Sustainable Futures 3 (2021) 100054

Contents lists available at ScienceDirect

Sustainable Futures

journal homepage: www.sciencedirect.com/journal/sustainable-futures

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

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ARTICLE INFO

Keywords:
2-MEV model
Science motivation
Technology
Knowledge acquisition
Gender
Science education
Waste

ABSTRACT

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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https://doi.org/10.1016/j.sftr.2021.100054
Received 15 March 2021; Received in revised form 4 June 2021; Accepted 11 July 2021
Available online 13 July 2021
2666-1888/

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 ($r = -0.357 \leq 0.001$), 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 ($r = 0.242$

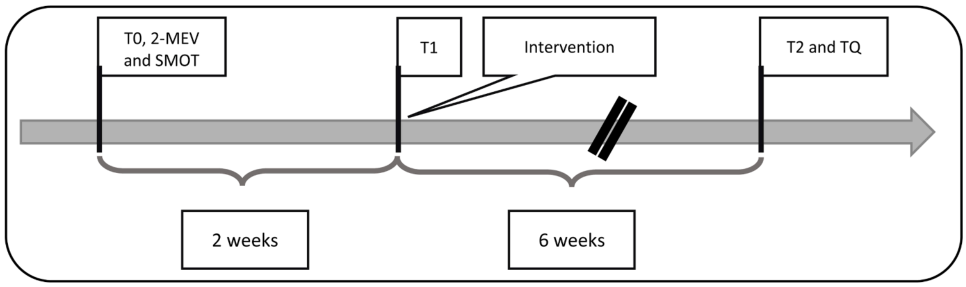

Fig. 1. Schedule of the questionnaire implementation.

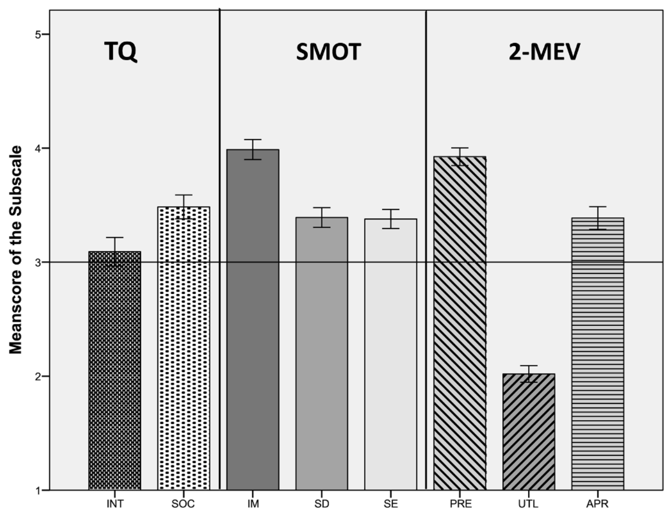

Fig. 2. Scores of the short Technology Questionnaire (TQ) with "social aspects of technology" (SOC) and "interest in technology" (INT), of Science Motivation (SMOT) with "intrinsic-motivation" (IM), "self-determination" (SD) and "self-efficacy"(SE) as well the environmental values "preservation" (PRE), "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

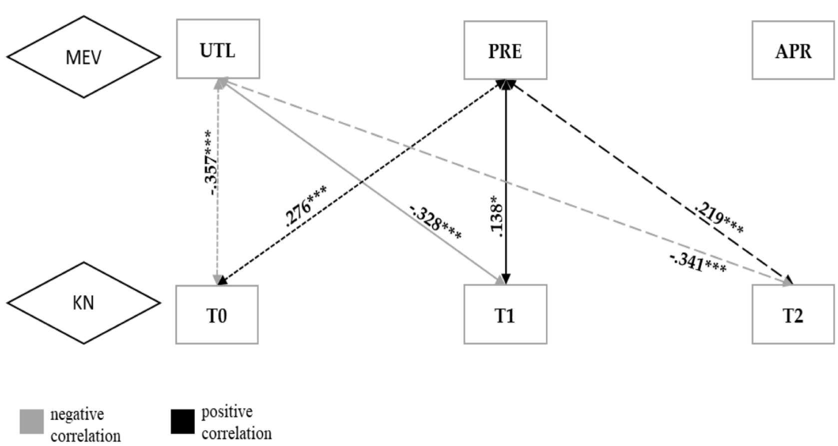

Fig. 3. Pearson correlation of the 2-MEV and knowledge acquisition about waste management, p- values indicated by asterisks (*** $p \leq 0.001$, *≤ 0.05)

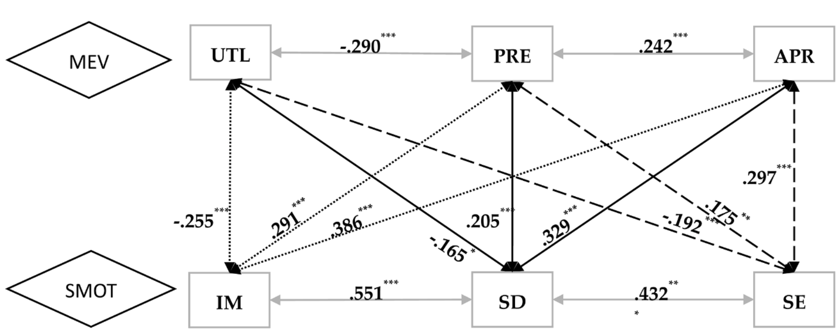

Fig. 4. Pearson correlations between science motivation with “intrinsic-Motivation” (IM), “self-Determination” (SD) and “self-Efficacy”(SE) and environmental values with “preservation” PRE, “utilization” UTL combined with “appreciation of nature” (APR). p-Values indicate a significance-level (*** $p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

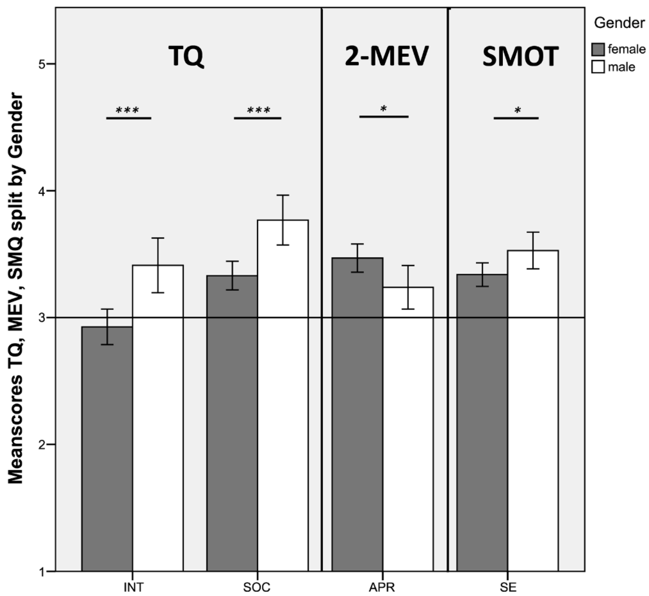

Fig. 5. Scores of the short Technology Questionnaire (sTQ) with "social aspects of technology" (SOC) and "Interest in Technology" (INT), the Two Major Environmental Value model (2-MEV) with "Appreciation of Nature" (APR) and the science motivation questionnaire with "Self-Efficiacy" (SE) split by gender. 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 modulés 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.

Funding

This research was funded by the German Federal Ministry of Education and Research (BMBF) within the programs' Qualitätsoffensive Lehrerbildung' (under Grant Agreement No. 01JA160), the horizon 2020 project OSOS (European Union Grant Agreement, [No.741572]) and also the University of Bayreuth granted financial support within the scope of the German Research Foundation (DFG) and the University of Bayreuth's Open Access Publishing [No. LA 2159/8-6]. The funders had no role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results. This article reflects only the authors' views. The funders are not liable for any use that might be made of the information contained herein.

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:

Acknowledgments

We appreciate the support of the students and the teachers. The Bavarian Ministry of Education had approved the empirical design which allowed data collection in schools (KMS: IV.8-BO5106/171/9).

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