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Virtual Reality Nature Experiences Involving Wolves on YouTube: Presence, Emotions, and Attitudes in Immersive and Nonimmersive Settings

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Abstract: As some nature experiences, such as viewing wild animals, may be difficult to implement in science education, immersive virtual reality (VR) technologies have become a promising tool in education. However, there is limited knowledge regarding the effectiveness of nature experiences in VR. In this study, 50 German university students (M = 23.76 years, SD = 3.73 years) from diverse disciplines were randomly assigned to an immersive (head-mounted display; Oculus Quest) or a nonimmersive setting (external computer screen; desktop computer) and individually watched two 360° videos from the social media site YouTube about wolves in their natural habitat. Besides measuring participants' attitudes towards wolves, we investigated their feeling of presence in the virtual environments with the Spatial Presence Experience Scale (SPES) and the retrospective emotions of interest, joy, and fear with the Differential Affect Scale (M-DAS). The immersive head-mounted display induced higher levels of presence and interest compared to the nonimmersive external computer screen. While higher interest in the screen setting was associated with more positive attitudes towards wolves, such a correlation could not be found in the head-mounted display setting. Thus, our study found that immersive technology could induce interest in a nature experience related to the tested socio-scientific issue, even among people who did not already hold positive attitudes toward the issue. Overall, our findings suggest that 360° videos using immersive technology provide nature experiences with positive affective learning outcomes, even though the study focused on nature experiences in VR and was not an educational experience per se. As we were unable to assess the role of novelty of VR experiences, the application of VR technologies and its effects in larger teaching and learning settings needs to be evaluated in further studies.

Keywords: virtual reality; nature experiences; immersion; presence; emotions; education for sustainable development; return of the wolf

1. Introduction

The destruction of the natural environment has reached an alarming pace and is accompanied by a steady loss of biodiversity [1]. This challenge can only be solved by a change in thinking and a significant increase in our efforts to safeguard natural resources and species conservation, which are also linked to the quality of life for all people on our planet [2–4]. Therefore, the international community has undertaken groundbreaking initiatives like the 2030 Agenda, which includes 17 goals for the sustainable development of our planet, known as the Sustainable Development Goals (SDGs) [5]. While the overarching aim of the SDGs is to address global challenges that are crucial for the survival

of humanity, they also touch upon the underlying ecological, economic, and social dimensions of the respective issues [5].

To overcome these challenges, society needs to make informed and responsible decisions for sustainable action. One major approach for achieving the SDGs and to prepare citizens for making such decisions is Education for Sustainable Development (ESD) [6]. As part of a holistic education, learners require the knowledge, skills, values, and attitudes that empower them to contribute to sustainable development [7]. Therefore, ESD focuses on integrating deeper learning experiences rather than just acquiring knowledge [8].

One way to achieve the goals of ESD is to encourage personal learning experiences connected to relevant environmental issues, as it has been demonstrated that acquiring knowledge alone does not facilitate learning or change behavior [9]. Instead, individuals should be given the opportunity to actively engage with the learning content [10]. Within the context of ESD, having more direct nature experiences is one approach to actively engage learners [11].

Generally, following the theories of John Dewey, experiences can be differentiated into primary or secondary experiences [12,13]. While primary experiences represent unmediated material interactions with the physical and social world, secondary experiences are indirect and more reflective ways of experiencing the world [13]. In ESD, especially primary experiences of the natural world may be called nature experiences [11] and may include objects such as landscapes, animals, and flowers. Primary experiences of these objects may extend beyond personally relevant concerns and induce people to engage in proenvironmental behaviors [11,14,15] and are positively related to environmental attitudes [16]. However, especially in formal education, personal nature experiences may be difficult to arrange, expensive, and potentially dangerous. Therefore, several recent research studies have proposed virtual reality (VR) learning experiences as a way to simulate reality and allow students to experience environmental issues in an emotionally engaging way beyond what is possible in classrooms [17]. The possibilities offered by immersive VR experiences are especially promising for ESD, as immersive VR affords lifelike, high-quality experiences [18,19].

At the moment, however, our understanding of how such experiences affect viewers is limited. An explorative study involving a nature documentary, for example, showed that proenvironmental attitudes can be fostered [20]. Another study found that a greater involvement in nature could be achieved using immersive VR technology [21]. However, there is scant research on implementing issues suitable for ESD in formal learning settings, such as universities. Moreover, prior studies have focused primarily on cognitive learning outcomes, which is why our study focused on affective learning outcomes. More particularly, we investigated the effects of two 360° videos on selected affective variables that may be relevant to foster proenvironmental behavior and could be applied to science learning in higher education.

2. Theoretical Background

2.1. Sustainable Development Goals in Science Education

In 2015 the United Nations (UN) General Assembly adopted the 2030 Agenda for Sustainable Development [5] with the aim to address the global challenges that are crucial for the survival of humanity [6]. At its core are 17 SDGs that lay the foundation for shaping global economic progress in accordance with social justice and within the planet's ecological limits. ESD is explicitly acknowledged in the SDGs as part of Target 4.7 [5], which aims to provide all individuals with sustainability competencies to address the challenges of each SDG [22]. Accordingly, "ESD empowers learners to take informed decisions and responsible actions for environmental integrity, economic viability and a just society, for present and future generations, while respecting cultural diversity" [22]. These competencies include the required knowledge and skills, but also values and motivations to enable proenvironmental behavior [23].

In order to achieve these competencies and for them to be applicable to education, educational initiatives aligned with the ESD goals need to address environmental issues in a manner that allows for socio-scientific decision-making [24] and includes not only cognitive but also socio-emotional and behavioral learning outcomes [8]. In research on science education, such issues are referred to as socio-scientific issues (SSIs). To accommodate the controversial nature of environmental discourse, SSIs should be based on an issue of sustainable development and fulfil specific criteria [25]. For example, the underlying debates should be based on deep premises, such as the values and attitudes of different groups, involve a substantial number of people and, lastly, it should not be possible to settle them through scientific evidence alone [25]. Taking these criteria into consideration, the example of returning wolves in Germany represents a suitable issue for learning in the context of ESD.

2.2. Returning Wolves as an Educational Topic

Wolves were once a widespread, native mammal species in several countries in central Europe, such as Germany [26]. Over the centuries, however, they were eradicated by humankind because they posed a threat to livestock and thus to agriculture [26]. Benefitting from European and national protection guidelines for the wolf and other wildlife species, wolves have been able to settle back in Germany since 2000 and are regaining some of their former habitats [27]. However, even though the proportion of people who depend on making a living on agricultural activities has fallen significantly, the return of wolves still causes conflicts [28,29]. While some environmental organizations celebrate their return as a success for the protection of biodiversity [30], for some farmers the return of an apex predator has had negative economic consequences due to livestock killings [27,31]. Besides these direct negative consequences, other socio-psychological factors affect people's perceptions and attitudes, such as values, beliefs, societal factors, and cultural norms [32].

The ecological (biodiversity), economic (cost of lost livestock), and social dimensions (conflict between farmers and conservationists) of returning wolves makes the issue quite complex and thus suitable in the context of ESD. Furthermore, it may explicitly address SDG 15, "Life on land", which aims to protect ecosystems and promote their sustainable use in order to halt biodiversity loss [5]. Finally, the issue sets a good example in biology education because the context aligns with curricular learning aims by referring to ecology, which is a traditional topic in biology education.

Besides the content-related aspect of the topic, wild animals like wolves allow for direct experiences and may provoke emotional responses. Experiential and learner-centred learning may be fruitful in ESD, for example to develop environmental awareness and skills related to managing sustainability issues [33]. However, experiential learning outcomes are sometimes difficult to incorporate in science education because they can realistically be achieved only with visits to zoos or science centers. The use of immersive VR, which allows for high-quality experiences that have been found to be similar to real-world experiences, may offer an alternative to these visits [18,19,34].

2.3. Immersive Virtual Reality as an Option in Education for Sustainable Development

While VR generally refers to all computer-mediated environments that aim to simulate reality [17], it also includes the interface in which users are able to interact with the artificially created realities [35]. Such digital realities were found to be beneficial for science learning in prior studies, for example in the topic of anatomy [36], although some studies showed positive effects of immersive teachnologies for affective, but not cognitive learning outcomes [37]. Regarding technological implementation, prior research used the level of immersion as a key element to differentiate among specific applications of VR [38]. The level of immersion depends on the quality of the system's technology and can therefore be regarded as an objective measure of vividness and interactivity while shutting out the physical reality [39]. Display equipment with a high level of immersion is characterized by the congruence of real actions and actions perceived in the artificial space [17,34].

The most effective way to achieve high levels of immersion is through the use of a head-mounted display (HMD) that covers the user's eyes, thus isolating them from the external world [40]. It separately

delivers 2D computer-generated images to each eye in order to create a realistic perspective for the viewer. In combination with the continually captured position of the user's head and other channels of human perception, such as audio or haptic feedback, the HMD creates the illusion that the user is located in a three-dimensional space and can explore that space [17,35]. When an HMD device may not be available, the possibility of free exploration of the digital environment can also be achieved in a nonimmersive VR setting in which the HMD is substituted by an external screen, for example [35].

Whereas fully immersive VR is characterized by a high level of interactivity by which the user is able to move within the environment and interact with objects, 360° videos are limited to a specific point of view from which the user can turn and look in all directions [17,41]. Due to the limited interactivity of 360° videos, there are contradictory views on whether they qualify as VR [17]. Slater and Sanchez-Vives [17] argued that 360° videos cannot be excluded as VR by definition. Instead, 360° videos capture a real environment and can then be manipulated using computer graphics to provide an interactive rendering of the same space. Compared to fully immersive VR, 360° videos have low costs and good accessibility [42]. The video platform YouTube, for example, offers a way to easily access 360° videos. Not only are users provided with a variety of different scenarios, but the videos are also free of charge.

Several studies have indicated the persuasive potential of immersive media, as their rich sensory impressions are perceived as unmediated [20]. The regions of the brain that are activated when accessing experiences that were created in VR are similar to those that are activated when accessing experiences from real life, which is why immersive VR experiences are remembered in similar ways as real experiences [18,19]. Interestingly, researchers were able to transfer this realness to relevant learning scenarios about environmental issues, suggesting that experiences in immersive VR may be an effective tool to promote involvement in environmental issues [20,21,43,44].

2.4. Aim of the Study and Hypotheses

Despite the potential of VR technologies for ESD, there is a lack of understanding of how VR may affect proenvironmental behavior and affective learning in the context of ESD. Therefore, in this study we investigated the effects of two 360° videos about wolves on selected variables that may be relevant to foster proenvironmental behavior and may be applied in science learning in higher education. As experimental variation we randomly assigned the participants to either an immersive group (HMD) or a nonimmersive group (external computer screen). Although the study was not embedded in an explicit educational experience, the selected videos may nonetheless be applied in educational settings. The following subsections further elaborate on the selected dependent variables and present the underlying hypotheses that were investigated in the study.

2.4.1. Spatial Presence

Spatial presence refers to the subjective perception of physically being in a specific environment [45,46]. It represents the extent to which an individual experiences a mediated environment as the one in which they are consciously present [39]. Wirth et al. [45] regarded presence as a two-dimensional construct characterized by the perception of being located in the mediated environment and the possibility to interact with objects in that environment. Presence arises from experiences induced by the immersive properties of the media [38,39,45]. However, presence is not limited to the experience of using sensory-rich VR technology. It can also occur when using less immersive media or text-based media with no direct sensory input [45,46]. Although technological factors are not sufficient to elicit feelings of presence, they can be considered as supporting elements [38,45].

As described above, presence gives rise to the feeling that events in the virtual environment are really happening [17]. Belief in the authenticity of an event gives it the feeling of being a real experience [18,47]. Therefore, presence is one of the prerequisites of a successful ESD experience. If VR experiences may lead to a higher level of presence, they may be suitable for creating higher-quality experiences also in formal learning contexts such as university courses.

Several studies assessing different degrees of immersion reported higher presence in more immersive VR settings than in less immersive settings. Such effects have been found in studies comparing different types of equipment: Cave Automatic Virtual Environment (CAVE) vs. HMD [47]; HMD vs. computer monitor [20,21,35,41]; and video wall vs. computer monitor [48]. Furthermore, Cummings and Bailenson [38] reported that the immersion features of the equipment are more important for presence formation than those creating a photorealistic environment. Based on theoretical considerations and empirical results reported in the literature, we therefore propose our first hypothesis:

Hypothesis 1 (H1): *Viewers who use immersive HMDs will report more intense feelings of spatial presence than viewers with nonimmersive external screens.*

2.4.2. Emotions

Emotions recently gained more attention in educational learning and were shown to have substantial influence on academic achievement [49]. Another reason for including emotions in our study was that research has found extensive evidence of a connection between emotions and proenvironmental behavior [50,51]. Especially in the context of returning wolves, research has shown that emotions toward wolves predict the acceptance of these predators [52]. Behavioral changes are necessary to overcome the ecological crisis and to promote sustainable development. Hence, we included emotions in the study.

Emotions can be defined as psycho-physiological phenomena that are perceived as emotional episodes evoked by a variety of stimuli [53,54], including real and imagined objects, situations, or persons [55]. Furthermore, emotions are of limited duration; this differentiates them from other affective psychological variables, such as attitudes [55]. Besides being episodic, emotions are often described with the help of appraisal theories. These theories assume a multidimensional concept of emotions. Starting from a certain stimulus, a mostly unconscious evaluation ("appraisal") of the situation takes place, which causes subsequent psychological action tendencies. The appraisal process also entails physiological changes which prepare motor activities that eventually transfer the emotional reaction to the external world. The subjective feeling component may be consciously experienced [53,54].

Different approaches describe emotions as either specific emotion schemas ("discrete emotions"; [56]) or general affective reactions ("dimensional emotions"; [55]). While dimensional emotions are characterized by two bipolar dimensions of valence (negative–positive) and activation (activation–deactivation), in the discrete approach specific emotions can be distinguished from one another using qualitative features [55]. Due to the fact that the latter approach allows for a more nuanced view and further differentiates between similar emotions, this study used discrete emotions to classify an emotional reaction.

As our study focused on emotions in education, we chose three of Izard's [56] basic emotions that are particularly relevant for learning: interest, joy, and fear. It has been shown that these emotions have a substantial influence on academic achievement. Interest motivates exploration and information-seeking, while joy signals pleasure and satisfaction generated from that activity [57]. In contrast to interest and joy, which contribute to academic achievement, fear inhibits cognitive performance [58]. It plays an especially significant role in the issue of returning wolves. Wolf behavior that matches the human notions of evil and danger is associated with negative feelings, especially fear [59].

Prior studies have already found evidence of the influence of presence on emotional reactions. Although there is limited research on the connection between presence and emotions in education [41,60,61], correlations between presence and emotional experiences in VR have been investigated in the field of VR exposure therapy [62–65]. Whereas the latter studies have found that fear increases with a higher level of presence, studies on emotions in an educational setting could not report analogous findings. Instead, these studies reported more positive emotions with an increased level of immersion [41,60]

and less negative emotions with an increased level of spatial presence [41]. The differences regarding the correlation of presence and fear have been explained with the use of different emotion-triggering materials in the studies. As our study was in the field of education and was not explicitly designed to elicit specific emotional reactions in selected participants, we propose the following hypotheses:

Hypothesis 2 (H2): *Viewers who use immersive HMDs will report more intense feelings of interest than viewers with nonimmersive external screens.*

Hypothesis 3 (H3): *Viewers who use immersive HMDs will report more intense feelings of joy than viewers with nonimmersive external screens.*

Hypothesis 4 (H4): *Viewers who use nonimmersive HMDs will report less intense feelings of fear than viewers with immersive external screens.*

2.4.3. Attitudes Towards Wolves

As discussed above, emotional responses vary depending on media content and technological factors. However, personal differences among individuals may also be a determining factor for media experiences [66]. To further understand individual differences in emotional responses to VR media, we incorporated relevant personality differences regarding attitudes towards the chosen topic of returning wolves.

An attitude is a positive or negative evaluation [67,68] of an object of thought, including things, people, ideas, and situations [69]. As they influence the way we feel, perceive, and act, attitudes serve to quickly classify objects and evaluate our environment [68]. While prior studies showed how general attitudes towards sustainable development may affect peoples' decision-making and behavior in environmental domains [70], within more specialized domains, such as species conservation, more specific attitudes also proved to be relevant [71].

Within the selected socio-scientific issue of returning wolves, attitudes towards wolves concentrate solely on the species and evaluate its existence. More particularly, they describe the positive or negative evaluation of wolves living in a specified area [72]. Such attitudes are seen as an important factor influencing the relationship between humans and wildlife, as they have a major impact on environmental consciousness and human behavior [71]. Thus, attitudes contribute to enhancing acceptance of species protection [73,74] and wildlife policies [75,76]. Prior studies also found that attitudes influence emotional dispositions: in a given scenario, participants with an already negative attitude towards wild animals demonstrated a more negative emotions towards wolves [76]. Therefore, we propose the following final hypothesis:

Hypothesis 5 (H5): *Viewers with positive attitudes towards wolves will report higher interest and joy, and less fear.*

3. Materials and Methods

3.1. Research Design and Sample

The study employed a randomized, controlled, between-subject design with pre- and post-tests. Participants were randomly assigned to one of the experimental groups. The study was conducted at a medium-sized university in Lower Saxony, Germany. In total, 50 university students from various disciplines participated in the study individually, with 36 of them (72%) being female and 14 (28%) male. Participants' ages ranged from 18 to 36 years (M = 23.76 years, SD = 3.73 years). Overall, 28 participants had a background in teaching (56%), eight in engeneering (16%), five in science (10%), and three in computer sciences (6%). Furthermore, two participants each studied design, management, and psychology (each 4%). While the selected university has a high proportion of students from teacher education, differences between the applicability of VR with students from different study backgrounds may be

of interest for further investigations. The sample size of 50 was set prior to any data collection and calculated with G*Power [77].

The participants, whose anonymity was assured, were informed via written and oral communication about the course, purpose, and objectives of the study and documented their consent to the data collection before filling out the pretest questionnaire in a paper-and-pencil format. After being randomly assigned to one of the groups, each participant individually watched two 360° videos about wild wolves in their natural habitat on the video platform YouTube (video 1: youtube.com/watch?v=vC8EVirfuMM; video 2: youtube.com/watch?v=rjQ5-UHQWC0; links checked on 30.04.2020). The order of these videos was randomized and both videos played automatically after each other, which was assured by assigning the videos to a playlist. The total duration of the two videos combined was 3 min and 36 s.

The participants either watched the videos on a normal external computer screen (nonimmersive group) or using an Oculus Quest HMD (immersive group). Each participant in the nonimmersive group watched the videos while seated in a chair in front of a desk on which a computer and screen had been placed. The same chair was also used for the participants in the immersive group, but it was positioned in the middle of a room so that the participants were able to freely rotate in the chair. After the videos had ended, the participants were asked to fill out the post-test questionnaire. The total duration of the procedure was less than 30 min and each participant was compensated with 5€.

The study was conducted in accordance with the relevant national guidelines and laws of the study country, the selected university, the Helsinki Declaration, and the Code of Conduct of the American Psychological Association (APA). All ethical and legal standards, such as guaranteeing the anonymity of participants and participation on a voluntary basis, were observed. At all times the participants had the opportunity to skip individual questions or the whole questionnaire, and to refuse to participate in the study. Approval by a local ethics committee was not required, as the study had no medical aspect and assessed no sensitive personal information. Finally, all participants were above 18 years and introduced to the aims of the study.

3.2. Measures

The questionnaire was structured using a pre–post-test design. The pretest comprised scales to assess sociodemographic characteristics and attitudes towards wolves. In the post-test we included scales to capture the sense of presence, emotional reactions, and attitudes towards wolves. The questionnaire was implemented in German. The English wording of all items can be found in the Appendix A.

To assess attitudes towards wolves, we selected a measure of general attitude towards wildlife from Kaczensky, Blazic, and Gossow [72] and adapted it to the animal context of the study. We therefore replaced the word 'bear' in the original scale with the word 'wolf.' Furthermore, we changed the original location in one item (Slovenia) to Germany, as this is the country where the study was conducted. The overall scale comprised six items, with the final item being reverse-coded. The translation into German was validated using backtranslation.

To measure the viewers' sense of presence, the Spatial Presence Experience Scale (SPES) by Hartmann et al. [78] was used. The scale measures two perceived dimensions: self-location and possible actions. For our study, we used a translated German version of the SPES [79]. The scale comprises eight items on a 5-point Likert scale.

To capture emotional reactions, we used the validated and modified German version of the Differential Affect Scale (M-DAS), which builds on Izard's Differential Emotion Scale [80]. It measures the quality and intensity of subjectively perceived feelings in media reception. We selected the discrete emotions of interest, joy, and fear. Each emotion was measured with three items utilizing a 5-point Likert scale with which the participants were asked how strongly they experienced each of the discrete emotions while watching the videos. The order of items for this scale was randomized.

3.3. Statistical Analysis

In order to ensure the validity of the scales, exploratory factor analyses (EFA) were carried out. The factor analyses showed meaningful factor loadings of all items on the corresponding scales (>0.40; [81]). In line with our theoretical assumptions, all scales also showed appropriate factor structures (for example eigenvalues above 1.00). Reliability was then calculated using Cronbach's alpha as a further measure of internal consistency; it showed sufficient reliability for all scales (Table 1). The strong correlation between the pre- and post-test scores for attitudes also illustrates the good measurement abilities of these scales, as this may be interpreted as retest reliability [81]. All items of each scale were merged to generate an overall index of the corresponding construct. Cases with missing values were excluded from further analysis, but no outliers were removed from the dataset.

Due to the significant deviation from normality with respect to skewness and kurtosis of some variables (see Table 1), we selected robust statistical procedures. After inspecting the intercorrelations and descriptive statistics (see Table 1), mean value comparisons using the Mann-Whitney U test were carried out in order to test whether the sense of presence (H_1) as well as the emotional reactions (H_2–H_4) differed between the immersive and nonimmersive groups. Finally, the correlation coefficient Spearman rho was used to analyze the connections between the attitudes towards wolves and the other variables (H_5). All statistical analyses were performed using IBM© SPSS© software 26. Due to the relatively small sample size of our study, we also calculated bootstrapped correlation coefficients with the built-in function in SPSS [81]. The dataset and the SPSS output for the replication of all analyses are available in the Supplemental Material of the paper. Information of the participants' study background were exluded from the dataset in order to gurantee their anonymity.

3.4. Intercorrelations and Descriptive Statistics

As shown in Table 1, most variables showed a slightly negatively skewed distribution. This concerned all variables except for presence and fear. The skewness was mainly due to relatively high values for both the attitude reported in the pretest (M = 4.48; SD = 0.92; Mdn = 4.67) and the post-test (M = 4.57; SD = 1.01; Mdn = 4.83). Also, the emotional reactions of joy (M = 3.15; SD = 1.14; Mdn = 3.00) and especially interest (M = 4.24; SD = 0.61; Mdn = 4.33) showed high values. Only presence (M = 2.98; SD = 0.86; Mdn = 3.00) and fear (M = 2.17; SD = 0.87; Mdn = 2.00) skewed positively.

Concerning the correlations of the whole sample described in Table 1, there was a significant negative correlation between group and presence with a large effect size (r = −0.55, $p < 0.001$) and group and interest with a medium effect size (r = −0.32, $p < 0.05$).

We were not able to detect significant correlations between the demographic variables of age and gender with any of the other variables. An explicit investigation of gender differences for the variable of presence may nonetheless be interesting for further studies, as gender showed a small correlation with presence, although it should be noted that the correlation was not significant due to our small sample size (r = –0.21, $p > 0.05$). Female participants reported a higher presence, a result that contrasted prior studies, which showed a larger presence for male users of VR [82]. This result may be explainable either by the context of wolves or nature experiences in general.

Table 1. Bivariate Spearman rho correlations with bootstrapped 95% confidence interval (95% CI) in upper half and descriptive statistics of the study variables (n = 50 university students).

	1	2	3	4	5	6	7	8	9
1. Group	-	−0.34, 0.21	−0.19, 0.36	−0.33, 0.27	−0.32, 0.25	−0.73,−0.35	−0.57,−0.03	−0.35, 0.24	−0.41, 0.16
2. Gender	−0.08	-	−0.12, 0.44	−0.20, 0.41	−0.27, 0.32	−0.47, 0.06	−0.38, 0.16	−0.31, 0.21	−0.25, 0.29
3. Age	0.10	0.17	-	−0.24, 0.37	−0.31, 0.31	−0.35, 0.23	−0.27, 0.36	−0.39, 0.19	−0.29, 0.24
4. Attitudes Pre	−0.02	0.10	0.08	-	0.87, 0.97	−0.36, 0.22	−0.04, 0.56	0.07, 0.63	−0.60,−0.04
5. Attitudes Post	−0.03	0.02	0.01	0.94 ***	-	−0.29, 0.25	0.06, 0.61	0.13, 0.65	−0.63,−0.10
6. Presence	−0.55 ***	−0.21	−0.07	−0.10	−0.03	-	0.19, 0.62	−0.22, 0.42	−0.13, 0.46
7. Interest	−0.32 *	−0.13	0.04	0.27	0.37 **	0.42 **	-	0.06, 0.65	−0.39, 0.17
8. Joy	−0.05	−0.06	−0.12	0.37 **	0.42 **	0.10	0.38 **	-	−0.65,−0.20
9. Fear	−0.13	0.02	−0.03	−0.34 *	−0.38 **	0.18	−0.11	−0.45 **	-
Items	-	-	-	6	6	8	3	3	3
Mean	-	-	23.76	4.48	4.57	2.98	4.24	3.15	2.17
Median	-	-	23	4.67	4.83	3.00	4.33	3.00	2.00
SD	-	-	3.73	0.92	1.01	0.86	0.61	1.14	0.87
Skewness	-	-	1.53 **	−0.58	−1.08 **	0.11	−0.66 *	−0.06	0.59
Kurtosis	-	-	3.09 **	0.06	1.76 **	−0.46	−0.18	−0.78	−0.16
Cronbach's α	-	-	-	0.89	0.90	0.89	0.79	0.95	0.80

Note. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$. Group was coded as (1) HMD and (2) computer screen; gender was coded as (1) female and (2) male. Significant skewness and kurtosis indicate a significant deviation from normality [81].

In addition, presence correlated significantly positively with interest with a medium effect size (r = 0.42; *p* < 0.01). Regarding the attitudes reported in the pretest, there was a significant positive correlation with joy with a medium effect size (r = 0.37, *p* < 0.01). Also, the post-test attitudes correlated significantly positively with joy (r = 0.42, *p* < 0.01) as well as interest (r = 0.37, *p* < 0.01) with a medium effect size. Furthermore, there was a significant negative correlation between both the attitude reports in the pretest (r = −0.34, *p* < 0.05) and post-test (r = −0.38, *p* < 0.01) and the emotion of fear with a medium effect size. Furthermore, there was a strong correlation between the attitudes in the pre- and the post-test (r = 0.94; *p* < 0.001). Besides indicating that there were only small changes in the attitudes due to the intervention, this may also be interpreted as retest reliability, as we found similar results at both times. Due to these meaningful correlations between the variables, we continued with the further analysis.

4. Results

4.1. Group Differences

To test the first four hypotheses, we conducted Mann-Whitney U tests to determine whether there were differences in the feelings of presence and emotional reactions between participants who watched the immersive video with an HMD and the nonimmersive video on an external computer screen. As displayed in Table 2, we found significant differences for the dependent variables of presence and interest, but not for the other variables.

Table 2. Descriptive statistics and results of the mean value comparison of the study variables for the head-mounted display (HMD) and screen groups.

Dependent Variable	HMD (n = 25)			Computer Screen (n = 25)			Mann–Whitney Test	
	M	**SD**	**Mdn**	**M**	**SD**	**Mdn**	**Z**	**D**
Attitudes Pre	4.50	0.86	4.67	4.46	0.99	4.67	−0.039	0.01
Attitudes Post	4.63	0.86	4.83	4.50	1.14	4.67	−0.097	0.03
Presence	3.46	0.75	3.50	2.51	0.69	2.50	−3.954	1.35 ***
Interest	4.43	0.53	4.67	4.06	0.63	4.00	−2.197	0.66 *
Joy	3.19	1.08	3.33	3.11	1.22	3.00	−0.480	0.14
Fear	2.29	0.97	2.00	2.04	0.74	2.00	−0.821	0.23

Note. * = *p* < 0.05, *** = *p* < 0.00.

The largest differences were found for the variable of presence, which differed between the HMD group and the screen group with a large effect size (Z = −3.954, d = 1.35, *p* < 0.001). In comparison, the participants within the immersive HMD group showed a significantly higher interest with a medium effect size (Z = −2.197, d = 0.66, *p* < 0.05). However, there were no significant differences between the groups in the emotions of fear (Z = −0.821, d = 0.23, *p* > 0.05) and joy (Z = −0.480, d = 0.14, *p* > 0.05). Figure 1 illustrates the distributions of, and differences between, the dependent variables presence, interest, fear, and joy in the two experimental groups.
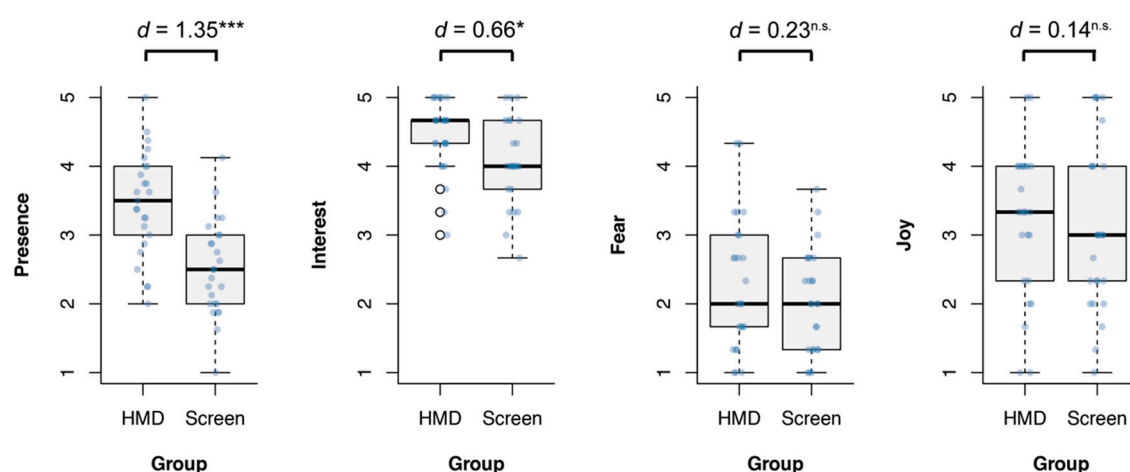
Figure 1. Mean value comparisons of the variables presence (H_1), interest (H_2), fear (H_3), and joy (H_4) for the HMD and computer screen groups. [n.s.] = not significant, * = $p < 0.05$, *** = $p < 0.00$.

Concerning attitudes reported prior to the videos (Z = 0.039, d = 0.01, $p > 0.05$) and after the videos (Z = −0.097, d = 0.03, $p > 0.05$), there was no significant difference between the groups. Using a Wilcoxon test we also tested whether there was a difference between the attitudes prior and after the videos for both groups. We found a larger effect size in the HMD group (Z = −1.929, d = 0.84, $p > 0.05$) than in the screen group (Z = −0.703, d = 0.28, $p > 0.05$), but there was no significant difference between the pre- and post-test attitudes in both groups.

4.2. Impacts of Attitudes Towards Wolves

4.2.1. Prediction of Emotions

To test the predictors of the reported emotions, we conducted regression analyses with the groups, presence, and attitudes from the post-test as predictors of interest, joy, and fear. As displayed in Table 3, presence ($\beta = 0.32$, 95% CI = [0.01,0.44], $p < 0.05$) and attitudes from the post-test ($\beta = 0.33$, 95% CI = [0.06,0.35], $p < 0.05$) were predictors of interest, while the group was not a significant predictor ($\beta = -0.11$, 95% CI = [−0.60,0.26], $p > 0.05$). This shows that attitudes are a slightly stronger predictor of interest than presence. Overall, this model predicted 23% of the variance for the reported interest (adj. $R^2 = 0.23$).

Table 3. Results from regression analyses for the reported emotions of all participants (n = 50) with standardized regression coefficients (β), standard error (SE), and bootstrapped 95% confidence interval (95% CI).

	Interest		Joy		Fear	
Predictor	**β (SE)**	**95% CI**	**β (SE)**	**95% CI**	**β (SE)**	**95% CI**
Group	−0.11 (0.18)	−0.60, 0.26	0.04 (0.36)	−0.66, 0.86	0.00 (0.28)	−0.49, 0.52
Presence	0.32 * (0.11)	0.01, 0.44	0.08 (0.21)	−0.36, 0.57	0.31 (0.16)	−0.07, 0.63
Attitudes Post	0.33 * (0.08)	0.06, 0.35	0.44 ** (0.15)	0.20, 0.75	−0.30 * (0.12)	−0.50, −0.09
Model results						
F (*df*)	5.806 ** (3)		3.696 * (3)		3.241 * (3)	
R^2	0.28		0.19		0.17	
Adj. R^2	0.23		0.14		0.12	

Note. * = $p < 0.05$, ** = $p < 0.01$.

As in the case of perceived interest, attitudes were also predictive of perceived joy ($\beta = 0.44$, 95% CI = [0.20,0.75], $p < 0.05$). The group ($\beta = 0.04$, 95% CI = [−0.66,0.86], $p > 0.05$) and presence

(β = 0.08, 95% CI = [−0.36,0.57], *p* > 0.05), however, were not found to be significant predictors of joy. The regression was able to explain 14% of the variance (adj. R^2 = 0.14).

Furthermore, attitudes were identified as a negative predictor for the reported fear (β = −0.30, 95% CI = [−0.50, −0.09], *p* < 0.05), while the group (β = 0.00, 95% CI = [−0.49,0.52], *p* > 0.05) and presence (β = 0.31, 95% CI = [−0.07,0.63], *p* > 0.05) were not significant predictors. This model predicted 12% of the variance (adj. R^2 = 0.12).

4.2.2. Correlational Differences within the Groups

Concerning the correlation differentiated by group, within the HMD group there was no significant correlation between the reported attitudes towards wolves in the pretest and the emotions of interest, joy, and fear. The attitudes reported in the post-test and fear had a significant negative correlation with a medium effect size (r = −0.46, *p* < 0.05). However, the post-test attitudes did not correlate significantly with the variables presence, interest, and joy (Table 4).

Table 4. Bivariate Spearman rho correlations between the study variables for the head-mounted display (HMD) group (n = 25) with bootstrapped 95% confidence interval (95% CI) in the upper half of the correlation matrix.

	1	2	3	4	5	6
1. Attitudes Pre	-	0.68, 0.97	−0.63, 0.25	−0.40, 0.53	−0.43, 0.41	−0.66, 0.05
2. Attitudes Post	0.89 ***	-	−0.59, 0.23	−0.30, 0.58	−0.37, 0.45	−0.74, −0.11
3. Presence	−0.21	−0.19	-	−0.27, 0.55	−0.40, 0.51	−0.28, 0.56
4. Interest	−0.07	0.17	0.17	-	−0.18, 0.66	−0.45, 0.29
5. Joy	−0.01	0.06	0.04	0.25	-	−0.69, 0.02
6. Fear	−0.32	−0.46 *	0.18	−0.09	−0.40 *	-

Note. * = *p* < 0.05, *** = *p* < 0.001.

Within the screen group, attitudes reported in the pretest were positively correlated with interest with a medium effect size (r = 0.48, *p* < 0.05). Also, joy and pretest attitudes had a positive correlation with a large effect size (r = 0.68, *p* < 0.001). Regarding the attitudes reported in the post-test, there was a significant positive correlation with interest (r = 0.54, p < 0.01) as well as joy (r = 0.72, *p* < 0.001) with a large effect size. There was no significant correlation between attitudes and fear (r = −0.32, *p* > 0.05) (Table 5).

Table 5. Bivariate Spearman rho correlations between the study variables for the screen group (n = 25) with bootstrapped correlation coefficients in the upper half of the correlation matrix.

	1	2	3	4	5	6
1. Attitudes Pre	-	0.86, 0.99	−0.36, 0.42	0.10, 0.76	0.33, 0.87	−0.76, 0.16
2. Attitudes Post	0.96 ***	-	−0.28, 0.49	0.17, 0.81	0.43, 0.89	−0.76, 0.13
3. Presence	0.03	0.10	-	−0.15, 0.67	−0.36, 0.46	−0.33, 0.56
4. Interest	0.48 *	0.54 **	0.29	-	−0.09, 0.81	−0.67, 0.15
5. Joy	0.68 ***	0.72 ***	0.05	0.40	-	−0.72, −0.09
6. Fear	−0.32	−0.35	0.16	−0.29	−0.52 **	-

Note. * = *p* < 0.05, ** = *p* < 0.01, *** = *p* < 0.001.

5. Discussion

5.1. Being Present with Wolves

Consistent with hypothesis H_1, the results showed a significant influence of the immersive qualities of the head-mounted display on the participants' sense of presence. Thus, in comparison to nonimmersive 360° videos, immersive 360° videos were able to elicit higher levels of presence. This finding is in line with prior research [20,21,35,60] and suggests that the mediated experience of

wolf contact was perceived as more real with an HMD. Interestingly, a significant difference in presence between the two groups could be identified even though the videos in our studies were very short. This may be especially relevant in formal education, as even short periods with HMDs may foster students' perception of presence, allowing such methods to be easily integrated into teaching. Even if we did not apply VR as part of an educational experience, other studies have shown how presence allows VR experiences to be felt as if they were real [45]. Therefore, we believe our findings suggest that immersive VR videos may complement field trips to zoos and science centers, for example in the preparation of such trips introducing students to specific contents of the real experiences.

We explicitly do not state that VR experiences may be able to replace real-world field trips, because even though VR may be better than just watching videos, field trips nonetheless enable unique learning experiences, for example by giving children the chance to explore freely [83]. Even though some VR apps allow a freer exploration of digital environments, they nonetheless need to be programmed and therefore anticipate specific learning pathways. However, in education this also represents an opportunity, as the prior programming may be a way of better guiding students in the learning process, which has often been mentioned as a requirement for successful discovery learning [84]. Most importantly, such videos also facilitate the opportunity to see wolves up close, which would be both difficult and dangerous in real life. Nonetheless, future research still needs to illustrate when and how such virtual nature experiences may be beneficial in formal educational settings.

Further studies are also needed to assess the role of novelty with VR experiences. Novelty was found to be one cause for interest [57], which is why the students could have experienced interest mainly because they were novices to VR. In further studies the same VR equipment could be applied using different videos in the same class over a larger time frame. This would allow researchers to evaluate if the interest may be due to the novelty of VR or the specific experiences. In the first case, the interest should systematically decline over time and the time points should explain a significant amount of variance in students' interest. In the latter case, there should be no systematic variation of interest with regard to the time points and most of the variance should be explained by variables that refer to the specific experiences.

Similar effects might have also occurred in this study regarding presence. However, given the alignment of this result with results from prior studies, we believe our results to be rather robust.

Notably, our study employed 360° videos available on YouTube. Although 360° videos inhibit interactivity due to their static camera position, by using immersive VR technology, higher levels of presence could nevertheless be detected. This illustrates how even low-threshold digital activities in social media platforms may allow life-like experiences of nature. Besides this, it needs to be considered that the videos only had a short duration of less than 5 min. Such short video clips may only allow for an incomplete picture of the livelihood of wolves in their natural habitat. Hence, it would be interesting to evaluate the results of longer videos that allow for other experiences, including, for example, the dynamics within wolf packs, the hunting behavior of wolves, or their reactions on humans. Further investigations in this direction seem promising, as we were already able to find significant results with very short video clips. Concerning YouTube as a platform, future studies could further investigate the role of such social media activities in proenvironmental motivation [85]. The lower cost and wide and simple accessibility compared to fully immersive VR environments represents a final advantage for (formal) education, as 360° videos may be easy to implement when the corresponding devices are available [42]. Yet, with the increased interactivity in fully immersive VR, presence is higher [17]. Watching a 360° video using VR technology is not the same as engaging with a fully immersive VR environment [41]. As the link between presence and learning is not yet clear [37], many questions regarding the effectiveness of VR videos remain open.

5.2. Differences between Emotional Reactions

There was a significant difference in interest (H_2) between the groups, but not for the other emotions of joy (H_3) and fear (H_4). Participants watching the 360° videos with the HMD reported

higher interest, which is in line with prior research [41]. Notably, the regressions showed that presence was a stronger predictor of interest than the group. Thus, it may be presence and not the group that influences the arousal of interest. This result suggests that the variance in interest may be based primarily on the prior finding that more immersive devices lead to more presence, due to a more direct interactivity with the digital environments [17,39,45]. The findings are in line with previous literature on media research, which stated that media in themselves do not make a difference in learning, but rather the activities that arise from the capabilities of the medium [86].

Research has shown that situational interest can be a first step in promoting learning, as it facilitates the intrinsic motivation to learn more about the content targeted in that situation [87]. Therefore, our study implies that using immersive VR technology can have a positive impact on learning. However, our research also implies that a fully immersive setting with interactivity that allows an even higher sense of presence might result in a higher level of interest. In addition to immersive equipment, the effectiveness of more interactive VR material should therefore be investigated in further research. It should be noted, however, that this effect could also be due to the first-time experience and novelty of HMDs, and that the effect may change over time [88]. This is an interesting issue that could be especially important for future research.

In contrast to other studies and our own hypothesis, there was no significant difference in joy between the groups. While Allcoat and von Mühlenen [60] as well as Rupp et al. [41] showed that greater immersion and presence led to increases in positive affect, in our study neither the group nor presence showed any significant influence on joy. We believe this result may be explained by the fact that the 360° videos in our study lacked interactivity, whereas Allcoat and von Mühlenen [60] provided the participants with a fully interactive environment. Another reason for the difference in results might be the short duration of the videos, whereas Rupp et al. [41] utilized video material twice as long. The specific context of wolves could also have affected the results, as we discuss below.

Concerning the emotion of fear, we did not find a difference between the groups. This finding is in line with prior research on emotions in education [41,60], but it contrasts with studies on exposure therapy that reported an increase in fear with more immersion [62–65]. We explain the difference in results with the choice of video material. Unlike videos in exposure therapy research, the material in our study was not chosen to elicit specific emotional reactions in selected participants. However, Allcoat and von Mühlenen [60], as well as Rupp et al. [41], also reported a positive influence of presence on negative affect, while in our study there was no connection between presence and fear. The mentioned studies used a dimensional approach, whereas we chose the discrete approach to emotions. Although fear is a part of negative affect, the difference may be due to the different approaches. To assess the general affective reactions and still have a nuanced view, future studies should assess both the dimensional and discrete approaches.

Overall, as presence and immersion did not have an effect on joy and fear and a significant difference between the groups was not found, the arousal of these emotions may be explained by variables connected to the content and visuals, as these were the same in both groups, which is also suggested by the predictive ability of attitudes towards wolves. Particular to our study compared to others, the chosen topic of returning wolves is embedded as an SSI in the context of ESD. As described earlier, within this issue there are deeply rooted values and beliefs belonging to the different groups involved [30,32,59], which might have also caused emotions in VR media usage.

5.3. Views on Wolves

In the overall sample, the attitudes towards wolves before and after the videos correlated with the emotion of joy, and post-test attitudes also correlated with interest (H_5), implying that positive attitudes towards wolves had an effect on positive emotions. In contrast, there was a negative correlation between attitudes and fear before and after the videos. Hence, more positive attitudes towards wolves resulted in less fear (H_5). The regressions further illustrate the relation between attitudes and emotions, as attitudes were the only consistent predictor of every emotion. As described above, only interest was

also significantly affected by presence. This result suggests that attitudes are more important than the feeling of presence for evoking emotions, except for interest. This shows the importance of attitudes within the appraisal process of emotional episodes.

The connections between attitudes towards wild animals and emotions have already been demonstrated by previous studies [76]. Our results show that existing attitudes influence the evocation of emotions while watching the 360° videos, even though this effect was not strong in the HMD group. Our results suggest that within the context of returning wolves, positive attitudes are decisive to elicit emotions that support positive learning outcomes. Nonetheless, the sense of presence also has a supportive effect on positive learning outcomes. The use of VR technology can therefore contribute to learning.

Interestingly, however, group-specific differences in correlations must also be considered with regard to interest. In the screen group, prior and post attitudes towards wolves showed significant correlations with interest, implying that only people with existing positive attitudes felt more interest. In contrast to our hypothesis, such effects were not found in the HMD group. Notably, these findings were not based on a difference of attitudes between the groups prior to the videos, as no difference in pretest attitudes could be found. However, our study found a difference in interest between the groups, with the HMD group experiencing significantly more interest while watching the 360° videos. Therefore, immersive VR technology may be useful to make content interesting for people who do not already have a positive attitude towards it.

Previous research has shown that emotions mediate the attitudes towards wild animals and the acceptance of lethal control, implying that positive attitudes lead to positive emotional dispositions and ultimately decrease the acceptance of lethal wildlife management [76]. In this regard, our findings are particularly interesting, as positive emotions could be elicited through the use of immersive VR technology even in the absence of pre-existing positive attitudes. Notably, concerning the difference in attitudes before and after the videos, we detected a larger difference in the HMD group than in the screen group. Due to the study's small sample size, however, this difference could not be tested as significant. The findings of our study thus cannot show whether interest can increase the acceptance of wolves or even the attitudes towards them, but this would be an interesting question for future research to investigate. Nonetheless, we were able to show that the use of HMDs is a suitable method to engage participants with the SSI of returning wolves. These and all other findings need to be considered carefully due to the rather selective sample with an overall good education and young age. Such a sample may hold more positive views about wolves than the general public, which was also illustrated by the high mean and the skewness of the attitudes towards wolves in our sample.

5.4. Limitations

There are several other limitations that need to be considered regarding the generalization and representativeness of the data. Our sample comprised students from only one university; it differs from the overall population, and it may also differ from the population of university students in Lower Saxony and Germany. Further studies should investigate how these results can be transferred to other educationally relevant samples, such as school students. Future research should therefore attempt to expand the participant base. We also recommend larger sample sizes; the small sample size in the present study made it difficult to identify significant differences and correlations with smaller effect sizes, as only effects with large and medium effect sizes could be detected as significant. One example for this may be the effect of gender on presence, for which we were unable to find a significant result due to the small sample size. In future studies, the samples should be more balanced concerning the gender ratio, as our study included a larger proportion of female participants. Nonetheless, even with this small sample size we were able to identify important effects of HMDs on the selected dependent variables.

Besides the sample, the chosen video material may also represent a limitation. First of all, we explicitly wanted to take publicly available videos that may directly be applied in the classroom. However,

these videos may not be the best choice for educating students about wolves. More particularly, the videos were rather short and therefore may only be able to give an incomplete view of the life of wolves. For further studies, the explicit application of purposefully created videos may allow for deeper insights and changes in other variables such as attitudes, which were not affected by the 360° videos in our study.

Furthermore, it must be noted that we only used self-reported questionnaires. Although these were all validated and have been effectively tested in several studies, the use of physiological measures may help to obtain a more comprehensive and objective understanding of the users' responses. This would be especially helpful for the emotional reactions, as the physiological response towards a stimulus makes up one component of an emotional episode [53,54].

Finally, our study only focused on the influence of immersive VR technology on emotions that are known to have a positive influence on relevant learning outcomes. However, other recent studies have shown a negative connection between low-immersive VR technology and cognitive learning outcomes [37,89]. So far, research has not addressed the complementary perspective of both cognitive and affective learning, especially with regard to topics that involve deeply rooted beliefs and values, as is the case with SSIs suitable for ESD. In order to make a profound statement about the effect of VR technology on learning outcomes, a comparative study with low- and high-immersive VR material that also includes the role of affective factors is needed. Such a study will hopefully lead to a better understanding of the link between affective factors and cognitive processing during learning.

6. Conclusions

Our study shows how immersive VR technology is connected to affective learning outcomes in the context of ESD. In more detail, with the use of VR technology, a difference in presence and interest could be found, leading to the result that feeling present in a virtual environment was associated with generating increased interest. Our study also identified other personality variables that influence affect in media usage. While pre-existing attitudes influence affect in nonimmersive VR technology, for immersive VR technology we found that attitudes play a smaller role in the feeling of interest. Nonetheless, our findings suggest that not only VR but also the level of presence is decisive for positive learning achievements. As presence was strongly affected by the group, our findings suggest that immersive VR technology may strengthen digital ESD due to its ability to generate higher levels of presence.

With regard to implementation in formal education, the results of our study show that immersive VR technology can be used to meet the requirements of ESD in a learner-oriented approach. Although the present study was not part of a larger educational experience such as a university seminar about the biology of wolves, the videos may nonetheless be applied in an educational setting with similar results. For example, immersive VR technology may be used in formal education to address affective learning outcomes. These results can be achieved by using readily accessible 360° videos, as well as short materials available on YouTube, which is another advantage for the implementation of VR in formal education. In this respect, VR technology has been shown to have a positive impact on learning by encouraging information-seeking and exploration. Understanding how to utilize the affective outcomes of virtual environments is a fundamental concern for learning, since research shows that initial interest can be a first step in promoting long term interest [87], and that an emotional reaction can have a significant impact on the learner's academic performance [90]. Future studies should also try to further differentiate among specific learning contents. For example, VR may be good for affectively oriented learning experiences about nature, but it may have less merit when other types of content are investigated. Furthermore, it may be interesting to investigate the suitability of 360° videos in other contexts, such as teacher education, as prior studies have shown that teacher education also needs to address affective learning outcomes such as values and emotions [91]. VR technologies may prove interesting in this regard.

Concerning the influence of immersive technologies on emotional reactions, our study shows that the use of immersive technologies has an advantage over nonimmersive technologies. Not only did the former technologies manage to evoke higher interest in general, but they also elicited interest in people without any pre-existing positive attitudes towards wolves. This is where the strength of immersive VR technologies becomes apparent. The findings show that with the use of immersive VR technology, an attitude change or a higher acceptance of wolves may be possible, as prior studies have found positive emotions to be a mediator between attitudes and acceptance of wolves [76]. Our study also found more positive attitudes in the post-test. Proenvironmental behavior could also be strengthened by triggering positive emotions [52]. It will be particularly interesting for further studies to investigate whether the evoked interest can lead to a deeper attitude change or foster proenvironmental behavior.

However, our study did not include cognitive learning achievements. Further research needs to investigate whether and how cognitive learning outcomes can be achieved. In order to achieve knowledge gains while watching immersive VR videos, text and audio commentaries were included in previous studies. These studies have so far shown contradictory results in this regard. While some studies showed less learning with an increasing sense of presence [37], other studies found a positive cognitive learning outcome with immersive VR experiences [41,44]. However, all of these studies were mostly conducted on novices to the technology. Therefore, it is necessary to conduct longitudinal studies that investigate whether long-term use of immersive VR technology leads to knowledge gains. In this context, it is also necessary for further studies to investigate the extent to which VR experiences should be integrated in teaching. Should immersive VR only serve as an experience to address affective learning, or is it also suitable to achieve cognitive learning outcomes?

Overall, especially when external circumstances make it difficult or even impossible, VR offers the possibility to provide students with life-like nature experiences. This is especially the case with the return of wolves. Students can have simulated close-up experiences with wolves and observe them from a close distance in their natural habitat, which would not be possible in reality. This may also be transferred to other SSIs in relation to ESD. Our study therefore shows that immersive VR has great potential. In that regard, the improved affordability and convenience of devices like the Oculus Quest is a further advantage. However, in future research it will be necessary to test the extent to which VR should be included in teaching to strengthen ESD in formal education. A successful implementation will hopefully lead to well-prepared future citizens who can overcome the conflicts between humans and wildlife and contribute to the achievement of the SDGs.

Appendix A

Table A1. Scales of the study and their corresponding items.

Construct	Item
Attitudes towards wolves (ATTWO)	
ATTWO01	I have a positive attitude towards the return of wolves to Germany.
ATTWO02	It is important for Germany to have a viable population of wolves.
ATTWO03	Wolves living in Germany are important, even if I never see one.
ATTWO04	Wolves are a sign of an intact nature.
ATTWO05 *	Because many wolves live in other countries, there is no need to have wolves in Germany.
Spatial Presence Experience (PRES)	
PRES01	I felt like I was actually there in the environment of the presentation.
PRES02	It seemed as though I actually took part in the action of the presentation.
PRES03	It was as though my true location had shifted into the environment of the presentation.
PRES04	I felt as though I was physically present in the environment of the presentation.
PRES05	The objects in the presentation gave me the feeling that I could do things with them.
PRES06	I had the impression that I could be active in the environment of the presentation.
PRES07	I felt like I could move around among the objects in the presentation.
PRES08	It seemed to me that I could do whatever I wanted in the environment of the presentation.
Differential Affect Scale (MDAS)	
How strongly did you experience the following feelings while watching the videos?	
Joy	
MDASJ01	Delighted
MDASJ02	Happy
MDASJ03	Joyful
Fear	
MDASF01	Scared
MDASF02	Fearful
MDASF03	Afraid
Interest	
MDASI01	Attentive
MDASI02	Concentrating
MDASI03	Alert

Note. * = Items were reversely coded for the analysis.

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