IBM SPSS Statistics version 24.0 (IBM, Armonk, NY, USA) was used for all statistical analyses. The item sets of both questionnaires were analyzed separately. For the 2-MEV, we conducted a principal component analysis (PCA) using an oblimin rotation. Since the sample size was large enough, we assumed a normal distribution based on the central limit theorem [40]. A univariate ANOVA followed by posthoc Bonferroni test was used to detect significant differences between the five student groups.

3. Results

In the following, we show (i) factor solutions for environmental values and technology preferences, (ii) correlations between both measuring instruments and their subscales, (iii) gender effects, and (iv) preferences of freshmen from different faculties.

The Kaiser–Meyer–Olkin measure confirmed sampling adequacy [41] with a value of 0.84. Kaiser and Rice [42] accepted values for the KMO measure exceeding 0.5 [40]. The Bartlett test displayed values of $p < 0.001$. Cronbach's alpha for the MEV scale was 0.73 and 0.83 for the short Technolgy Questionnaire (sTQ).

3.1. Factor Solution for Environmental Values

A factor solution was extracted reflecting preservation (PRE), "utilization" (UTL) and "appreciation" (APR), as delineated by Bogner [22] (Table 1). The factor structure of the MEV was confirmed, also resulting in the three main components, as described by Bogner [22]. Individual factor scores indicate how accurately a single variable measures the main components: higher values of the single factor score for each item correlated with stronger item values for the superordinate main components and vice versa. Two singular cross-loadings occurring for factors UTL and PRE indicate different degrees to measure both main components.

Table 1. Loading pattern of the Two Major Environmental Value model (2-MEV) with "preservation" (PRE), "utilization" (UTL) and additionally "appreciation of nature" (APR) (factor loadings under 0.3 are not shown).

Items	APR	UTL	PRE
I consciously watch or listen to birds.	0.767		
I enjoy gardening.	0.755		
I take time to consciously smell flowers.	0.749		
I deliberately take time to watch stars at night.	0.692		
I take time to watch the clouds pass by.	0.654		
I personally take care of plants.	0.649		
Listening to the sounds of nature makes me relax.	0.643		
We need to clear forests in order to grow crops.		0.684	
The quiet nature outdoors makes me anxious.		0.678	0.381
We must build more roads so people can travel to the countryside.		0.607	
We do not need to set aside areas to protect endangered species.		0.433	
Nature is always able to restore itself.		0.360	
Our planet has unlimited resources.			
Humans don't have the right to change nature as they see fit.			0.660
Humankind will die out if we don't live in tune with nature.			0.640
Not only plants and animals of economic importance need to be protected.			0.585
Human beings are not more important than other creatures.			0.542
Dirty industrial smoke from chimneys makes me angry.			0.505
People worry too much about pollution.		0.322	−0.504
I save water by taking a shower instead of a bath (in order to spare water).			0.359

3.2. Factor Solution of the Technology Preferences

A two-factor solution appeared for the total sample (Table 2), as reported by Marth and Bogner [29] and Rennie and Jarvis [25], regarding the technology questionnaire. High factor scores resulted in the confirmation of all variables measuring the main components "social aspects of technology" (SOC) and "interest in technology" (INT).

Table 2. Loading pattern of the technology questionnaire with "social aspects of technology" (SOC) and "interest in technology" (INT) (factor loadings under 0.3 were cut off).

Items	INT	SOC
I am interested in technology.	0.852	
I like to read books and magazines about technology.	0.748	
I would like to learn more about technology.	0.741	
I would like a career in technology later on.	0.718	
I would like to join a hobby club about technology.	0.627	
Technology has brought more good things than bad things.		0.870
Interventions in technology are doing more good than harm.		0.853
Technology makes the world a better place to live in.		0.675
It is worth spending money on technology.		0.603
Technology is needed by everybody.		0.582

3.3. Relationship of Both Measures

Figure 1 shows the Pearson correlation coefficients of environmental preferences with its subscales (PRE, UTL, APR (Table 3)) and of technology (INT, SOC meaning (Table 3)). We identified positive correlations between PRE and APR ($r = 0.422$, $p < 0.001$), INT and SOC ($r = 0.435$, $p < 0.001$) as well as UTL and SOC ($r = 0.186$, $p = 0.003$). Negative correlations were observed between UTL and PRE ($r = -0.345$, $p < 0.001$), INT and PRE ($r = -0.234$, $p \leq 0.001$), SOC and PRE ($r = -0.406$, $p < 0.001$) as well as SOC and APR ($r = -0.312$, $p < 0.001$). Monitoring the connection between APR and UTL showed no significant relationship ($r = -0.110$, $p = 0.083$).

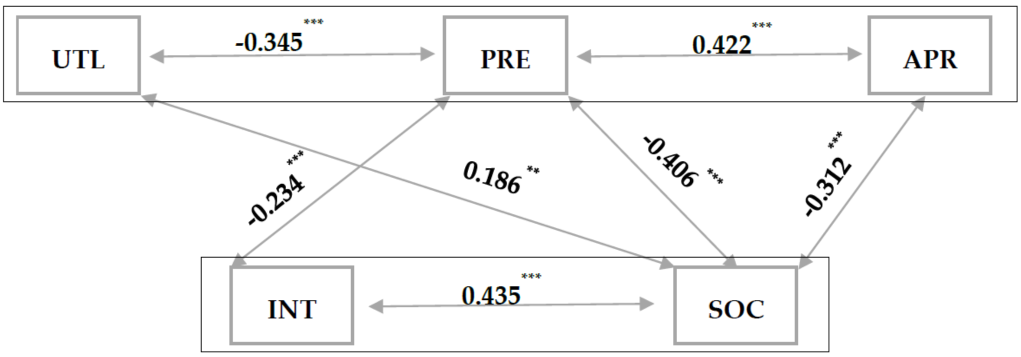

Figure 1. Pearson correlations between environmental values "preservation" PRE, "utilization" UTL and additionally "appreciation of nature" (APR) and technical preferences "social aspects of technology" (SOC) and "interest in technology" (INT). p-Values indicate significance-level (** $p \leq 0.01$, *** $p \leq 0.001$) (we displayed only significant correlations).

Table 3. Overview abbreviations of subscales for both instruments.

Abbreviation of the Subscale.	Meaning
PRE	Preservation of Nature
UTL	Utilization of Nature
APR	Appreciation of Nature
SOC	Social Aspects of Technology
INT	Interest in Technology

3.4. Gender Effects for the Different Subscales

We discovered significant differences between females and males in the total sample across all subscales. For the subscales PRE, APR and INT, the Levene-test was not significant so the values of the *t*-test were reported. For the subscales UTL and SOC, we used the Welch test.

The *t*-test produced significant differences between males and females in the subscales:

- PRE: females (N = 132, M = 3.96, SD = 0.60) and males (N = 130, M = 3.47, SD = 0.69) (95% CI (0.32, 0.63), t (260) = 5.96, p < 0.001)
- APR: females (N = 132, M = 3.17, SD = 0.91) and males (N = 130, M = 2.67, SD = 0.83) (95% CI (0.29, 0.71), t (260) = 4.67, p < 0.001)
- INT: females (N = 132, M = 2.07, SD = 0.66) and males (N = 131 M = 2.79, SD = 0.63) (95% CI (−0.88,–0.55), t (261) = −8.41, p < 0.001)

The Welch test yielded a significant difference between females and males in the subscales UTL (females (N = 132, M = 1.69, SD = 0.42) and males (N = 130, M = 1.89, SD = 0.59) (95% CI (−0.32, −0.07), t (232.63) = −3.16, p = 0.002)) as well as SOC (females (N = 131, M = 3.16, SD = 0.50) and males (N = 131, M = 3.74, SD = 0.71 (95% CI (−0.74, −0.44), t (232.87) = −7.74, p < 0.001; see Figure 2).

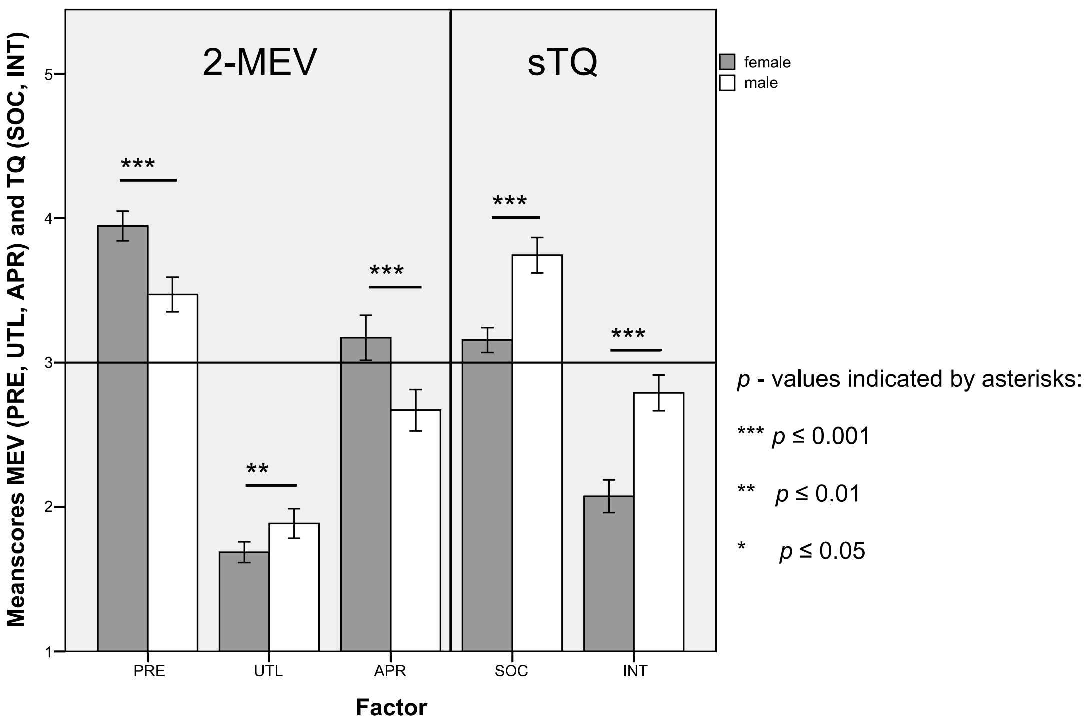

Figure 2. Scores of environmental values PRE, UTL of the Two Major Environmental Value model (2-MEV) and APR as well as of the short Technology Questionnaire (sTQ) with “social aspects of technology” (SOC) and “interest in technology” (INT) split by gender. Bars are 95% confidence intervals. *p*-Value indicates significance-level.

3.5. Different Attitudes of Freshmen of Various Faculties

Comparing freshmen´s attitudes from all five faculties, the subscales PRE, APR, and SOC produced differences between the observed groups, whereas UTL and INT did not. Mean scores of each group in each subscale were used for all calculations. The ANOVA showed a significant effect F (4, 250) = 6.47, p < 0.001 for the five observed groups in PRE. Bonferroni post-hoc test for PRE reported significant differences between “law” (M = 3.46. SD = 0.84) and “science” (M = 3.92, SD = 0.62; p ≤ 0.001) as well as between “economics” (M = 3.50, SD = 0.64) and “science” (M = 3.92, SD = 0.62; p ≤ 0.001; Figure 3). The ANOVA test also yielded significant differences for APR across the five different groups: F (4,

249) = 8.36, $p < 0.001$). The Bonferroni posthoc test for APR yielded significant differences between "law"—($M = 2.75$, $SD = 1.00$) and "science"students ($M = 3.26$, $SD = 0.80$; $p \leq 0.010$) as well as between "economics"—($M = 2.63$, $SD = 0.80$) and "science" students ($p < 0.001$). Moreover, there are significant distinctions between "economics" and "cultural studies" students ($M = 3.25$, $SD = 0.95$; $p = 0.003$). Also "pedagogy" students ($M = 2.51$, $SD = 0.80$) scored differently in APR within the "cultural studies" ($M = 3.25$, $SD = 0.95$; $p = 0.034$) and the "science" sample ($M = 3.26$, $SD = 0.80$; $p = 0.001$); see Figure 4.

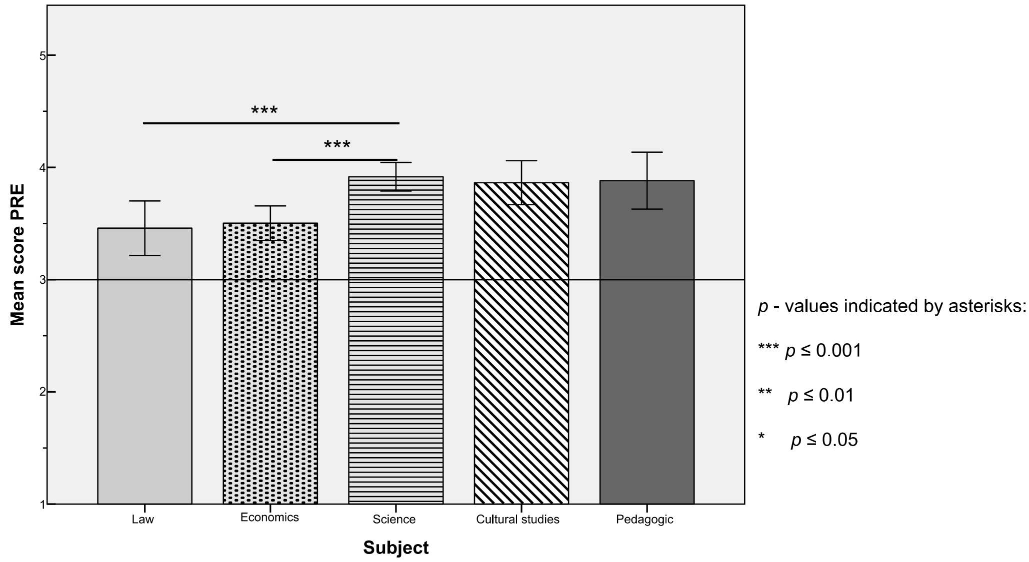

Figure 3. Mean scores of the sub-scale "preservation" (PRE) and the five different areas of study. Bars are 95% confidence intervals. *p*-Value indicates significance-level.

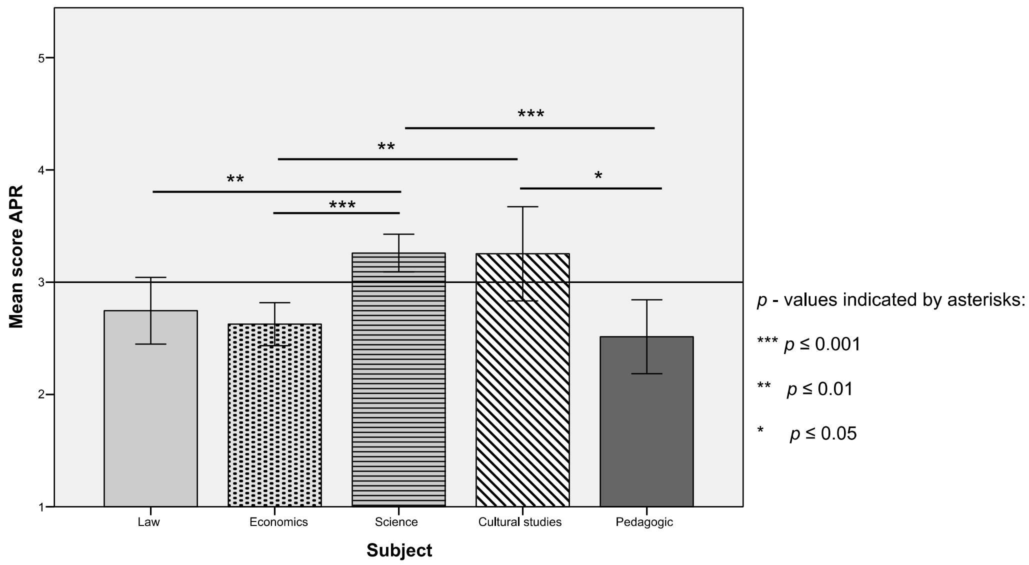

Figure 4. Mean scores of the sub-scale "appreciation" (APR) and the five different areas of study. Bars are 95% confidence intervals. *p*-Value indicates significance-level.

UTL did not produce an effect between the five observed student groups, nor did INT. For SOC, the ANOVA yielded significant effects between the five observed groups F (4254) = 6.23, $p < 0.001$. After applying Bonferroni posthoc test for SOC, significant differences between "law"($M = 3.66$, $SD = 0.63$) and "cultural studies"students remained ($M = 2.96$, $SD = 0.61$; $p < 0.001$) as well as between "economics"($M = 3.63$, $SD = 0.67$ and "cultural studies"studies ($p < 0.001$; Figure 5).

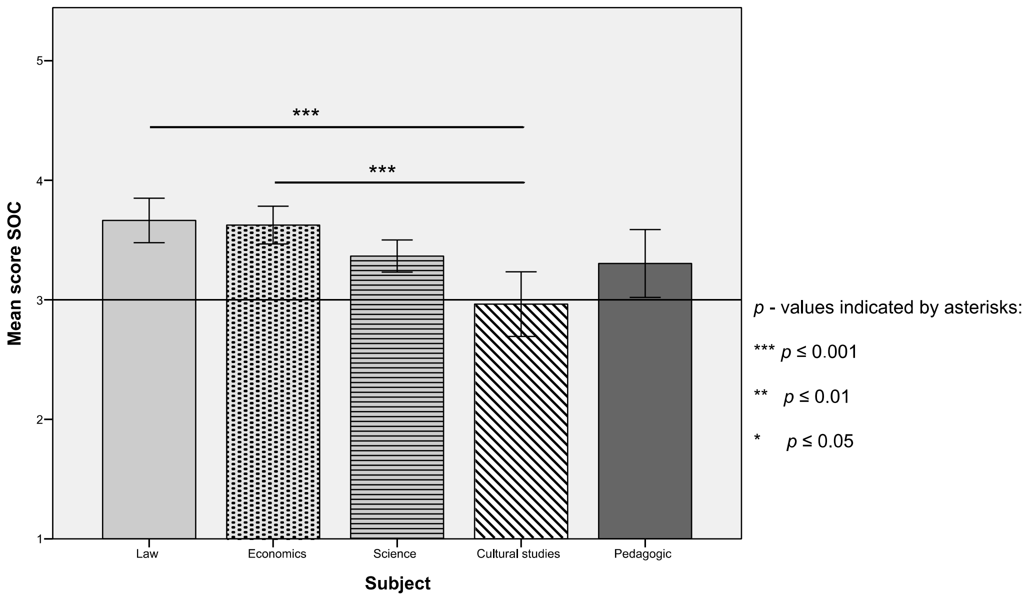

Figure 5. Mean scores of the sub-scale "social" (SOC) and the five different areas of study. Bars are 95% confidence intervals. *p*-Value indicates significance-level.

4. Discussion

Individual environmental values and technology preferences of freshmen matter and interact. (i) The observation of freshmen's preferences in technology related to environmental attitudes showed positive correlations between UTL (utilization of nature) and SOC (social aspects of technology) as well as negative correlations between PRE/APR (preservation/appreciation of nature) and the technical preferences INT and SOC (Figure 1). (ii) Monitoring gender differences in both subscales displayed significant differences in each subscale (Figure 2). (iii) Looking at the different subject areas, significant differences in PRE between science and economics as well as law (Figure 3) could be observed. Furthermore, we recorded significant differences for SOC between cultural studies and economics as well as law (Figure 5) and significant differences for APR between several subject areas (Figure 4).

4.1. Environmental Attitudes of Freshmen

As previous studies [9,19,22] have already indicated, the bi-dimensional structure of the 2-MEV scale even occurred when the applied items set was shortened, and the APR scale was added. Especially in on-site outreach assessments, short versions are easier to apply.

A study examining college students' use of social media reported that all sampled students use social networks [43]. In social media, our planet's limited resources are very topical. Lower factor loadings of the item "Nature is always able to restore itself" and "People worry too much about pollution" (see Table 1) stress the need for change. Thus, students have discussions about environmental challenges with their peers, family, and friends via social media and are informed about the topic. Still, there might be a need for more profound educational programs to get a clear, holistic overview of the different topics comprising environmental disciplines, interfaces with humanities, and technological disciplines.

In addition, cross-loadings of UTL_5 ("People worry too much about pollution.") reveal that students who tend to use nature as a resource are not willing to protect it. As explained by Kibbe et al. [44], this is due to the contrasting two factors. Only the item "The quiet nature makes me anxious" askes for participants' emotions, especially their worries. Utilizers prefer to exploit nature, e.g., in technological processes or industry. Thus, silence in nature is experienced as the opposite of industrial growth and progress, which preservers would enjoy as they see nature as a place of recreation and recovery. It should nonetheless be remarked that admiring nature could also be part of utilization, although this kind of utilization would not count as exploitation (preying on nature or damaging it) [22], because it does not harm nature visibly. Therefore, it is necessary to show people cycles of matter in nature. Thus, people understand that not only obvious environmental pollution can cause damage to nature, but also that processes in nature are disturbed, for instance by human mass tourism.

4.2. Use of Technology in Modern Society Influences Interest in Technology

We obtained a two-factor solution: Factor loadings for "interest in technology" and "social aspects of technology" are high and reliably measure the interest in technology and the social relevance of technology (see Table 2). We, thus, showed that students who are interested in technology also accept technology in society. This is not surprising as today the use of technologies is omnipresent. Lepp, Barkley and Karpinski [45], for instance, observed the distribution and use of smartphones on college campuses where they are frequent devices to obtain information, to learn, or to communicate via social media. Sometimes, they are even used as a life logging device [46]. The item "Technology is needed by everybody" has the lowest factor loading and is in line with findings of Marth and Bogner [29], where university freshmen yielded an even lower score. A possible explanation would be that students already know technologies, e.g., smartphones, are non-essential for life. Factor loadings for social aspects of technology are high, proving the scale's reliability and applicability to different age groups. Based on these results, it is possible to develop and implement educational programs specifically designed for this target group.

4.3. Correlation between Environmental Attitudes and Technology Preferences

As seen in Figure 1, PRE and UTL correlate negatively, as reported Bogner and Wiseman [47] or Kibbe et al. [44]. Bogner et al. [48], on the basis of large longitudinal cohort data, confirmed the structure. In contrast to utilizers, preservers do not exploit nature, which is consistent with the 2- MEV scale's initial meaning. APR and UTL do not correlate, giving no information on how utilizers appreciate nature but revealing their interest in exploiting nature. Furthermore, there is a positive correlation between APR and PRE (see Figure 1) which is in line with earlier studies [49,50]: Appreciators tend to preserve nature and act eco-friendly. INT and SOC correlate positively showing that students who are interested in technology also accept technological progress in society.

Besides confirming the findings of earlier studies, we combined both structures (2-MEV and technology questionnaire) and recorded negative correlations between PRE and INT/SOC which imply that preservers have little or no interest in technology. A possible explanation could be the low social acceptance and the almost unstoppable progress of technology. Thus, appreciators who are fond of nature do not accept technology in society. We also found a positive relationship between UTL and SOC, showing that people who are willing to exploit nature also accept technology in society. To develop educational initiatives that aim at educating students about sustainability, it is important to keep in mind that some aspects of technology oppose nature conservation. Therefore, such programs should use as many different channels of information as possible in order to address as many groups as possible. A less polarized overview of both technology and nature and their mutual interaction can help to avoid misconceptions.

4.4. Gender Differences Regarding Environmental Attitudes and Technology Preferences

We recorded stereotypical gender differences for all subscales in both questionnaires. In an analysis covering the various fields of environment and technology, it was possible to show that women and men have different perceptions of technology and the environment.

Women are more likely to act environmentally friendly, scoring higher in PRE and APR (see Figure 2) which is in line with earlier studies (e.g., [4]) This phenomenon prevails across all social groups and cannot be explained with ethnicity or religion [51]. One approach to explaining different environmental behaviour is based on gender roles and socialization [52,53]. Following socialization theory, behaviour is rooted in early childhood socialization processes. According to Beutel & Mooney [51], Eagly [54], or Zelezny et al. [53], women across different cultures have more pronounced "ethics for care": they seem to be more compassionate, more cooperative, and more helpful in nursing roles. Values [7] are, therefore, able to predict behavior to a certain extent [53,55]. Women also display more altruistic and helping behavior particularly when they take responsibility for a person or recognize potential hazards. This is also in line with the findings of Beutel and Mooney [51], who described women as ready to take responsibilities and aware of other people's physical comfort.

In contrast to females, males score higher in UTL, INT and SOC. Thus, men are more willing to exploit nature, to profit from it, or to show materialistic and anthropocentric behavior. Beutel and Mooney [51] take competitiveness and quest for social status as a basis to explain this behavior. Not only environmentally friendly behavior follows social stereotypes but also attitudes towards technology [56].

Today women are also established in male domains such as STEM subjects but are still underrepresented. We discovered significant differences between males and females for SOC and INT: men are more interested in technology and open to the social implications of technologies than women. Marth and Bogner [29] also reported this phenomenon for pupils, students, and teachers, although differences for the subscale SOC were smaller and there were no significant differences in the teachers´ group [25,57]. The question is when exactly the gender gap develops in a child's socialization process. Dasgupta and Stout [38] suggest three possible developmental stages for establishing gender differences: from childhood to adolescence, in nascent adulthood, and middle-aged adulthood. It is well known that children learn social stereotypes from parents' behavior [58]. Another factor influencing young adults is their social peer group [59]. Whatever the reasons, women in STEM careers are under-represented and sometimes, despite strong affiliation to the subject, avoid such careers [38]. Therefore, it would also interesting to look at the phenomenon's distribution across different programs to see how this global trend develops in young adults attending university.

4.5. Personal Preferences Strongly Influence Technology and Environmental Attitude Sets

A study by Munoz et al. [19] observing a pre- and in-service teacher cohort of 16 countries showed the 2-MEV structure as a very robust and reliable instrument for different social and economic contexts in different countries. In our study, we assessed five different groups of freshmen regarding their environmental attitude and looked for correlations with different areas of study. Especially science and cultural studies showed significantly higher scores compared to law and economics concerning preferences like "enjoying the garden" or "taking time to smell flowers". The same trend is visible for PRE. Utilization showed no significant differences between the observed study groups. Looking at all subscales, economics and pedagogy, however, slightly differ. With regard to environmental attitudes, the largest and most significant differences appear in the science sector between PRE and APR.

Especially, natural scientists are committed to protecting nature, as is reflected in the group comparisons using PRE and APR. This leads to the conclusion that people who tend to protect or appreciate nature are more likely to study science. People who are interested in economics are consequently less interested in the beauty and the protection of nature. The origin of these preferences may be back in childhood; this needs further research. This relationship seems even more important as many political decisions are based on economic rather than scientific considerations. Current political initiatives, however, may have the power to reverse this dependency.

Looking at SOC, economic groups (law and economics) differ from humanities groups (cultural studies and education). We observed the same pattern for the APR subscale, proving that people who show little interest in APR tend to be more technically interested. This claim is also supported by negative correlations between APR and SOC. As modern technologies, e.g., smartphones, enable students to be more independent, it is apparent that technological developments are not only disadvantageous for the environment. Technical progress can support environmental protection and is necessary to show students the beauty of nature all around the globe without traveling. Thus, promoting positive attitudes towards environmental protection should be possible through technologies at university and in the classroom. The findings of McRobbie et al. [24] suggest that various educational initiatives in schools or universities may improve students' understanding of technologies. Taught in a relaxed learning atmosphere, units about the scientific aspects of technology, e.g., limitation of fossil fuels, climate change or advantages and disadvantages of potential technical solutions. in consequence, students should feel comfortable with technologies at the beginning of their lessons to be successful in this field later on. It requires positive attitudes towards technology regardless of the chosen course of study [29].

4.6. Limitations of the Study

Our study only represents a small group proportion of the population (freshmen). To get a holistic idea of the interrelationships, several studies with several groups of people will have to be conducted. Especially studies in elementary or middle schools would help to understand preference developments or the gradual appearance of gender differences. Within this context, our study of freshmen preferences shows results of primary and secondary education before specialisation in the tertiary sector. This is important to brainstorm a suitable educational intervention. Data about the impact of different study areas later on would also shed light on preference developments.

In the questionnaire, no socio-biographical data were collected since universities have an international audience. For further research, however, it would be reasonable to collect this data to analyse their influence on the respective attitudes.

5. Conclusions

Our study shows that it should be a future goal of higher education to link environment and technology in the educational programs to meet the zeitgeist. At the beginning of university, students from different subject areas have different attitude-sets, although they have just entered their study programs and have not yet obtained any degree. Thus, differences will probably increase after having finished their degrees. Only holistically educated students are in a position to solve problems with regard to sustainability and technological progress. Therefore, further research will be required to understand when and why preferences for the environment or technology are formed. A collaboration between technological research groups and natural scientists or other sciences is to recommend to add as much information as possible to find an ideal solution. Our study shows a strong connection between individual preferences and attitudes of students towards technology and the environment. This is relevant to create educational programs designed for each target group.

Our sample of young adolescents contains either technology-enthusiastic "utilizers" or technology-critic "preservers". As preferences seem to be already set in freshmen's minds, more profound education about environmental issues maybe needs its introduction earlier at school levels. Developing holistic educational approaches (such as including aspects of technology, environment and sustainability) might be a key to overcome the well-known gaps, especially as today's young adolescents are the politicians, scientists, and decision-makers of tomorrow. Combining questions regarding environmental attitudes and technology may offer opportunities to optimize educational programs. Investigating primary and secondary school students' attitude-sets towards technology and environment might help to evolve school programs minimizing the gap between environment and technologies.

The gender gap is another crucial unsecured open side, as students' individual preferences influence their later specialization: specific technical courses for girls might convince them not to follow stereotypes. Thus, schools should make more effort, for instance, by integrating technical courses into regular curricula and thus to reduce stereotypical gender socialization in childhood.

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5.4 Teilarbeit B

Technology and Inquiry-Based Outreach Learning

waste to energy—think sustainably!

by Alexandra Stöckert and Franz X. Bogner

Our current lifestyle is inextricably linked to waste production (Bogner & Fremerey, 2017). Everything we consume results in waste of one kind or another, which is why children should learn how to reduce and sustainably handle waste (Hasan, 2004). Sorting waste and bringing it to the respective bin is just a small contribution to effective waste management. Therefore, it is crucial to include important technical and ecological foundations of sustainable waste management in school curricula (Stöckert & Bogner, 2020).

Most students have only limited knowledge of what happens to their waste after having been disposed of in a bin. A scientist and teacher designed an outreach module to address this particular gap in knowledge. This module outlines the treatment of waste, from collection management to incineration plants, providing valuable technical insights for participating students. Inspired by these, students acknowledged the importance of waste separation and reconsidered individual options to reduce the quantity of produced waste (Grodzińska-Jurczak, Bartosiewicz, Twardowska, & Ballan-

Figure 1. A larger group working together at Station 1A.

tyne, 2003). The teacher also differentiated between waste that can be recycled and converted into usable energy and waste that cannot be recycled and requires special treatment using a simple functional model. In the end of this module, students visited an incineration plant, adding firsthand experience to their previously obtained technological and scientific knowledge. This combination constitutes a holistic, interdisciplinary, and integrated learning approach, which encourages students to conceive and critically discuss solution strategies.

Student Objectives and Goals

Since effective waste management entails many scientific and technical processes, students should improve their respective theoretical knowledge to understand the importance of waste avoidance and to communicate its benefits for society (Grodzińska-Jurczak et al., 2003).

The first goal was to make students reconsider their consumption patterns and to encourage a sustainable mindset and lifestyle. This will ultimately contribute to conserving their hometowns,' countries,' and planet's nature. Therefore, students performed activities focused on reducing, reusing, and recycling of potential waste in the first module. The second goal was to foster their understanding of technological processes relevant to effective waste management, such as the substantial use of modern waste incinerators. They should, hereafter, also be able to explain these processes and confidently apply the respective terminology. Since modern technologies have pervasive effects on all areas of life, students should moreover learn to assess their advantages and drawbacks critically. In this intervention, which is part of a research study to analyze knowledge acquisition (Stöckert & Bogner, 2020), students learned to define different types of energies, discovered how they can be converted or conserved and how they interact with other physical forces. Basic knowledge about energy, theories of matter, and open or closed systems was indispensable. The latter also helped students to design solutions, to create explanations, and to develop models. Hence, this interdisciplinary approach improved students' overall factual knowledge in physics and biology as well as industrial technology. This module provided a basis for in-depth reflections on the beneficial effects of technological developments on environmental protection. It also contributed to students acknowledging the necessity to act sustainably and to think responsibly as a society in order to protect our planet.

Links to Standards

This intervention also considered *Standards for Technological Literacy* (ITEA/ITEEA, 2002/2007/2013) and *Standards for Technological and Engineering Literacy* (ITEEA, 2020). It not only aimed at fostering a basic understanding of the technological processes necessary for an effective waste management, but also tried to raise students' awareness of resource-saving waste treatment. Since our waste still contains valuable raw materials, it must be carefully separated and sorted to later recover those materials in recycling plants. Thus, recyclable materials, like glass, metal, or plastic, will have to be disposed of separately, as they undergo different recycling processes. Building a model to illustrate the relation between structure and function helped students realize that recycling only works if all components are arranged according to their function. To see a large proportion of their waste recycled and reused for industry or everyday objects, students understood the importance of collecting waste from beaches, roadsides, or woods. A visit to industrial companies in their neighborhood provided the respective firsthand experience of how industrial waste can be efficiently reused. In this context, students also critically discussed the effects of technologies on the environment.

In this context, the students discussed the effects of technology on the environment and got a glimpse of industries in their neighborhood. By building a model that only worked if the individual components were arranged correctly according to their function, they also learned about the relationships between structure and function.

The intervention was comprised of the three dimensions of science education. First, "crosscutting concepts" connect all four domains of science and enable students to understand cause and effect of complex scientific phenomena. Second, "combining science and engineering" offers students the chance to act as real researchers and engineers who investigate scientific phenomena using models and experiments designed for their level of proficiency. Third, "inter-disciplinary core ideas" comprise key concepts and structures to connect different realms of science (Achieve, Inc., 2013). Respective examples can be taken from Station 3A – 3C below. In so doing, the module included relevant sustainability benchmarks of *Standards for Technological and Engineering Literacy* (ITEEA, 2020) and *Education for Sustainability* (ESD) (Unesco, 2016, Unesco, 2009) to help the young generation become respectful and responsible citizens.

Costs, Adaption Possibilities and Pitfalls

The lessons were free of charge. Material costs were manageable since, for example, electric motors are already an integral part of physics lessons and can be used as generators in the model. Even if parts of the model must be added, the price per model including LEDs does not exceed $40. If the model's steam station does not generate enough pressure to drive the turbine, blowing into the silicone hose helps instead. The model is also applicable to other lessons about wind, hydro, and thermal power plants since their operating principles are comparable and only differ in minor technical details. Moreover, visiting a power plant is not mandatory. The entire module can be implemented exclusively in the classroom using a multimedia-guided tour through a power plant via AV glasses or film. Thereby, student working groups can vary in size (Figure 1 and Figure 4), but we recommend a group size of 2-3 students.

Before you start

Materials required for a class of 20 students are listed in Table 1.

Module Flow Chart, Content, and Student Activity

The intervention "Waste to Energy—Think Sustainably!" (Table 2) was designed for students aged 10-13 and comprises about three 45-minutes lessons. Knowledge was assessed at three testing times: two weeks prior to the intervention, and then directly, and six weeks thereafter, as described in Stöckert and Bogner (2020). The lessons were formally divided into three phases. In the beginning, teachers explained the course schedule and different stations. Then each student received a workbook (Appendix A) containing tasks for each station and space to write down the respective results. Before students were divided into groups of two or three, with whom they worked for the next hours, an expert in the industry provided a short general introduction to waste incineration plants (e.g., which processes are involved? How much waste arrives there every day? Which catchment area has our neighborhood's incineration plant?). If no expert is available, the teacher can also take on this task.

Doing the *"Waste to Energy—Think Sustainably!"* Module

MODULE 1: REDUCE, REUSE, RECYCLE (3R)

The "3 Rs", Reduce, Reuse, and Recycle, are also an integral part of this module's content-related design. Teachers, therefore, instructed their students to brainstorm possible ways for waste reduction.

Station 1 A) "Does this mountain have to be that high?"
Each student received a small colored paper and the picture of a garbage mountain (Appendix A, Workbook, p. 3) or, alternatively, pictures of full dustbins in their classrooms, to raise awareness for the global problem of waste production. This should encourage students to acknowledge the problem, to critically reflect on their contribution to the problem, and to find feasible solutions to reduce their waste production. Students wrote their respective ideas on the colored paper and matched them with the different "baskets" (reduce, reuse, recycle, recover) on the poster. After this exercise, students

Table 1. Material for the waste to energy unit.

Station	Count	Material
1A)	1	poster with four illustrated rubbish bins
	1	Label with heading: - Reduce - Reuse - Recycle - Recover
	4	Marker with different colors
	10	Glue
	20	Colored papers
1B)	5	Puzzle of recyclables in an envelope
	20	Sticker of recyclables (Solution)
	3-4	Examples for recyclables; labelled Solution
	2	Sheet 1B
2)	5	Information graph 2 / Solution sheet 2
3A)	10	Ruler
	5	Information sheet 3A / Solution sheet 3A
3B)	5	Information sheet 3B / Solution sheet 3B
	5	Information graph
3C)	5	Set: model of an incineration plant: construction manual 1x backing strip 6 inch (black) 1x shallow ground 2,4 inch V-track left and right 1x shallow ground 0,6x0,6x0, 2 Inch 1x brick, 1,2 Inch (black) 1x gear-wheel (black) 1x generator with LED and shallow ground 6x0,6x0,2 Inch 1x gear-wheel threaded 1x brick 0,6 inch with screw 1x hub retaining nut 2x cantilevered slab 1,2x0,6x0, 2 Inch 1x flexible tube 1x cord cover 1x brass pipe
	20	Workbooks

Table 2. Flow chart of the waste to energy module (from Stöckert & Bogner, 2020)

Waste to Energy—Think Sustainably!		
Module 1: *Reduce, Reuse, Recycle (3R)*	***Module 2:*** *Recovering Energy*	***Module 3:*** *Excursion to an incineration plant*
Presentation of the problem 1A) Does this mountain have to be that high? Elaboration Phase 1B) Cycle of waste	2) What if recycling is not possible? 3A) Waste in … energy out 3B) The end of waste 3C) Model of an incineration plant 4) Optional Station for higher achieving students	Virtual or onsite

Figure 2. Students write down the requirements of the substances to categorize them according to the 3Rs or recovering energy.

discussed potentially reusable materials and their required substance properties. Teachers also encouraged students to find examples for the aforementioned categories and to put them on the poster (Figure 2).

Educational Background

In addition to professional competencies, this module also fosters social skills like teamwork, effective communication, and self-assessment. The matching exercise, for instance, required students to categorize their ideas and match them with the teacher's four categories. Since students in one group have different ideas and choose different categories, each idea and match is intensely discussed before being put on the poster. Teachers may catalyze reactions and responses from classmates but are generally encouraged to keep a low profile, since the exercise aims at encouraging students to discuss problems within their peer groups. In the end, teachers can address

Figure 3. The cycle of recyclables, students find the solution on their own by comparing it with the natural cycle of matter.

Figure 4. The cycle of recyclables, done by a larger peer group.

Figure 5. Labeled recycling products.

Figure 6. Natural cycle of matter and the recycling cycle.

potential solutions to reduce waste production, like reusing things or buying unpacked food. Students should also realize that the technological progress is ambivalent: it is vital to recycling waste but is also in itself one reason for the waste mountain.

Elaboration Phase

The teachers primarily deployed cooperative and self-explanatory learning methods. These were supported by additional information in workbooks (Appendix A), informational texts, supplemental material, and solution keys. Teachers only observed and supported if necessary. Material required for this phase is listed in Table 1.

Station 1 B) Cycle of Waste

Apart from relevant instructions in the student workbook (Appendix A, p. 5), this station followed an inquiry-based (Bybee, 2007), self-explanatory, and hands-on learning approach.

Short informational text provided an overview of the natural materials cycle, which fostered a basic understanding relevant for the transfer of its general principle to the recycling cycle of waste. Hereafter, students applied their newly acquired knowledge, arranging the recycling cycle of waste (Figure 3, Figure 5) and comparing their proposed solution to the sample solution. They recorded the results in their workbooks.

In the second part of this task, students examined various labels for recyclable products (Figure 6) and retraced their origin. They thereby discovered that these labels comply with recycling processes that the respective recyclable products undergo. Students also learned about relevant material properties of waste in order to qualify for recycling as well as the different materials from which raw materials can be recovered.

Educational Background

This exercise aimed at identifying recyclable products and correctly sorting them prior to disposal. It also fostered students' understanding of issue-specific connections between technology and science. For weaker students, the teacher provided supplementary material to help them understand the recycling cycle. The teachers could thus differentiate between stronger and weaker students on a technical level. In the end, all students should be able to differentiate between recyclable and nonrecyclable materials and sort them according to their material properties in order to recover reusable raw materials. They should also know that recycling processes heavily depend on energy.

MODULE 2: RECOVER AND ENERGY (1R)

Station 2) What if recycling is not possible?

This station (Figure 7) introduced students to the second module. There, students had to find environmentally friendly solutions for waste that cannot be recycled or reused. The teachers only provided the most important information for students in graphs and a brief summary in their workbooks (Appendix A, p. 6). After having completed the exercise, students compared their responses to the suggested solutions. The aim of this exercise was to foster students' understanding of waste incineration and storage. This topic will be intensified at Station 3.

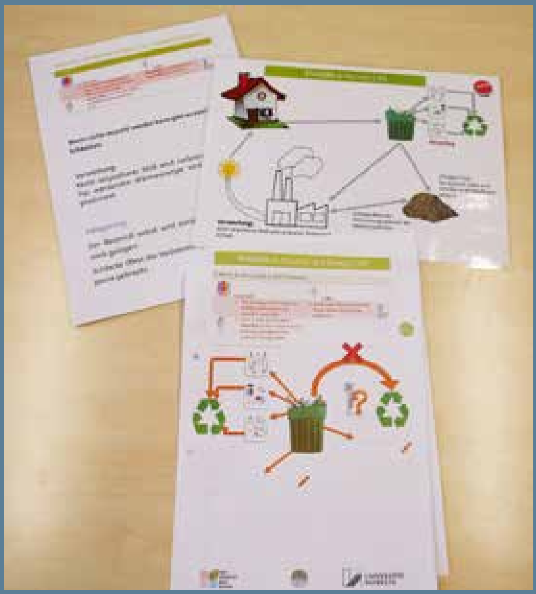

Figure 7. Worksheets containing "What if recycling is not possible?"

Figure 8. Worksheet about the technical terms and their meaning.

Station 3 A) Waste in … Energy out

This station focused on technical terminology and its meaning (Figure 8). Thereby, students had access to an informational text with technical terminology. Explanations for every technical term were hidden, and students had to use their newly acquired knowledge to match the technical terms with a corresponding example in the workbook (Appendix A, p. 7). To check their results, the teachers provided students with a solution sheet.

Station 3 B) The end of waste

The students read an informational text about the individual technical sections in an incineration plant and drew a functional diagram of a waste power plant (Figure 9).

Figure 9. Worksheets explaining the sections in an incineration plant.

Figure 10. Model of an incineration plant.

Educational Background

Students correctly used and applied the required technical terminology. They could describe the schematic structure of an incineration plant and explain the most important steps of energy conversion and conservation. These steps were categorized using different colors to help students recognize, apply, and transfer them to the model in the next station.

Station 3 C) Model of an incineration plant

Students received a construction kit with components they could assemble independently (Figure 10). The overall aim was to make the LED light shine. As already mentioned, an electric motor with low initial resistance was required as a generator, which could easily be borrowed from the physics department. The model also comprised a steam station. If it is not possible to build one in the classroom, air also possesses the relevant kinetic energy to drive the turbine (Figure 11).

A steam station is, however, quite easy to rebuild. Teachers generate heat with a hotplate, which makes water in a pot boil. (Attention: Steam can cause injuries to the skin!) The steam will then be passed to a silicone hose attached to a machine comparable to a turbine. A brass tube, narrowing the cross section, limits energy losses resulting from the transfer of steam to gear. The gear is connected to a generator, which converts the steam's kinetic energy into electrical energy, illuminating an LED light attached to the generator (Figure 11, Figure 12).

In order to understand how the individual components work and interact, students matched the appropriate technical terms with the respective components and described the entire process in full sentences, Figure 12 (Workbook, Appendix A, p. 11).

Educational Background

This station aimed at fostering independent learning in a social peer group. Students taught themselves how incineration plants operate and deepened their knowledge gained in Stations 3A and 3B. They understood the beneficial impact of modern technologies on effective waste management and critically discussed advantages and disadvantages of waste incineration. Possible effects of energy recovery from recyclable waste on the environment have been realized, and students roughly know how power technologies create electrical energy. This station also promoted cognitive, affective, and psychomotor skills.

Station 4) Ready?

The students were invited to write down their individual opinions about the importance and necessity of waste separation.

Educational Background

An optional fourth module was available for more adept students where they holistically assessed the entire intervention's content by noting their ideas about waste separation (Workbook, Appendix A, p. 12). This station aimed at deepening the information students have obtained at previous stations and enabled them to differentiate between recycling and reusing of products.

MODULE 3: EXPLORING A WASTE-TO-ENERGY PLANT

The third phase entailed a visit to a real waste-to-energy plant. This firsthand experience enabled students to transfer their knowledge obtained from building the model to the machines on-site. An expert guided the students through the waste-to-energy plant and answered questions when needed (Figures 13 and 14). Alternatively, teachers can also show a film or video about waste incineration to students if a field trip to an incineration plant is not feasible.

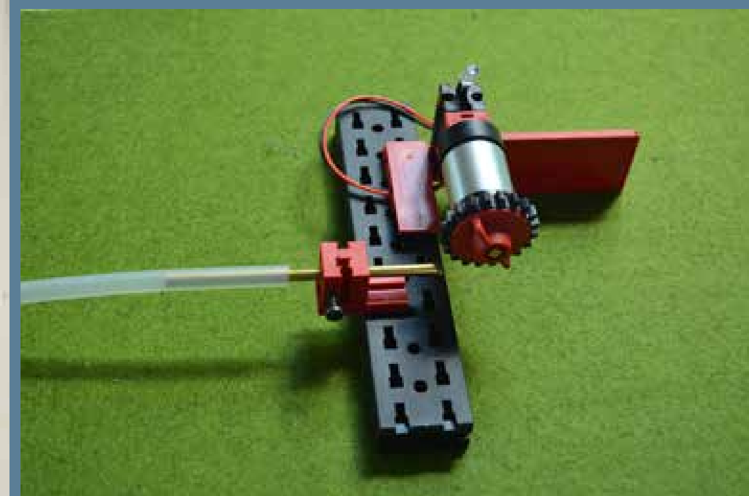

Figure 11. Students combining technical terms with the individual components of the model.

The field trip, however, provided students with firsthand experience about the sheer dimensions of waste disposal operations and demonstrated the logistical efforts involved to optimize these processes. It also addressed students' different sensory channels. In the waste bunker, for instance, students saw, smelled, and heard the incoming waste dropping to the ground. This waste was then transferred to the incineration hall where it was burned. Students were able to feel the resulting heat used to boil water and to create steam for the turbines in the turbine chamber. Literally seeing and feeling thermal energy being transformed into kinetic energy helped them understand the underlying physical processes. In the generator hall, students learned that emerging electrical energy was directly transferred to regional power suppliers. A final, all-encompassing overview of the processes was provided in the control room, where students also discovered how much electricity the incineration plant produced and how by-products, like pollutants and other contaminants, were removed from water and steam before being released into nature.

Educational Background

Seeing the waste piled up in the waste collection bunker, students realized the impact an individual's handling of waste has

Figure 12. Students matched the appropriate technical terms with the respective components and described the entire process in full sentences.

on waste production. This experience also raised their awareness of effective waste management as well as of a sustainable and resource-saving consumer behavior. Knowledge about the underlying technical processes of waste recycling and energy production

Figure 13. Students visiting the waste bunker in front of the incineration chamber.

Figure 14. Students visiting the control room of a waste-to-energy plant.

clearly displayed the interrelation between the needs of society and technological progress. Students could, moreover, transfer their knowledge obtained from building the model of the incineration plant to the processes observed on-site. It helped them realize the dimensions of waste disposal operations and demonstrated the logistical efforts involved to optimize these processes.

Conclusion

The intervention combined classroom hands-on and peer-guided activities with an out-of-class practical experience, considering *Standards for Technological and Engineering Literacy* and *Next Generation Science Standards*. The out-of-class practical experience at an incineration plant is optional, since teachers could also show a video about waste incineration to students if a field trip is not feasible. The rest of the modules' activities are fit for classroom teaching.

To reconsider the impact of their own consumer behavior and waste-production habits on the environment, students obtained technological, physical, and biological knowledge about effective waste management. The time-consuming processes involved in recycling waste helped students understand how important sorting waste is for energy production and the recovery of essential resources. The visit to the incineration plant also transferred their theoretical knowledge into more tangible firsthand experience. Students, thereby, encountered practical and technical challenges that the waste recycling industry faces on a daily basis due to the sheer amount of waste produced. The entire module aimed at promoting sustainable attitudes as well as resource-saving consumer behavior. It was designed to be compelling and accessible to students at all different ability levels. We consider our module suitable for successfully changing individual consuming and littering behavior.

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Appendices

A. Workbook
B. Workbook Solution
C. Informational Material

NOTE: Appendices are posted online at: www.iteea.org/TETDec20StockertWorkbook.aspx

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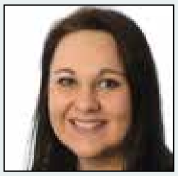

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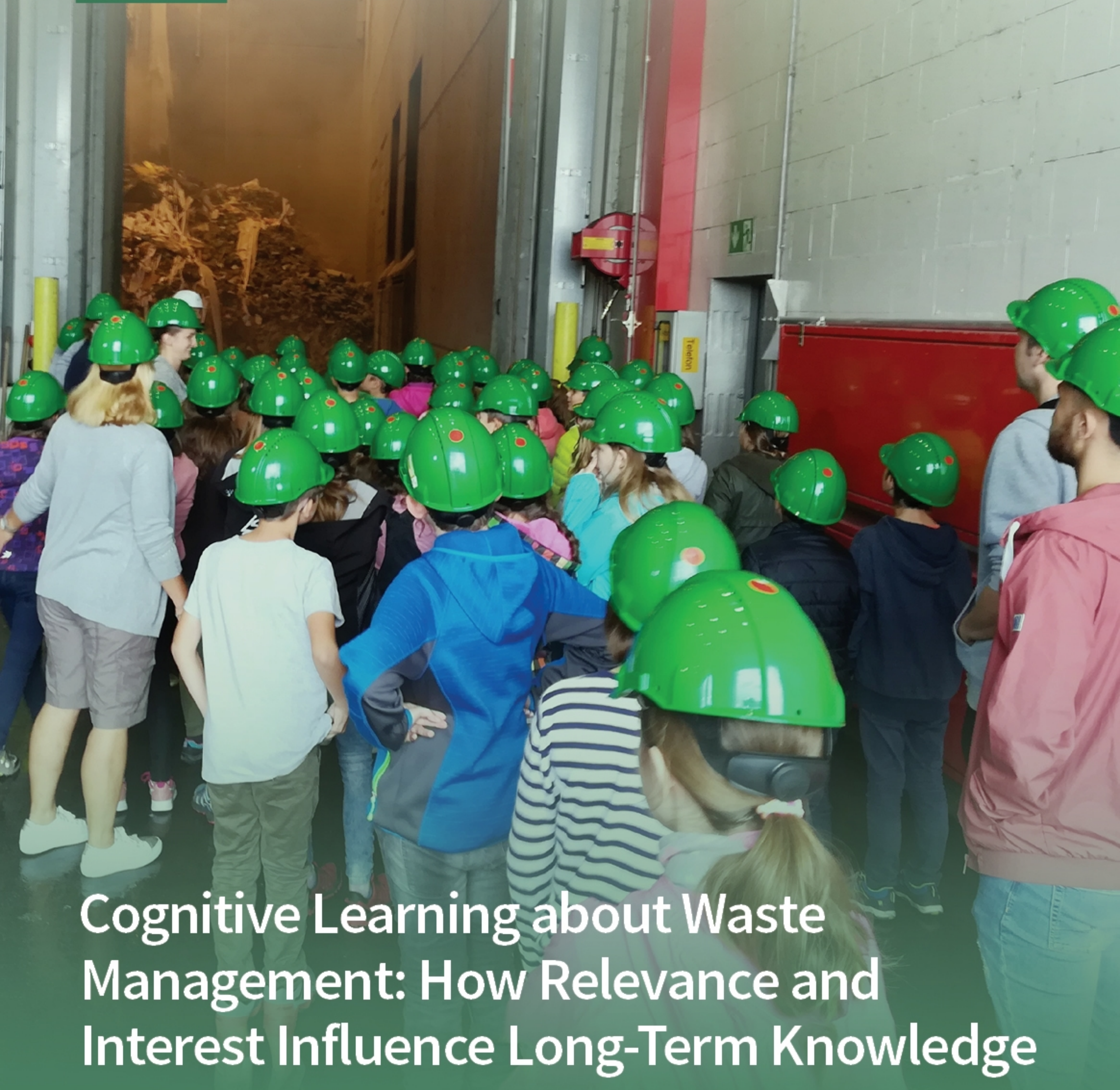

Cognitive Learning about Waste Management: How Relevance and Interest Influence Long-Term Knowledge

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Cognitive Learning about Waste Management: How Relevance and Interest Influence Long-Term Knowledge

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Abstract: Efficient waste management is a major prerequisite for reaching sustainability as every one of us produces waste. Thus, educational interventions need to offer promising assistance to reduce individual waste as much as possible to promote environmentally friendly behavior beyond stereotypical notions about waste disposal. Those who know about all facts and circumstances are more likely to correct their behavior. Our hands-on module for fifth graders was designed and implemented to support "4R": Reduce, Reuse, Recycle and Recover, by retracing waste's usual journey from collection management to incineration plants. The first module focused on minimizing waste by recycling, reusing and reducing it. The remaining waste was the second module's core, which explained the waste-to-energy path using an age-appropriate functional model of how to effectively generate energy from waste. Both modules are suitable for outreach (informal) implementation as well as for formal classroom learning. The third module comprised either an onsite visit to an incineration plant or a classroom multimedia presentation. A total of 276 fifth graders participated in our three-module implementation study, completing three questionnaire cycles: two weeks before the intervention, immediately after and six weeks later. A subsequent analysis showed a clear pattern: knowledge scores increased immediately after participation and remained constant for at least six weeks. Surprisingly, no significant difference between the multimedia and outreach group appeared. When applying a semantic differential, two response pattern factors, "Relevance" and "Interest", showed significant intercorrelations, as well as positive correlations with knowledge scores. In consequence, learning about waste management matters, and produces short- and long-term effects.

Keywords: incineration plant; 4R (reduce, reuse, recycle, recover); assessment; semantic differential; education for sustainability; collaborative learning; outreach learning

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1. Introduction

Waste is a global manmade problem that pollutes environments on land, air and sea. Everyone produces waste, and, thus, action is required to return to sustainability. The "Fridays for Future" movement shows that young people in particular are deeply concerned about environmental responsibilities, as they face an uncertain future. How waste is being handled may be influenced by social norms and self-confidence [1,2]. Behavioral norms are supposed to support socially acceptable preferences. Many studies have shown, for example, that people in polluted areas tend to pick up waste more often when well-prepared guidance models exist [3,4]. Hasan [5] noted that involving the public in active waste management and raising their awareness is key to solving these problems; using examples from the US, the study found that specific training regarding waste avoidance and recycling, as well as the appropriate adjustment of curricula, have positive effects on raising awareness. Another study, in Poland, showed that taking part in an extra waste management modules encourages students to act as multipliers, in that they inspire discussions about waste disposal with their families [6]. This is also true for other studies where students assume multiplicator roles, e.g., in positively influencing parent behavior [7–9]. Hartley, Thompson and Pahl [10] described lessons about waste management as potential ways to solve a global problem since they also have effects beyond school life. Students need to consider the environment worth protecting and to take decisive steps against irresponsible waste disposal; subsequently, they may involve society in realizing and assessing the problem to ensure long-term conscious consumption.

1.1. Teaching Methods as Triggers for Knowledge Acquisition

Well-prepared teaching staff are essential for supporting hands-on skills and for initiating individual action. Koehler and Mishra [11], for instance, described good teaching as a complex interaction of three different components: namely, technology, pedagogy and content. Teacher content knowledge, referring to the "amount and organization of knowledge per se in the mind of the teacher" [12] (p. 9), plays a central role. Teachers need to adapt learning contents to respective age groups by correctly delivering preconcepts and involving students from different backgrounds. Moreover, in addition to pedagogical skills, confidently handling media is required, as Koehler and Mishra [11] described with the aspect of "technology". In consequence, classroom competencies within a common sense need to contain four aspects of biology lessons [13]: (1) specialist knowledge (concrete subject contents); (2) gaining knowledge (in developing questions regarding a phenomenon or problem, finding solutions and testing them experimentally); (3) communication (accessing and exchanging information in a subject-related way); and (4) evaluation (which is how to recognize and evaluate biological facts in different contexts). For the knowledge acquisition process, three higher-order levels of abstraction were distinguished: (1) reproduction (content is reproduced unchanged in the same context); (2) reorganization (acquisition in a different context); and (3) transfer (new knowledge is abstracted and applied in a completely different context, mostly abstracted and rearranged). All three combined may contribute to a successful science knowledge construction by considering a balance of all the preconditions.

In summary, inquiry-based science education (IBSE) may unite different aspects of scientific knowledge acquisition, which is comparable to exploring natural phenomena in science [14]. It combines observing phenomena; generating hypotheses and formulating research questions; planning and carrying out appropriate experiments; interpreting data; and reasoning about potential results, as well as presenting them to peers [15,16]. As IBSE occurs quite often, a precise definition is required before its implementation in science teaching. The National Science Education Standards (NSES) and Anderson [15] (p. 2) label three essential aspects of IBSE:

1. Scientific inquiry. This part considers different working methods that scientists use to study natural phenomena and explain findings. In our case, the students built a functional model of an incineration plant, did text-guided parts and integrated their solutions to solve the waste problem.
2. Inquiry learning. This is a learning process organized collaboratively with small scientific investigations on various questions, interactive communication and explanations to peers. In our module, students worked collaboratively in pairs, small groups or as a whole class in order to investigate the technological parts of an incineration plant, the circular flow of waste or how to reduce the waste.
3. Inquiry teaching. According to Anderson [15], a central aspect of learning is to investigate, but not to gloss over. According to NSES, the consideration of real-life issues in order to expand knowledge is a central element of good teaching. The teacher in our study acted in the role of a supporter, not as a mere supervisor.

When using different teaching methods, we need to bear in mind that students do not only learn science at school. It is important to know that experiences, both in school and outside, influence social life [17]. Thus, learning outside and inside of school must be distinguished. Formal learning, with its main focus on cognitive learning success, is the goal of all classroom actions and subsequent assessments [18]. Gerber et al. [19] define informal learning as learning activities outside of formal classrooms. However, definitions are still controversial, as for instance museums offer formal learning without a teacher [20]. Another term may focus on knowledge acquisition, supervised by a teacher but out of school; outreach learning opportunities offer a wide range of possibilities to feasibly impart knowledge to students. Generally, outreach is defined as "the activity or process of bringing information or services to people" [21]. In this context, small hands-on activities are often offered in collaborative actions [22] where experts join the respective activities. Therefore, an in-class learning environment can also be created in learning locations of research centers or universities. In this case, outreach means the combination of real-life elements, constructed learning environments and skills such as teamwork [23].

1.2. Social Form: Cooperative Learning

In general, cooperative learning includes supporting each other's learning progress by working together in small groups (mainly used in primary schools). In science education, many different studies investigate cooperative learning and its effects on, for instance, behavior, social interactions and school results in different subjects, although it is controversially discussed why and how this method has positive effects on achievement and which conditions are essentially needed [24–29]. Rohrbeck et al. [30] identifies two aspects of how learning together in groups promotes knowledge growth: (1) the group serves as a teacher who is at the same mental level of development; and (2) the group serves to solve tasks with perseverance and a goal-oriented approach. This is in line with the descriptions of Vygotsky [31] and Piaget [32], who identify social interaction as a root of cognitive development.

Cooperative learning entails students working in groups and communicating with each other. It is, however, not that simple. Johnson and Johnson [33] identify five conditions that enable efficient cooperative learning: "1. Clearly perceived positive interdependence. 2. Considerable promotive (face-to-face) interaction. 3. Perceived individual accountability and personal responsibility to achieve the group's goals. 4. Frequent use of relevant interpersonal and small-group skills. 5. Frequent and regular group assessments regarding group capabilities to improve the group's future effectiveness (p. 2)". In consequence, combining hands-on learning with cooperative learning often shows higher scores for cognitive achievement than normal classes [34]. A combination of both methods might help to motivate and support low achievers. Such synergies are also reported by Marth and Bogner [35] as well as Kyndt et al. [36]. However, just a few teaching modules covering all waste disposal processes exist, e.g., Grodzińska-Jurczak et al. [6], which is why our teaching module intended to provide a holistic overview for various age groups and to focus on different possibilities of waste treatment ("4R": Reduce, Reuse, Recycle and Recover). However, it is not only important how knowledge is communicated; individual preferences also play an important role.

1.3. Interest and Relevance as Components of Motivation

Interest was described by Palmer [37] as a form of motivation that occurs in special situations on a short-term basis and initiates as well as maintains learning processes. As an important component for motivation, it has the power to effectively influence behavior. Since different studies described 'interest' as a strong variable to influence learning, attention and goal finding [38], it can be regarded as a person-object-related relationship [39] playing a directive role to naturally approach activities [22]. Overall, two forms of interest are important: (1) individual (trade) interest, described as long-term interest and preference for a particular subject area [40]; and (2) situational (state) interest, described as a short-term emotional state that arises from situational stimuli [41–44]. The latter is considered to contain two phases. In the first part, attention is aroused by the environment, and in the second, attention is maintained [45]. For the latter, Mitchell [46] describes another classification of interest, distinguishing between catch- and hold-phases. He attributed the ability to catch interest to the social form or special methods, thereby stabilizing situational interest into the hold and phase levels and supporting special interest in a certain topic. Therefore, situational interest may play an important role in the development of individual interests. Palmer [37] also identifies different sources that arouse interest within this context: novelty, physical activity, social involvement, surprise and choice. Therefore, teaching should initiate situational interest to achieve long-term interest that is sufficient for learning processes [44]. However, it is not only subject choices that matter; attitudes and interest also influence learning success, as do social forms and chosen methods [47].

Relevance is the extent to which a judgment has considerable consequences for personal needs, personal goals or personal career [30,31]. Frymier and Shulman [48] describe it as the learning content which is considered useful for personal career paths. In addition, besides immediacy, relevance is provided as closely related to state motivation. Gilman and Anderman [49] see relevance as important to aligning a curriculum with students' interests, and consider it essential to ensuring an optimal learning process. Thus, knowledge about aspects of the content that will be relevant from students' point of view is important. According to Albrecht and Karabenick [50], students need to recognize the importance of instruction in a respective subject and also value social relevance.

These studies identify relevance and interest as very important components and conditions of motivation. According to Alexander [51], social psychologists see relevance as the connection between extrinsic and intrinsic motivation to perform in a particular area. The National Research Council [52] even suggests that an educational program should not only take into account the aspect of relevance, but also build on the cultural and personal experiences of students. This allows identification with everyday learning situations outside of school. Newby [53] positively links relevance with learning time and motivation as such. Therefore, teaching methods should support motivation and promote relevance and interest.

1.4. *Focus of the Study*

Based on a newly developed teaching module about waste management., our research objectives were three-fold: (1) to evaluate the knowledge acquisition in our collaborative hands-on-module, and to evaluate our ad hoc instrument to monitor knowledge acquisition; (2) to determine the impact on short-term and delayed effects of knowledge acquisition in an outreach learning location compared to classroom lessons; and (3) to determine the relevance and interest involved with cognitive learning (classroom vs. outreach).

2. Procedures and Methods

2.1. *Participants*

Overall, 276 fifth graders ($M \pm SD$: 10.2 ± 0.42 years) participated in our study. All schools used in the study were located in Bavaria, in both rural and urban regions. Teachers officially registered their students before participating in our module. Parents gave their written consent.

2.2. *Intervention Design*

Our intervention was designed as a IBSE [14] module, combining hands-on and peer-guided activities in class or out-of-class. It followed the Declaration of Helsinki, and its application was approved by the Bavarian Ministry of Education. Our activity was planned flexibly and was able to be applied in conventional classrooms or at an out-of-class site. The module about waste-management and the "4R" (Reduce, Reuse, Recycle, and Recover) was designed for three school lessons (135 min), with an optional 60-min visit to an incineration plant. The impact of the increasing amounts of waste, in combination with individually generated solutions, were key to the first module. Students worked in peer groups to retrace the waste cycle and to compare it with natural processes of decomposition.

The second module introduced the incineration of waste that had resisted any recycling procedures. It explained the process of waste incineration, and the fact that the emissions of particles or poisonous gases are prevented due to filter applications. Students learned technical terms about energy ranges and the generation of electricity using steam (produced by incineration). These theoretical foundations were then put into practice when students constructed a miniature functional model of a waste power plant. Successfully built models illuminated an LED when tested. Additionally, a subsample completed the optional onsite visit in an incineration plant in order to provide a link to real-life objects (Figure 1). Optionally, a virtual visit was prepared as a film for the remaining subsample.

"4 R" collaborative hands-on learning		
Module 1: *Reduce, Reuse, Recycle (3R)*	*Module 2:* *Recovering energy*	*Module 3:* *Excursion to an incineration plant*
<u>Presentation of the problem</u> 1A) Does this waste mountain have to be so high? <u>Elaboration Phase</u> 1B) Cycle of waste	2) What if recycling is not possible? 3A) Waste in … energy out 3B) The end of waste 3C) Model of an incineration plant 4) Optional Station for higher actuering students	Virtual or onsite

Figure 1. Different stations of the three modules of our "4R" intervention.

Students collaborated in pairs or small groups, guided by a workbook and instructed by the same teacher. After a short introduction, students worked mostly independently. In order to ensure efficiency, all steps were available six times, including the solutions and supplementary tools. Students self-assessed their results by comparing them with the teacher's desk booklet.

2.3. Test Design and Instruments

To assess prior knowledge, a paper pencil test (T0) was completed two weeks before the intervention. After participating in our module, a post knowledge test (T1) was applied, and six weeks later a retention test (T2) was administered (see Figure 2). Waste management unites different aspects of science (biology, physics, and chemistry), and this was reflected in our knowledge questionnaire. The knowledge test contained 13 items, assessing knowledge about waste management and the technical function of incineration plants. Examples are given in Table 1. For each testing point, questions and answer possibilities were mixed and randomly arranged. Knowledge scores were based on sum scores (1 = correct, 0 = incorrect answer). Secondly, to monitor individual willingness to take action, a semantic differential was applied with response options to two antithetic possible choices [54].

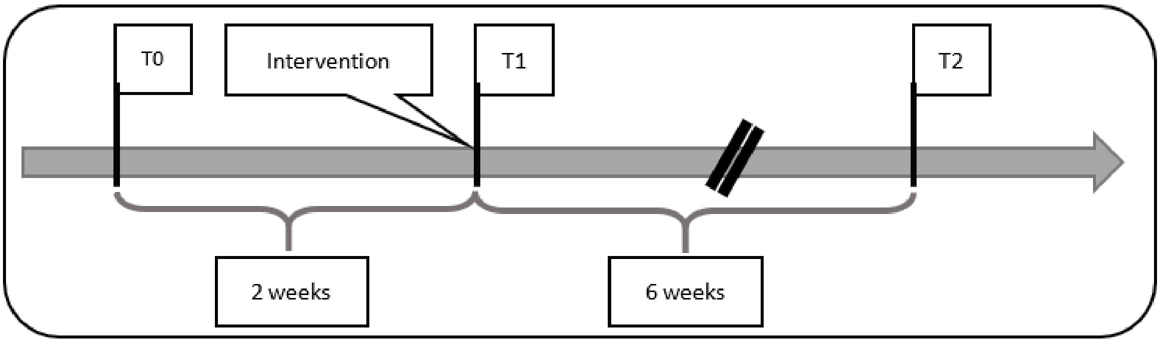

Figure 2. Schedule of the questionnaire implementation at three testing points. T0 assesses prior knowledge, T1 assesses the knowledge directly after the intervention and T2 assesses retention after six weeks.

Table 1. Example items of the knowledge test.

Example Questions	
W1_1 What is left when incinerating residual waste in the waste-to-energy plant? (a) particulate matter (b) slag (c) nothing (d) soot	W1_17 A generator turns ... (a) . . . Kinetic energy into heat energy. (b) . . . Heat energy into electrical energy. (c) . . . Kinetic energy into electrical energy. (d) . . . Heat energy into kinetic energy.
W1_3 The waste-to-energy plant supplies the people in the area with ... (a) . . . Energy for power generation. (b) . . . Water for toilet flushing. (c) . . . Soot for tire production. (d) . . . Garbage bins for disposal.	W1_16 Which transport packaging for your purchases generates the least amount of waste? (a) paper bag (b) plastic bag (c) textile bag (d) cardboard box

The method of applying semantic differentials can be useful to describe individual preferences, identifying tendencies involved in emotions or attention regarding an object [55,56]. As a tool to quantitatively analyze word meanings, originally developed by Osgood [57], it was chosen for application in our settings and applied by focusing on the two variables "Interest" and "Relevance". Both are supposed to support knowledge acquisition as they are often also used in connection with motivation [48,50,58]. Participants were subsequently asked, based on a five-digit Likert scale with respective adjectives ("boring-fascinating", "unnecessary-necessary") adapted from Schönfelder and Bogner [11,58], for attitudes regarding waste to energy plants ("I think a waste to energy plant is . . . "). Thereby, the relevance of and the interest in a waste to energy plant were measured. Most of our study took place in the classroom with a virtual tour through the incineration plant. Only a small subsample (N = 47) completed the onsite module. A test/retest sample N = 52 with students M = 11.08 completed the knowledge test without taking part in our intervention.

2.4. Statistical Analysis

Statistical analyses were conducted with IBM SPSS Statistics 24.0 (IBM, Armonk, NY, USA). All in all, 276 complete data sets were assessed. Due to the sample size, the central limit theorem is implied which means it can be calculated with parametric tests [59]. Difficulty indices of knowledge items were determined by relating the number of correct answers to the total number of participants. Responses were, thereby, recoded as (1) for correct and as (0) for incorrect answers. For reliability analysis, Cronbach's alpha was calculated to assess the internal consistency of the knowledge questionnaire which consists of 13 multiple-choice questions, each offering four possible answers. The internal consistency of the questionnaire was acceptable, with Cronbach's alpha for T2 ($\alpha = 0.617$).

Sum scores were formed for each knowledge item and then analyzed, using repeated measurement ANOVA to detect knowledge differences between the three different test times. Post-hoc testing with Bonferroni correction was used for pairwise comparison of the different testing times (T0, T1 and T2).

3. Results

3.1. Item Difficulties

Due to the subject dependency, knowledge assessment required an ad-hoc instrument. The relevant criteria showed item difficulties ranging from 0.06 to 0.84, with higher scores indicating simple, easy to answer items and low scores indicating difficult items. The item spectrum (Figure 3) shows their spread over the entire range. Taking hierarchy response patterns into consideration, easy questions are associated with more reproduction of given information, whereas questions of medium difficulty indicate reorganization and difficult questions, suggesting transfer of knowledge (see Table 1). Response patterns of the preknowledge test calculated with Kolmogorov-Smirnov-Test show a normal distribution ($p = 0.20$) of the item difficulties.

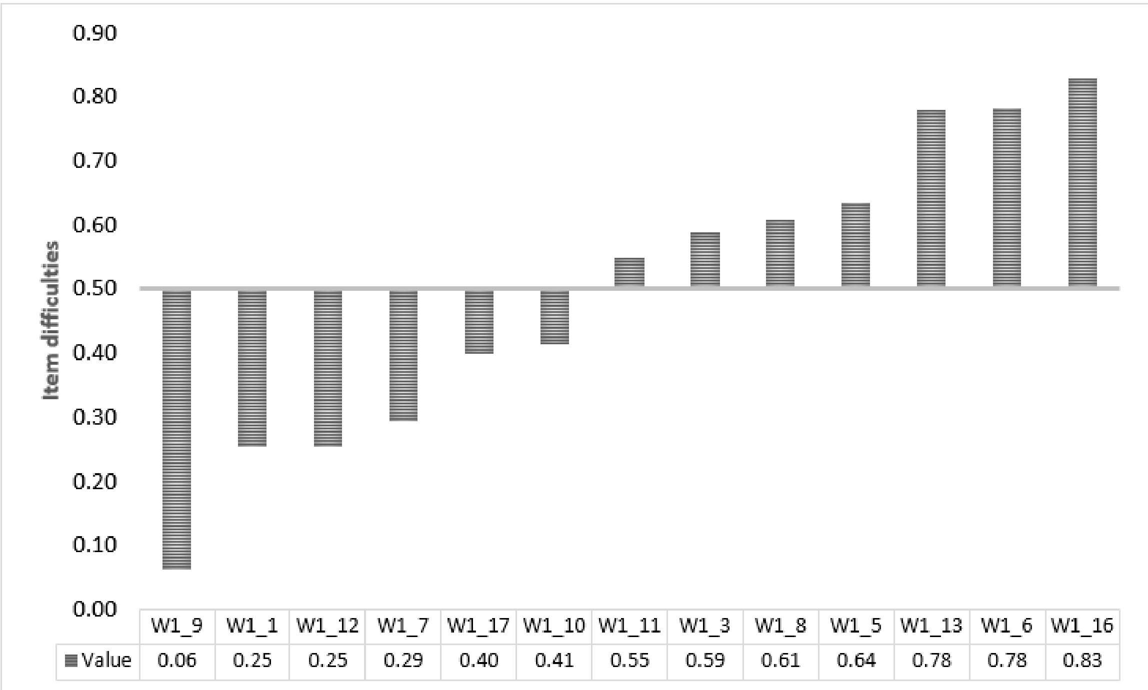

Figure 3. Item difficulties displayed for all 13 items (low scores indicate difficult items, high scores easy ones).

3.2. Knowledge Acquisition in and beyond Intervention

Knowledge acquisition peaked at T1 ($M = 8.91.$, $SD = 2.24$) for the classroom sample $N = 229$ with a marginal drop after six weeks T2 ($M = 8.55$, $SD = 2.37$). Nevertheless, the low original pretest scores T0 ($M = 6.32$, $SD = 2.25$) were never reached again. The Huynh-Feldt adjustment was used to correct violations of sphericity as $\varepsilon > .75$. In combination with repeated measures, ANOVA analysis showed different achievement levels between the three testing times, F (1.94, 900.49) = 18.6.28, $p < 0.001$, partial $\eta^2 = 0.45$. Bonferroni-adjusted post-hoc analysis revealed a significant increase in knowledge scores from T0 to T1 ($MD = -2.59$, $p < 0.001$***, 95%- CI [−2.95, −2.23]) as well as from T0 to T2 (*MD* = −2.23, $p < 0.001$***, 95%- CI [−2.60, −1.85]) with pairwise comparison for all three testing schedules. A difference between T1 to T2, however, did not appear. Our outreach subsample $N = 47$ also reached its highest knowledge scores at T1 (*M = 8.43, SD = 1.75*) even with an increase after six weeks T2 (*M = 8.79,* SD = 1.65) compared to pretest T0 (*M = 6.98., SD = 1.62*). Here, Huynh-Feldt adjustments also were applied as ε >.75, detecting significant differences between the three testing schedules, F (2.00, 86.09) =25.18, $p < 0.001$, partial $\eta^2 = 0.35$. Bonferroni-adjusted post-hoc analysis was applied to all and revealed a significant increase in knowledge scores from T0 to T1 (*MD* = −1.45, $p < 0.001$***, 95%- CI [−2.11, −.78]) as well as from T0 to T2 (*MD* = −1.81, $p < 0.001$***, 95%- CI [−2.49, −1.13]) (Figure 4) with pairwise comparison. T1 to T2 scores did not differ. Similarly, the test/retest groups (T0: *M = 7.31, SD = 2.00*, T1: *M = 6.69, SD = 2.339*) did not differ.

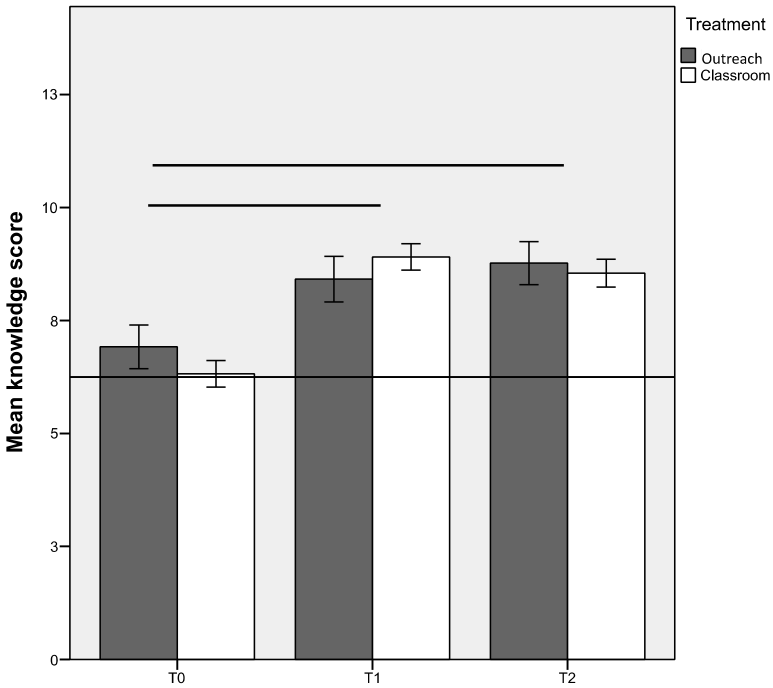

Figure 4. Mean knowledge scores at three testing points of the outreach and classroom treatment. Bars are 95% confidence intervals. T0: prior knowledge; T1: postknowledge test after completing our module; T2: retention test after six weeks. *P-value* indicates the significance level. T0 to T1 and T0 to T2 differed significantly (p ≤ 0.001).

3.3. Semantic Differential Scores

A principal-axis factor analysis extracted two factors for the seven-word pairs of the semantic differential. Both could be interpreted and summarized as follows: "Relevance" contains three-word pairs, "Interest" four. The Kaiser-Meyer-Olkin measure of sampling adequacy KMO (Kaiser, 1970) yielded a score of 0.84. As the acceptable limit is defined at 0.5 [59], our score drastically outnumbered this limit. The Bartlett's test of sphericity was significant (p < 0.001), indicating correlations between items were sufficient for performing factor analysis. An examination of Kaiser's criteria and the scree plot yielded empirical justification for retaining two factors and explained 70.69% of the total variance. Table 2 shows factor loadings after oblimin rotation. As a predictor for reliability [60], Cronbach's α scored "Relevance" with 0.85 and 0.81 for "Interest".

Table 2. Loading pattern of the exploratory factor analysis of the semantic differential.

	Factor Loadings: Relevance	Factor Loadings: Interest
worthless/worthy	0.807	
unimportant/important	0.802	
needless/ needed	0.772	
uncool/cool		0.738
nasty/likeable		0.701
uninteresting/interesting		0.655
boring/fascinating		0.600

An independent t-test showed differences between the two factors of the semantic differential regarding the authentic outreach and multimedia group (Figure 5). We found statistically significant differences between the factor "Relevance" of the onsite group and the classroom group (95%-CI [0.25, 0.84]), with lower scores for the classroom group t (299) = 3.62, p < 0.001. The same effect could be observed for the factor "Interest" (95%-CI [0.13, 0.69]), with lower preferences for the classroom group t (299) = 2.89, p < 0.001.

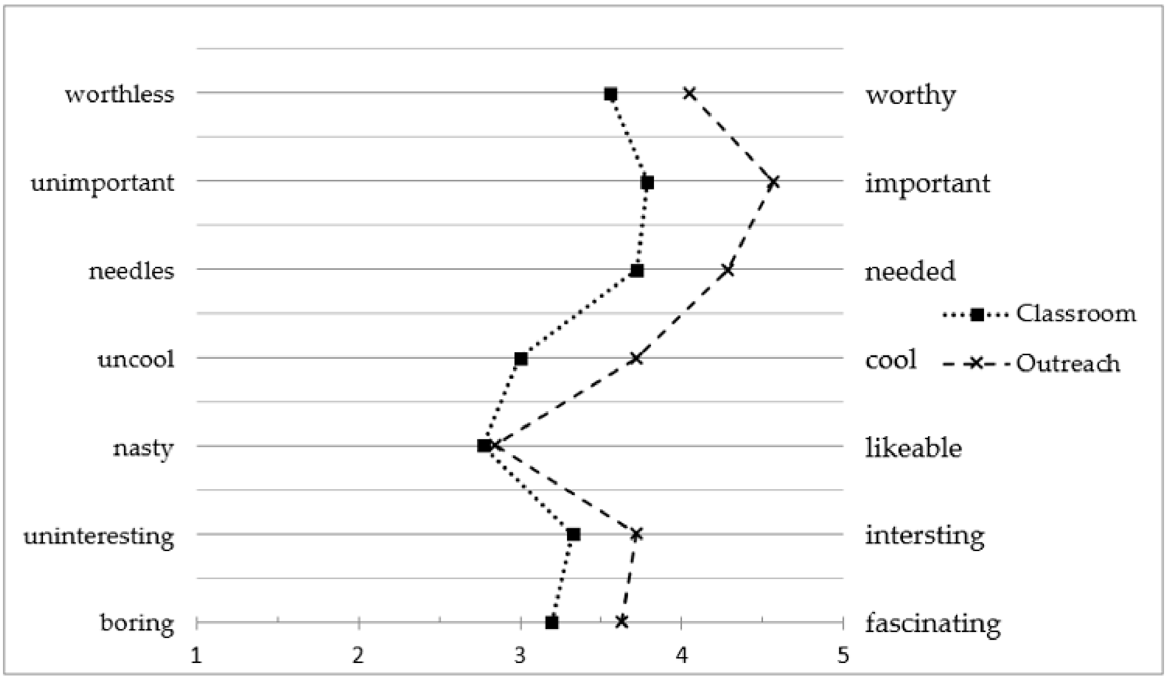

Figure 5. Semantic differential scores of outreach and classroom groups of each word pair.

3.4. Correlation between Semantic Differential and Knowledge Acquisition

"Interest" and "Relevance" correlated with knowledge scores and intercorrelated with each other (Table 3). Furthermore, a positive correlation appeared between the retention test T2 and the factors "Interest" as well as "Relevance".

Table 3. The semantic differential in correlation with the knowledge acquisition of the main sample.

		Semantic Differential:		Knowledge:		
		Interest	Relevance	T0	T1	T2
Interest	Sig.		<0.0001	n.s.	n.s.	<0.0001
	Corr.	1	0.581 ***			0.202 ***
Relevance	Sig.	<0.0001	1	n.s.	n.s.	<0.0001
	Corr.	0.581 ***				0.255 ***

4. Discussion

The highlights of the study are clear: individual "Interest" and "Relevance" clearly correlated with cognitive learning; and the collaborative hands-on module supported knowledge acquisition, even for some delayed duration, in both formal and outreach settings. The following chapters put the outcomes into relation with the literature.

4.1. Cognitive Learning Context

We were surprised by the similarity between the short-term and delayed effects on knowledge acquisition in this study. It seems our participants did not forget their newly acquired knowledge. The learning location seemed to play a subordinate role, since classroom and outreach onsite instruction resulted in similar learning effects. Bogner and Fremery [61] had shown similar results in similar circumstances (of an incineration plant) regarding the short- and delayed effects at knowledge acquisition, examining the three dimensions of knowledge [61]. One reason for having obtained such a surprising result might be the link between situational emotions like interest or relevance [25].

The knowledge questions seemed well chosen for the study, as a relevant increase in knowledge before and after the educational measure became apparent, which is in line with another study of Marth and Bogner [35]. Item difficulties were well-balanced and showed a normal distribution of the items; easy and difficult questions had the same ratio. A reason for successful learning might be the selection of learning activities which, besides a focus on knowledge acquisition, offer methodological variation, according to Tennyson and Rasch [62], and altogether benefit knowledge acquisition.

Consequently, our interactive module about waste management, including the main functions of an incineration plant, had a significant impact on mid- and delayed effects on knowledge, regardless of whether the module was delivered onsite or virtually [35]. This is in contrast to several earlier studies regarding waste and environment [27,61] which reported long-term learning only as a success of outreach modules.

4.2. Interest and Relevance

There is a strong link between relevance and interest in influencing delayed effects on knowledge. Looking at individual interest, Schiefele [58] describes two components: the emotional part, focusing on feelings or emotions to an object or topic; and the value-related part, considering the personal relevance and attachment to an object. As the tool of a semantic differential frame is considered to capture feelings about a selected subject and to provide information about interest, we consider both to be predicting variables of retention achievement. Renninger et al. [40], for instance, observed a wide-ranging knowledge if interest was present. Müller [63] further describes interest as correlating with willingness to learn and learning strategies, which in our case would also provide an explanation for the retention performance after six weeks. Furthermore, the aforementioned factors identified by Palmer [37] (i.e., novelty, physical activity, social involvement, surprise and choice) have been implemented in our teaching module, not only offering new content but also social and physical action. An incineration plant in a neighborhood, for instance, may contain social involvement in relation to a learning object which may possibly explain the link between "relevance" and "interest". This is in line with Värlander [64] who postulates that emotions are a natural and important part of learning, whereas retention and attention problems are reported to be related to boredom [43,65]. Classroom intervention may already indicate a medium interest, whereas an outreach visit may further increase interest scores. This small difference could be an indication that outreach teaching increases interest in the subject matter, and thus promotes retention performance. Furthermore, applying an inquiry method seems to involve both interest and relevance. In this context, Gibson and Chase [66] reported higher interest scores after an inquiry-based session, recommending research-based teaching to encourage interest and motivation.

4.3. Long-Term Knowledge

Knowledge acquisition seemingly does not depend on the length of an intervention, as short units also have positive effects on long-lasting knowledge [25,67]. Short lesson units are also considered to be more practicable, since it is easier for teachers to integrate them into school curricula. Furthermore, Bogner [68] showed that short interventions can positively influence knowledge over a period of four weeks. This is also in line with other studies that have shown this effect over a period of six weeks [35,69]. All studies display a clear increase in knowledge after such interventions. This was also true for our teaching module. Furthermore, it seems to be relevant who is teaching and where the information is being distributed. According to Johnson & Manoli [70], extracurricular learning programs also lead to enhanced environmental awareness with related increase in knowledge after several weeks [71,72]. Stein, Isaacs and Andrews [73] describe professional knowledge transfer as helpful for students to better understand and retain what they have learned. Regarding knowledge acquisition, in our intervention approximately 6.32 of 13 questions were correctly answered at testing time T0. Immediately afterwards, our classroom group was able to answer about 8.91 questions, and after six weeks, about 8.55 questions out of 13. This result can also be obtained in other half-day lessons about waste with a permanent increase in knowledge [61,69] and is also in line with other studies [71,74,75]. However, students usually have a significant increase in knowledge shortly after the intervention followed by a substantial drop afterwards [69], but never below preknowledge levels. Such findings are common not only for a period of six weeks but sometimes also for longer periods e.g., more than one year [26,35]. Educational activities in a certain subject area thus improve knowledge, and with some losses may retain it even for long periods. In our case, a lack of any such drop was apparent and quite surprising, since an almost constant level of knowledge scores remained. Possible reasons for this remarkable knowledge acquisition need closer argumentation regarding e.g., teaching styles (IBSE, cooperative learning) or formal/informal contexts.

A potential reason for delayed effects at knowledge acquisition and the low drop rates of our module could be, inter alia, our use of IBSE as a learning strategy. When students are guided step by step through an intervention they are more likely to acquire scientific knowledge [17]. They autonomously formed a functional model of an incineration plant, a replica of the original, and thus developed an understanding of scientific work, which enabled problem-solving skills and creative thinking. These variables are important features of IBSE because finding meaningful explanations is key for learning science [14]. In consequence, the IBSE method is supposed to help develop knowledge from the exploration of scientific phenomena [14]. Furthermore, an exchange of knowledge between peers allows the transfer of knowledge within previously unknown areas. This is also a central point of active learning [76]. IBSE is, therefore, not the only condition for delayed effects on knowledge acquisition, as different teaching methods can achieve comparable results [15]. Another reason for retaining knowledge could be the small group size of a maximum of 3–4 students. By working together, students achieve common success with common "learning goals" [77]. Blumenfeld et al. [78] mention in this context that creating a good learning environment is not enough; the willingness to supplement missing information is also required, whereby possible solutions and their verification/falsification is vital to critically evaluate their results. In our module, students were encouraged to learn hands-on and to compare solutions independently with the solutions provided. There was no need to fear an evaluation via grades or immediate feedback by a positive result, as in our case the LED lighting. Graham and Golan [79] note that students focusing on self-improvement rather than competition seem to have better retention performance, which could have also influenced the here-assessed intervention.

Interpersonal relationships also play an important role in group learning. Accomplishing a task together positively influences STEM-specific self-concepts [80]. Another probable reason for delayed effects on knowledge acquisition is our hands-on design. This is also in line with the constructivist learning theory. According to Mayer [81], hands-on activities support a learning process due to independent thinking and problem-solving. These results are similar to those of e.g., Bissinger & Bogner; Marth & Bogner [35,75] who also observed a long-term increase in knowledge similar to our post-test. Good retention performance, in our case achieved by half-day intervention, is also consistent with the observations of. The lack of difference between a formal classroom group and an outreach group requires further in-depth discussion as outreach learning normally is considered more beneficial than classroom learning. Therefore, it can be assumed that for our subject area, outreach is not necessary to ensure good knowledge acquisition. However, it is conceivable that outreach will increase interest and relevance, but not significantly in our case (Figure 5). A simple explanation could also be that a visit to the incinerator is about something new, which in itself increases the interest and the novelty effect takes effect [82].

4.4. Limitations of the Study

Limitations often originate in small sample sizes, which is also true in our case. Another concern often is the chosen age group, which in our case was defined by the existing syllabus. Clearly the older the participants, the more sophisticated the lesson designs could be. The best designed modules are useless when a teacher cannot integrate an issue into a curriculum.

Although our knowledge test only assessed subject knowledge, our teaching module also was supposed to promote other aspects—such as communication, social skills or how to deal with teaching material—that were not assessed in our case. These are important learning objectives that should be learned in school, but we limited ourselves to the collection of knowledge, as this corresponds to the standardized performance measurement at school.

5. Conclusions

In summary, outreach learning adds substantial value to school life but apparently is not preconditional to achieving better knowledge outcomes. A good classroom learning environment also allows successful learning beyond mere short-term peaks. Soft skills such as interest seem to contribute as important players and to network newly acquired knowledge horizontally and vertically. Similarly, the chosen method of inquiry-based learning seems to positively influence retention efficiency. Additionally, the condition remains important that for a learner, some things are worth being learned. Of course, our intervention is only one problem-oriented possibility to address the waste problem with its technical solution possibilities, but it offers an approach for making a topic relevant for students and integrating it into a school context. Nevertheless, it embeds a vital issue into school contexts as other current aspects do such as microplastics, GMOs or very recently the coronavirus pandemic.

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Learning about waste management: The role of science motivation, preferences in technology and environmental values

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A B S T R A C T

Waste education modules were designed to tackle waste production. Knowledge acquisition, the promotion of individual sustainable attitudes combined with technology and science motivation are supposed the key players in achieving science citizenship. We assessed the identified parameters by monitoring the learning effect of fifth-graders, the Two Major Environmental Value scale (2-MEV), the Science Motivation scale (SMOT) as well as the Technology Questionnaire (TQ). Preservation correlated positively with knowledge acquisition, while Utilization correlated negatively. Moreover, intrinsic motivation correlated positively with pre-knowledge levels. Male students preferred the social implications of technology, as well as self-efficacy. Female students focused on appreciation of nature.

1. Introduction

In the wake of global environmental protection efforts, various waste management initiatives should help promote sustainability and tackle excessive waste production. The involvement of the younger generation is, thereby, crucial since individual waste management is believed to be based on social norms and self-perception [1,2]. Thus, education about the impact of waste on the environment and health at school is important [3], while initiatives that focus on public involvement in creating feasible solutions further contribute to overall sustainable waste management [4,5]. Students who took part in educational programs on waste management could share their expertise with families and friends [6–8]. Therein presented recent findings in science and technology [9] could be combined with environmental protection to highlight its timeliness and relevance while motivating students. This leads to the question as to how the motivation to learn natural sciences is connected to enthusiasm for technologies and the environment and if this connection expands to knowledge acquisition in environmental sciences in combination with topics such as waste recovery. The UNESCO's charter on environmental education [10] highlighted awareness, attitudes, skills, and content knowledge as key components of individual environmental competences. In consequence, many instruments have been developed to investigate these predicted interrelationships. The refined instruments were used in this study and are described below.

1.1. Review on technology and environmental attitudes

1.1.1. Preferences in technology

Environment and technology are related but the numerous dimensions associated with the respective terms may lead to misunderstandings: McRobbie et al. [11], for instance, described five dimensions of technology: (1) The social and (2) human dimension of technology while other dimensions encompass (3) processes, (4) the contextualization of technology, and (5) product development [12]. There is, however, no uniform definition of the term technology in literature. To at least describe the effects of technology, reliable measuring instruments, such as the Technology Questionnaire [13,14], have been developed. The questionnaire combines aspects of the Pupils' Attitudes Towards Technology scale (PATT questionnaire; [15]) and Attitudes and Perceptions About Technology scale (APAT questionnaire; [16]) to assess classroom teaching. That is, from initially seven subscales ranging from technology is easy, diversity of technology, interest, technology as a design process, the importance of technology, technology as problem solving to career in technology, Rennie et al. [17] focused on two. "What is technology?" (Part A), which measures "cognitive perceptions about the diversity of technology and technology as design process" and "What do you think about technology?" (Part B), which assesses "students' effect in terms of their interest in technology." "Interest" (INT) was, thereby, adapted from the APAT-questionnaire and "social aspects of technology" (SOC) from the PATT-questionnaire. Both

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were considered relevant to evaluating the attitudes towards technology.

1.1.2. Environmental attitudes

The Two Major Environmental Value scale (2-MEV) [18–20] [18,20,21] was specifically developed for adolescents to monitor environmental attitudes. The empirical model builds on two orthogonal factors "Preservation" (PRE), which describes the individual drive to protect the environment, and "Utilization" (UTL), which measures anthropocentric drivers to utilize nature. Independent research groups in culturally distinct countries confirmed the scale. First, Milfont & Duckitt [22] assessed freshmen in New Zealand; second, Johnson and Manoli [23,24] used the scale to evaluate earth education programs for US 6th graders; third, Boeve-de Pauw and Van Petegem [25], evaluated samples of Flemish secondary school students; fourth, Borchers et al. [26] analyzed West African student samples and fifth, Braun et al. [27] monitored Asian students. Since UTL was initially limited to exploiting nature, it was later expanded by the sustainable use of nature [28]. Following Campbell's paradigm [29], which connects individual attitudes with respective behaviors, an exploratory factor analysis indicated a close link between APR and PRE [30]. That is, appreciation of nature leads to protective behavior and vice versa.

1.2. Science motivation and knowledge acquisition

Motivation seems to positively impact knowledge acquisition as was shown in science teaching [31]. With more than 100 different definitions of motivation [32], it is generally referred to as self-efficacy, self-determination, the feeling of self-responsibility, and the feeling of being able to fulfill a duty [33]. For science education, however, motivation has more specific meaning and describes "an internal state that arouses, directs, and sustains science learning behavior" (Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011, p. 1160;[34]). Successful teaching thus may entail motivating students with different classroom activities. Although motivation cannot directly be measured, it can indirectly be observed in activities and behaviors of students [35]. The science motivation scale [36] originally contains a 30-item set, which has later been reduced and contains five subscales in line with Bandura's [37] theory of learning: self- efficacy (SE), self-determination (SD), intrinsic motivation (IM), grade motivation (GM) and career motivation (CM). The scale was successfully trialed with high school students in studies by Marth and Bogner [31] and Schumm and Bogner [38]. Schmid and Bogner [39] proposed a reliable shortened version, containing only three subscales, in their inquiry-based, interdisciplinary education module. Since motivation can be either intrinsic, which describes the performance of an activity as linked to the pleasure derived from performing it, or extrinsic, which rather result-driven (Ryan & Deci, 2000, p. 54; [40]) both should be considered to foster motivation in the classroom. Also self-determination [41] and self-efficacy, which encompasses the individual judgement of the quality of action to perform in prospective situations, may be important in this context [37].

Inquiry-based science education (IBSE) is supposed to guarantee successful science education while maintaining motivation [42,43]. It combines investigations of phenomena with the generation of hypotheses and research questions, independent planning and conducting of experiments, conclusions drawn from the observations, and their presentation [44]. According to Anderson [44] and the National Science Education Standards (NSES) [45], IBSE is characterized by three essential dimensions: (1) Scientific inquiry, that is students use working methods of scientists, (2) Inquiry learning, which combines collaborative learning with small hands-on and peer-to-peer activities. (3) Inquiry teaching, which describes the role of teachers as guides to help students investigate real-life phenomena. Many of these theories indicate that good teaching does not lose its touch to reality, which is why learning outside of school is equally important [46]. That is, not only classroom teaching influences the behaviour and attitudes of students but also social factors and individual prerequisites.

1.3. Preferences evolved by gender

Possible differences between genders in environmental attitudes, attitudes towards technology, and science motivation needs consideration when planning a science education module. Due to social stereotypes, gender roles and technology were often assessed regarding differences in age groups and in STEM (Science, Technology, Engineering, and Math) learning [14,47,48]. Studies indicate that men often show significantly more interest in and understanding for STEM subjects than women [49]. Negative classroom experiences could be a potential reason for this development [50], which outlasts adulthood [51,52]. Since it could also influence secondary education and career decisions, science education should foster gender-balanced teaching to close gender gaps [53]. Not only career choices and STEM subject performance are gender-specific, also certain attitudes and behaviors as previous studies on MEV [12,21] have shown: Also, women received higher PRE and APR scores and display an environmentally friendly behavior while men show utilitarian preferences with low environmental protection motivation. These salient differences raise questions as to why, how, and when this behavioral gender gap appears. Dasgupta and Stout [51] have identified three possible stages in life, when individuals could develop gender-specific behaviors: between childhood to adolescence, the second in early adulthood and third in nascent adulthood.

Previous studies [54] about science motivation have shown that boys and girls correspond regarding interest and self-determination in STEM programs. On closer examination, however, boys emphasize their performance in STEM subjects as compared to girls. This is also reflected in the self-concept of both genders. Nevertheless, motivational experiences from primary school may have a lasting effect on gender-specific science motivation. These could also be influenced by role models, such as teachers, and leads to an increased motivation from practical action for boys whereas girls require the feeling of self-efficacy to be motivated [55].

1.4. Focus of our study

1.4.1. Studies of the past

Past studies have found that the choice of academic program at the end of the school career correlates with attitudes toward the environment and technology. These attitudes are even expected to influence career choice. Furthermore, gender differences were found, showing males as technology enthusiasts and females as environmentalists [12]. However, the question arises as to when these attitudes and differences emerge. Thus, this study focuses on participants who are at the beginning of their high school careers. Thus, a teaching module was developed that combines both, environmental attitudes and technical aspects, and combines the idea of sustainability and the problem of waste [56].

1.4.2. Research questions of this study

Our present study based on the described waste management module examines different properties of individual science motivation, environmental values, technology preferences and their interaction with knowledge acquisition.

Our research questions are three-fold: (i) How is knowledge acquisition of fifth graders about waste management influenced by science motivation, technology preferences, or environmental attitudes (ii) How does science motivation interact with environmental attitudes (iii) How do gender differences reflect in our three scales.

In the following, the sample of our study and the applied scales are described. Furthermore, results examining the research questions are shown and discussed. Finally, conclusions are drawn from the results, suggestions for further studies and proposals for educational activities are given.

2. Procedures and methods

2.1. Participants

We collected data from 276 fifth graders for our study (Table 1). Science teachers officially registered their students and parents gave their written consent prior to participation. Participation was voluntary and anonymous. Most schools were located in rural and urban regions of Bavaria. Incomplete questionnaire sets were excluded from the study. A test/retest sample with students at the age of $M = 11.08$ completed the questionnaire set without taking part in our intervention.

2.2. Intervention and test design

After the students were enrolled in the study participation, the same teacher always visited the classes. Knowledge acquisition was assessed at three test times: Previous knowledge (T0) two weeks before, short-term knowledge (T1) directly after, and long-term knowledge (T2) six weeks after the intervention [57] (Fig. 1). The knowledge questions included the field of science (physics, chemistry and biology) and contained 13 items to asses knowledge about waste management and the function of an incineration plant as described in Stöckert and Bogner [57]. Four possible answers were given. At each testing point, questions and answers were randomly mixed for every questionnaire. Students completed further a set of paper-and-pencil questionnaires including the technology questionnaire (TQ), which comprises five items to measure social aspects of technology (SOC) and five items for interest in technology (INT) which were randomly arranged [12,14]. They also answered 12 items assessing intrinsic motivation (IM), self-efficacy (SE) and self-determination (SD) in the Science Motivation Questionnaire (SMOT) [34] as well as the Two Major Environmental Value model (2-MEV)complemented by the appreciation scale (APR) [30] containing 20 items. Utilization (UTL), thereby, describes the exploitation of nature and preservation (PRE) the drive to protect and conserve the environment, while appreciation (APR) measures the sustainable use of nature. The questionnaires were answered using a five-point Likert scale (1 = completely incorrect, 5 = completely correct) and were randomized.

Our study was approved by the Bavarian Ministry of Education and combined peer-guided hands-on activities in- and out-of-class. Our module detailed waste-management with its four dimensions of reduce, reuse, recycle, and recover (“4R”). The module was designed for overall 135 minutes, but the visit of an incineration plant was optional. Students were guided by a workbook, instructed by the same teacher, and collaborated in small groups or pairwise [57].

2.3. Statistical analysis

We assessed 276 complete data sets using IBM SPSS Statistics 24.0 (IBM, Armonk, NY, USA). The central limit theorem was implied and, due to the sample size, we assumed normal distribution [58]. For our three questionnaires (TQ, SMOT and 2-MEV), we deployed a principal component analysis (PCA), using oblimin rotation and varimax (TQ).

The difficulty indices of the knowledge questionnaires were determined. Sum scores were formed and analyzed using repeated measurement Anova as described at Stöckert and Bogner [57] to detect differences between the three testing times (T0, T1 and T2).

Table 1
Characteristics of the survey participants.

	Participants	Test/retest sample
Sample size *N*	276	52
Age $M \pm SD$	10.2 ± 0.42	11.08 ± 0.33
Gender (f: m)	198: 83	-

3. Results

In the following we show i) scores for technology preferences, science motivation and environmental values of the implemented questionnaires, ii) how attitudes interact with knowledge acquisition, iii) correlations between our measuring instruments and iv) gender effects.

3.1. Implemented instruments

Sampling adequacy [59] was confirmed by the Kaiser-Meyer-Olkin measure with values listed in (Table 1). Kaiser and Rice [60] recommend a limit of over .5 [58]. The Bartlett test provides a value of $p \leq 0.001$ (Table 1). The internal consistency of the established questionnaires was satisfactory, with Cronbach’s alpha scores shown in (Table 1).

For the whole sample (N=276), the Technology Questionnaire scored with INT $M = 2.98$, $SD = 0.96$ (95% CI 2.88; 3.08) and SOC $M = 3.45$, $SD = 0.82$ (95% CI 3.34, 3.51). The SMOT subscales scored: IM $M = 3.95$, $SD = 0.70$ (95% CI 3.87; 4.02), SD $M = 3.42$, $SD = 0.69$ (95% CI 3.34; 3.50) and SE $M = 3.39$, $SD = 0.65$ (95% CI 3.32, 3.46). Finally, the 2- MEV scored with PRE $M = 3.90$, $SD = 0.60$ (95% CI 3.83, 3.96), UTL $M = 2.04$, $SD = 0.56$ (95% CI 1.97, 2.10) and APR $M = 3.38$, $SD = 0.74$ (95% CI 3.30, 3.46) (Fig. 2).

3.1.1. The Technology-Questionnaire (TQ)

The principal component analysis (PCA), using Varimax rotation yielded a two-factor solution tagged "interest in technology" (INT) and "social aspects of technology" (SOC) (Table 2).

3.1.2. Science Motivation (SMOT)

a) Confirmation of the structure. We received a three-factor solution after principal component analysis (PCA) with oblimin rotation (Table 3), showing three factors as delineated by Glynn *et al.* [34] “self--Determination” (SD), “self-Efficacy” (SE) and “intrinsic-Motivation” (IM).

We identified significant correlations between intrinsic motivation (IM) and the knowledge pre-test (Table 4). No further correlations appeared.

3.1.2. The Two Major Environmental Value model (2-MEV) with Appreciation and knowledge acquisition

a) Confirmation of the structure. As expected, principal component analysis (PCA) with oblimin rotation confirmed the strong structure of the Two Major Environmental Value model (2-MEV) as delineated in several studies [9,12,30,61,62] (Table 5 and Table 6).

b) Knowledge acquisition about waste management. We identified significant Pearson correlations between the subscales of the 2-MEV preservation (PRE) and utilization (UTL) and the pre-post- and the retention-test of knowledge acquisition. In detail, we discovered positive correlations between PRE and T0 (r = 0.219 $p \leq 0.001$), PRE and T1 (r = 0.138, $p \leq 0.05$) as well as PRE and T2 (r = 0.551, $p \leq 0.001$). Negative correlations were observed between UTL and T0 (r = −0.357 ≤ 0.001), UTL and T1 (r = −0.328, $p \leq 0.001$), UTL and T2 (r = -0.341, $p \leq 0.001$). No significant correlations were found between the three testing times and appreciation (APR) (Fig. 3).

3.5. Relationship between SMOT and MEV

The Pearson correlation coefficients of the environmental preferences with its subscales (PRE, UTL, APR) and the science motivation subscales (IM, SD, SE) are detailed in (Fig. 4).

We identified positive correlations between PRE and APR ($r = 0.242$

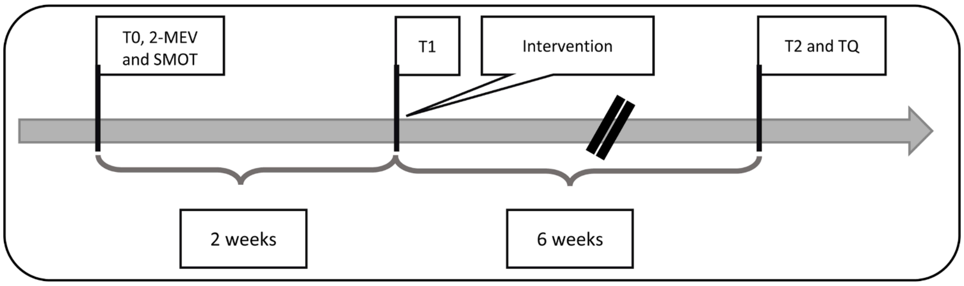

Fig. 1. Schedule of the questionnaire implementation.

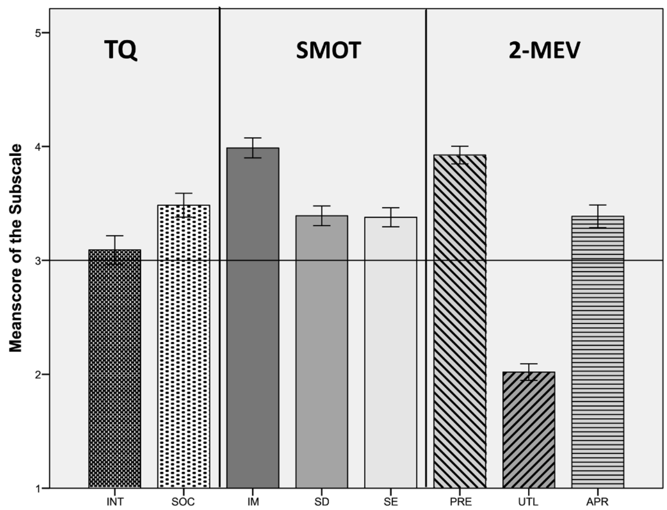

Fig. 2. Scores of the short Technology Questionnaire (TQ) with "social aspects of technology" (SOC) and "interest in technology" (INT), of Science Motivation (SMOT) with "intrinsic-motivation" (IM), "self-determination" (SD) and "self-efficacy"(SE) as well the environmental values "preservation" (PRE), "utilization" (UTL) of the Two Major Environmental Value model (2-MEV) and "appreciation" (APR). Bars are 95% confidence intervals.

Table 2
KMO-Criteria, Bartlett test and Cornbach's alpha of deployed questionaires Technology-questionaire (TQ), Science Motivation Questionnaire (SMOT) in combination with Appreciation and the Two Major Environmental Value (2-MEV) scale.

	TQ	*SMOT*	*2-MEV*
Kaiser-Meyer-Olkin	.79	.85	.74
Bartlett test	.001	.001	.001
Cronbach's alpha	.86	.84	.55

Table 3
Loading patterns of the technology questionnaire with "social aspects of technology" (SOC) and "interest in technology" (INT) (factor loadings under 0.3 were cut off).

Items	INT	SOC
I would like a career in technology later on.	.875	
I like to read books and magazines about technology.	.788	
I would like to join a hobby club about technology.	.722	
I am interested in technology.	.718	
I would like to learn more about technology.	.653	
Technology makes the world a better place to live in.		.828
Interventions in technology are doing more good than harm.		.820
Technology has brought more good things than bad things.		.748
It is worth spending money on technology.		.708
Technology is needed by everybody		.619

Table 4
Loading pattern of the science motivation questionnaire with "self-Determination" (SD), "self-Efficacy" (SE) and "intrinsic-Motivation" (IM) (factor loadings under 0.3 were cut off).

Items	SD	SE	IM
I spend a lot of time learning science	.770		
I study hard to learn science	.761		
I prepare well for science tests and abs	.710		
I put enough effort into learning science	.438		
I believe I can earn a grade of "A'' in science		.809	
I believe I can master science knowledge and skills		.793	
I am confident I will do well on science tests		.680	
I am confident I will do well on science labs and projects		.519	
The science I learn is relevant to my life			.795
Learning science is interesting			.651
I am curious about discoveries in science	.414		.612
Learning science makes my life more meaningful			.607

Table 5
Pearson correlation and p-Value of SMOT and knowledge acquisition about waste management.

		SD	*SE*	*IM*
Knowledge T0	*R*	.059	.067	.158
	P	n.s.	n.s.	**≤ 0.01**
Knowledge T1	*R*	.014	.012	.019
	P	n.s.	n.s.	n.s.
Knowledge T2	*R*	.038	-.027	.077
	P	n.s.	n.s.	n.s.

$p < 0.001$), INT and SOC ($r = 0.466$, $p < 0.001$) as well as IM and SD ($r = 0.551$, $p \leq 0.001$) and between SD and SE ($r = 0.432$, $p \leq 0.001$). Further positve correlations occurred between PRE and IM ($r = 0.291$, $p \leq 0.001$), PRE and SD ($r = 0.205$, $p \leq 0.001$), PRE and SE ($r = 0.175$, $p \leq 0.01$), as well as between APR and IM ($r = 0.386$, $p \leq 0.001$), APR and SD ($r = 0.329$, $p \leq 0.001$) and APR and SE ($r = 0.297$, $p \leq 0.001$). There were positive correlation between IM and INT ($r = 0.128$, $p \leq 0.03$) and SE and SOC ($r = 0.195$ $p \leq 0.001$).

Negative correlations were observed between UTL and PRE ($r = -0.290$ $p < 0.001$, UTL and IM ($r = -0.255$, $p \leq 0.001$), UTL and SD ($r = -0.165$, $p < 0.05$), UTL an SE ($r =$ -0.192, $p \leq 0.001$)) as well as SOC and APR ($r = -0.195$, $p < 0.01$).

3.2. Gender differences

We discovered significant differences between female and male students in the subscales of the Technology Questionnaire, in APR in combination with the 2-MEV, and for the subscale self-efficiacy of the science motivation questionnaire (Fig. 5).

For the subscales INT, SOC, APR and SE, the Levene-test was not significant so the values of the *t*-test were reported.

The *t*-test produced significant differences between male and female students in the subscales:

Table 6
Loading pattern of the Two Major Environmental Value model (2-MEV) with “preservation” (PRE), “utilization” (UTL), and additionally “appreciation of nature” (APR) (factor loadings below 0.3 are excluded).

Items	APR	PRE	UTL
I consciously watch or listen to birds	.774		
I take time to consciously smell flowers	.761		
I take time to watch the clouds pass by	.712		
I deliberately take time to watch stars at night	.710		
I personally take care of plants	.622		
I enjoy gardening	.595		
Listening to the sounds of nature makes me relax	.549		
People worry too much about pollution.		−.647	
Humans don’t have the right to change nature as they see fit.		.554	
Dirty industrial smoke from chimneys makes me angry.		.515	
Humankind will die out if we don’t live in tune with nature.		.461	
Not only plants and animals of economic importance need to be protected.		.438	
We do not need to set aside areas to protect endangered species.		−.426	
Human beings are not more important than other creatures.		.389	
We must build more roads so people can travel to the countryside.			.663
We need to clear forests in order to grow crops			.585
Our planet has unlimited resources.			.570
Nature is always able to restore itself.			.557
The quiet nature outdoors makes me anxious.			.376

- INT: female students (N =193, M = 2,92, SD = 0.94) and male students (N = 83, M = 3.38 SD = 0.87) (95% CI (-0.70, -0.22), $t(277)$ = -3.81, $p < 0.001$).
- SOC: female students (N = 193, M = 3.30, SD = 0.77) and male students (N = 83, M = 3.82, SD = 0.82) (95% CI (-0.72, -0.33), t (282) = -5.19, $p < 0.05$)
- APR: female students (N = 193, M = 3.45, SD = 0.76) and male students (N =83, M = 3.25, SD = 0.69) (95% CI (-0.24, -0.38), t (307) = 2.24, $p < 0.001$)
- SE: female students (N = 193, M = 3.33 SD = 0.64) and male students (N = 83 M =3.53, SD = 0.66) (95% CI (−0.35,–0.05), t (315= −2.56, $p < 0.05$).

4. Discussion

Individual science motivation, environmental values, preferences in technology of 5th graders shifted due to participation in our inquiry-based module, independent of learning environments. We subsequently discuss the role of all variables in detail.

4.1. *How preferences in technology matter*

As expected, we obtained a two-factor solution with reasonable factor loadings for “social aspects of technology” and “interest in technology” (Table 2). Similarities between factor patterns of 5th grader an freshmen, indicate that these two variables are independent of age [12]. Only the item "Technology is needed by everyone" is rated higher among freshmen [12,14]. High factor loadings for both scales, however, confirm the scales’ validity in different age groups. Positive correlations between INT and SOC indicate that individual interest in technology is linked to acceptance of social implications of technology.

Stereotypical gender differences could be observed for INT and SOC, although women are increasingly well represented in the MINT subjects. Our results show that boys are more interested in technology and its

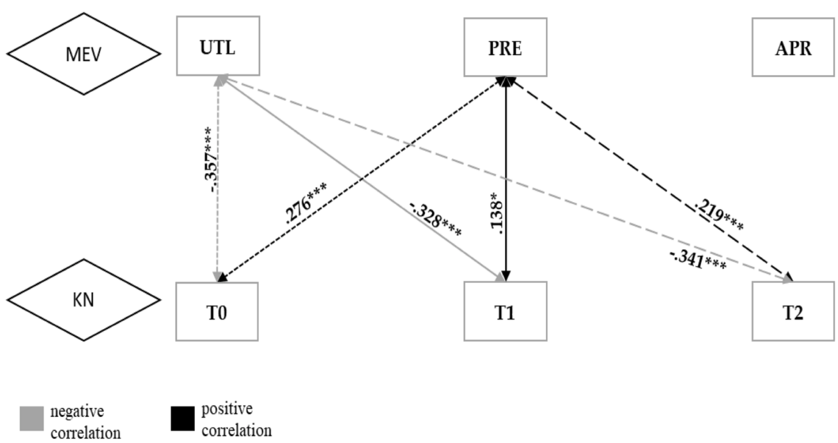

Fig. 3. Pearson correlation of the 2-MEV and knowledge acquisition about waste management, p- values indicated by asterisks (*** $p \leq 0.001$, *≤ 0.05)

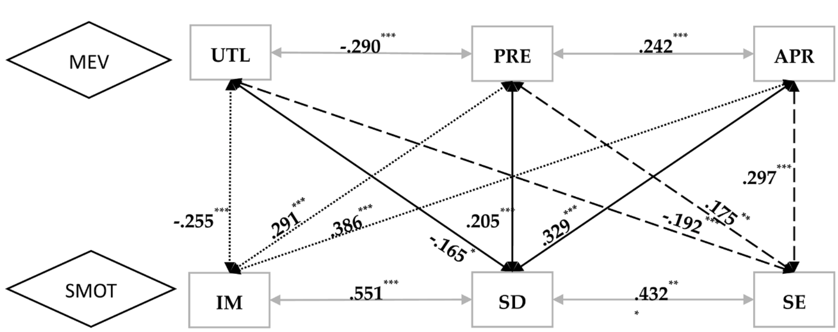

Fig. 4. Pearson correlations between science motivation with “intrinsic-Motivation” (IM), “self-Determination” (SD) and “self-Efficacy”(SE) and environmental values with “preservation” PRE, “utilization” UTL combined with “appreciation of nature” (APR). p-Values indicate a significance-level (*** $p \leq 0.001$, ** $p \leq 0.01$) (we displayed only significant correlations).

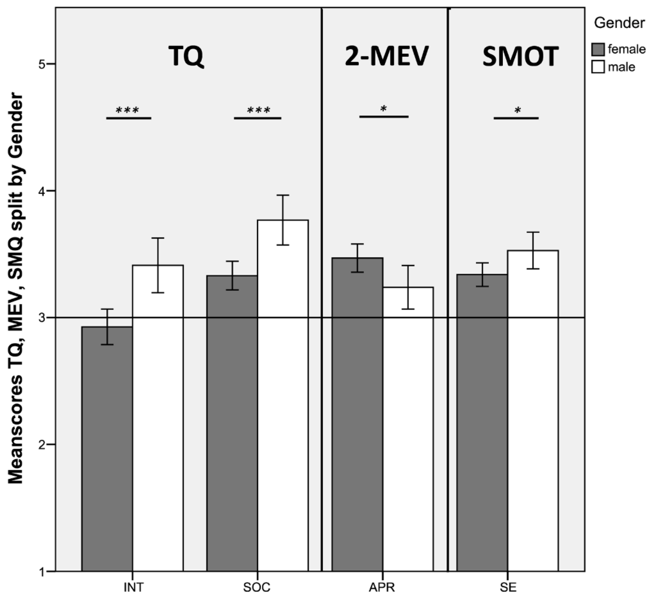

Fig. 5. Scores of the short Technology Questionnaire (sTQ) with "social aspects of technology" (SOC) and "Interest in Technology" (INT), the Two Major Environmental Value model (2-MEV) with "Appreciation of Nature" (APR) and the science motivation questionnaire with "Self-Efficiacy" (SE) split by gender. Bars are 95% confidence intervals. The *p*-Value indicates significance-level. (*** $p \leq 0.001$, * $p \leq 0.05$)

social implications than girls, confirming findings by Marth and Bogner [14]. This seems to extend into adolescence, which is why educational programs should counteract this trend and provide gender-neutral education [63]. The gender gap is first recorded in early childhood and further evolves in three critical developmental processes [51]: first in the transition from childhood to adulthood, second in middle adulthood, and third in adolescent adulthood. In these critical phases, children are particularly vulnerable to social stereotypes mirrored in views and behaviors of parents [64]. Also peer groups could have a long-lasting effect on the formation of gender differences [65]. Despite all these possible influences, neither literature nor our studies could determine a specific source for gender differences and why women are still underrepresented in STEM subjects [51].

Unlike Marth & Bogner [31], no strong relationship between individual environmental attitudes and knowledge acquisition appeared. This discrepancy may originate in our module's emphasis on technology relevance. Also age group differences could play a role, since 5th graders may not yet have the mental capacities to connect abstract technological properties with recycling processes and are generally regarded as mentally and physically less mature [66]. Our findings could, however, significantly contribute to tackling difficulties in understanding technological problems how they could contribute to solutions in another context.

4.2. How science motivation matters

Although the measuring instrument was developed for university students, it can be applied to student groups irrespective of age. This is in line with Schmid and Bogner [39], who implemented the scale with 10th graders. The instrument is also available in different versions, adapted to the countries' respective language and specific subjects without forfeiting reliability [67–69]. As expected, the extracted three factors were positively correlated, showing that intrinsically motivated students increased their self-determination and self-efficacy, which in turn influences intrinsic motivation (Figure 4). This outcome is, however, dependent on age-group concerned since person experiences and interests come with age and can act as motivational factors along self-determination and independent learning [70,71].

We could observe significant gender differences for self-efficacy, wherein boys scored significantly higher than girls, which is in line with previous studies [9,34,38]. This could be due to successful male role models in science careers who boys try to imitate [9,72]. The assumption is rooted in the social learning theory [73] and describes how the learning success of a potential role model impacts faith in individually perceived efficiency. Also, the support and recognition of parents regarding academic achievements could influence the development of stereotypes. That is, girls are often confronted with doubts of their parents, when they pursue science instead of stereotypically female subjects [74]. Thus, individual self-efficacy is strongly influenced by role models and outdated social stereotypes and should be tackled by educational initiatives especially in regular classes. Thereby, teachers also contribute to the formation of different self-concepts. Studies have shown that male teachers or scientists foster the scientific concept of self-competence in boys but not to the same extend in girls [75].

In contrast to previous findings [14], only a connection between knowledge pre-test and intrinsic motivation appeared, but none with self-determination and self-efficacy as further components of science motivation. Since intrinsic motivation also depends on meeting own expectations, it is important that students are provided with their personal sense of achievement. Personal attitudes, many of which are tied to standards of morale, could thus also drive intrinsic motivation. Our module about sustainable waste management especially addressed attitudes based on moral concepts, which is why the discovered connection between the two factors is in line with literature. Students, thereby, also acknowledge the relevance of sustainable resource management and waste avoidance, leading to respectable learning outcomes. This newly gained awareness may also trigger and retain motivation [76–78].

4.3. How environmental attitude-sets matter

Consistent with previous studies, the combination of APR and 2-MEV scale in its shortened version does not impair overall validity [12,30]. This is particularly advantageous, since it increases the usability of this scale for younger students. All items received factor loading patterns as expected (Table 5), confirming other studies [28]. That is, utilizers tend to exploit nature whereas preservers are prone to protect nature (Fig. 4) with appreciation being closely tied to preservation [9] it is evident that people who admire and enjoy nature desire to protect it. Two items ("People worry too much about pollution" / "We do not need to set aside areas to protect endangered species"), originally developed as UTL items, showed negative loadings in PRE, which, however, does not impair the overall structure. Reversing from positive to negative would only allocate an item to the other pole of the model [28].

Gender did not produce any differences in PRE and UTL but in APR, which is consistent with previous studies [12,21,22,79]. Results, however, differ dependent on age group, social status, and country [80] although there is no direct comparability due to different applied measures. Overall, female students display heightened altruistic behavior, caring and taking responsibility for others or the environment [79,80] whereas male students usually tend to exploit nature, favor anthropocentric approaches, and strive for competition. This is often accompanies by high scores in UTL [80], which we could not confirm in our study this might be possibly reasoned in the youth of our students.

Salient gender differences in APR and missing ones in PRE may be connected to the stepwise development of environmental awareness with increasing age and education. In addition, APR measures only appreciation of nature while our teaching module involves other dimensions of nature in combination with technologies as well as economic and ecologic considerations. This may also explain our positive correlations between PRE and the pre-, post- and retention results. That is, preservers know more about behaving environmentally friendly and obtain better knowledge pre-test results. We obtained opposite results regarding correlations and knowledge pre-test results UTL, indicates that exploitation preferences are connected with a lack of knowledge.

4.4. How Science motivation relates to environmental attitude-sets

Previous studies reported a connection between science motivation and individual environmental attitudes [9]. Individual predispositions to preserve and admire nature also influence the motivation to obtain useful scientific knowledge about nature. In this context, also intrinsic motivation and self-determination play an important role, since self-determination also affects self-efficacy. That is, students who are interested in environmental topics, such as sustainable waste management and waste reduction, are prone to acquire more scientific knowledge about their personal area of interest, leading to better learning results [38,57]. This may impact extrinsic and intrinsic motivation on various levels [70,81]. Of course, other factors, such as extrinsic incentives via grading, may also influence performance but were not considered in our study. For classroom teaching, the overall learning is that students when committed to protect the environment are also motivated to increase their scientific knowhow. Students who aspire to protect the environment, moreover, have a positive self-perception and are driven to solve the problem in teamwork with peers or alone [82–84].Thus, combining known biological procedures with novel technologies is appealing to previously unmotivated students and fosters environmental education.

4.5. Limitations of the study

Our sample size may have produced a possible limitation as well as the chosen age group. Studies with 5th graders provide less detailed information and impair musing about more complex reasons for certain behaviors. Moreover, apart from our assessed factors, also social skills or morale could play an important role but were not subject of the present study. Moreover, for more rigorous statements regarding gender differences and their origin in various academic contexts, a long-term study with different age groups would help. Additionally, a differentiation in urban and rural students may raise further insight. Due to GDPR compliance, we refrained from including socio-biographical parameters to assess their influence on our assessed factors.

5. Conclusion

Our described waste management module positively influenced both, learning success and individual environmental attitudes. In addition, clear gender differences appeared showing girls as less enthusiastic about technology and willing to work in science, but with a good tendency for to appreciate the environment.

For the school curriculum, educational initiatives that address environmental and technological aspects must be integrated into regular science lesson planning. Combining educational initiatives with modern technologies and the environment could even help bridge the detected gender gap by supporting both male and female students in their enthusiasm for one or both fields. In the future, the focus of further studies should be on where and when gender stereotypes emerge. For identifying the necessary adjusting screws knowledge about developments of gender stereotypes in childhood would help.

The background monitoring of a person's environmental attitude and her/his science motivation shows the more a person is inclined towards environmental protection, the more likely he or she will build up long-term knowledge through an educational module. The combination of these results points the addressing environmental attitudes and science motivation as a key for promoting long-term knowledge in science. However, the long-term effects of such educational modules on society and sustainable behavior remain unclear. Integration of environmental and technical issues into education as early as possible helps to void developing gender stereotypes, as young people are still forming their opinions and are open to new things. In consequence, out-of-school approaches that raise awareness of conservation can further enhance sustainability and enable scientific citizenship in the adulthood.

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Declaration of Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Anhang

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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).

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(§ 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