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#### Research Article

# Virtual Field Trip: A study to analyse the raising awareness of biodiversity loss through biodiversity analyses in Virtual Reality

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**Abstract:** Biodiversity loss poses a significant threat to global ecosystems, with human activities driving extinction at an increasing rate. Despite international agreements such as the Convention on Biological Diversity and the Biodiversity Strategy 2030, biodiversity continues to decline. Education about biodiversity is therefore of crucial importance, mainly as part of teacher education. This study examined the effectiveness of Virtual Field Trips (VFTs) in university-based geography teacher education to raise awareness of biodiversity loss. Therefore, two study groups, the experimental group (EG) and the control group (CG), participated in a quasi-experimental longitudinal study. The EG carried out a VFT as an intervention in which two different ecosystems in Berlin, Germany, were experienced and analysed in terms of biodiversity. With a pre-test and post-test, we examined if the VFT as an intervention affects the EG. The results show no significant differences between the groups after the intervention. However, high mean values for most of the questionnaire scales can already be found for both groups in the pre-test. Likewise, the EG showed intrinsic motivation after the intervention based on the VFT, indicating its potential in education.

**Keywords:** Virtual Reality; Virtual Field Trip; Biodiversity; Environmental Education; Higher Education, Geography Education

#### Highlights:

- Geography pre-service teachers show a high level of interest in biodiversity and a willingness to act to protect it.
- Virtual Reality promotes the student's intrinsic motivation.

# 1. Introduction

'One million out of eight million species globally are threatened with extinction' (European Parliament, 2021b), and biodiversity loss has increased in recent years, mainly due to human activities (European Parliament, 2021a). A healthy ecosystem generated through biodiversity is an important factor in human life (European Parliament, 2021b). The planetary boundaries framework identifies nine processes '[...] that are critical for maintaining the stability and resilience of Earth system as a whole' (Richardson et al., 2023). These processes are earth-system processes that can generate unacceptable environmental changes with crossed thresholds. One of these nine processes is the rate of biodiversity loss, terrestrial and marine. With an extinction rate of more than 100 species per million species per year, the rate of biodiversity has already exceeded the proposed boundary of the extinction rate of 10 (Rockström, 2009). So, there is a strong need for action to protect biodiversity.

With the Convention on Biological Diversity (CBD) (Secretariat of the Convention on Biological Diversity, 1992) and the 2030 Biodiversity Strategy, there are international existing agreements on biodiversity protection. With article 13 of the CBD on public education and awareness, contracting parties of the convention aim to promote a deeper understanding of the significance of biodiversity preservation and the requisite measures through various means, including media dissemination and educational integration. They also pledge to collaborate with other nations and international bodies to develop educational and public awareness campaigns (Secretariat of the Convention on Biological Diversity, 1992).

With Biodiversity Education, Education for Sustainable Development (ESD), and Environmental Education (EE), there are existing concepts to bring biodiversity into schools. 'Environmental Education is aimed at producing a citizenry that is knowledgeable concerning the biophysical environment and its associated problems, aware of how to help solve these problems, and motivated to work toward their solution' (Stapp, 1970). The EE describes four objectives that should help individuals acquire: first, the understanding of humanity as an inseparable part of the system and the ability to change the interrelationships of this system. Second, the knowledge of the biophysical environment. Thirdly, an understanding of the biophysical environmental problems and, at last, to motivate the citizens to participate in solving problems, the attitude toward the quality of the environment (Stapp, 1970). As a bridge between EE and nature conservation education, biodiversity education has the same basic objectives. As an integral part of the ESD, the global and socioeconomic spheres give biodiversity education broader scopes (Fiebelkorn & Menzel, 2013; Kyburz-Graber et al., 2006). So, some concepts and strategies for protecting biodiversity have been in place for more than just a few years, but biodiversity continues to decline. There is, therefore, a need to sensitise society to the decline in biodiversity. University-based teacher education is one of the best options for bringing biodiversity education to school systems because of the multiplier effect of teachers (Fiebelkorn & Menzel, 2013). In ESD, teachers are efficient change agents for the orientation of education to sustainable development because they are the most important multiplier in promoting educational change and learning (German Commission for UNESCO, 2014). Therefore, it is necessary to integrate



biodiversity education as part of ESD into university teaching. Especially in the university teaching of geography teachers because geography is at the intersection of society and the environment, combines the natural sciences with the social sciences, and thus offers methodological diversity (Gebhardt et al., 2020).

There is also a long tradition of fieldwork in geography and other sciences, like biology (Minocha et al., 2018), which can be an essential aspect of the awareness of biodiversity loss because 'only by exploring biodiversity's different meanings, values and uses will people be able to develop the critical thinking skills needed to deal with the issue of biodiversity loss' (Navarro-Perez & Tidball, 2012). For an easier understanding of resource dilemmas and biodiversity loss, educators must have a deeper understanding of the socioeconomic and ecological facts, which can be achieved if there are real-world examples (Menzel & Bögeholz, 2008). So, fieldwork in geography is a good opportunity to give different real-world examples and the possibility of exploring different biodiversity. Nevertheless, fieldwork is often connected with high costs, issues of equal opportunities for students, difficulties faced by disabled students, or, in the case of experiences, biodiversity and the endangerment of ecosystems by the excursion participants (Stainfield et al., 2000). One possibility to face these problems is to use Virtual Field Trips (VFTs). VFTs aim to digitally represent the real-world environment without the costs of being physically there, they also offer potential to create new learning environments, particularly in the field of geography education (Bengel & Peter, , 2024, ; Horota et al., 2023). When a destination cannot be experienced in reality, Virtual Reality (VR) can enable learning environments with intensive experiences (Bürki & Buchner, 2020).

With the three main characteristics of VR – immersion, interaction, and imagination – students are allowed to immerse themselves in various environments and time periods, overcoming the boundaries of time and space and gaining experiences when learning (Chen et al., 2024). One of the main advantages of VR in education, which has been investigated in many studies, is the increase in motivation, interest, and learning engagement (Chen et al., 2024). Some main motivational aspects of extracurricular learning include the experience of interest, enjoyment, and autonomy (Wilde et al., 2009). Intrinsically motivated behaviours are actions determined by interests that are not associated with consequences in order to be maintained. Intrinsic motivation includes an interest in the immediate conditions of the environment (Deci & Ryan, 1993). Immersive technologies such as VR offer high interactivity and presence, not only promote learning but also increase intrinsic motivation, leading to a deeper understanding and a stronger emotional connection to the topic of biodiversity (Makransky & Lilleholt, 2018; Parong & Mayer, 2018)This creates the basis for learners to recognize the extent of biodiversity loss and feel the urgency and moral responsibility to take action to prevent it.

Thus, the objective of this study was to evaluate the effect of VFTs on pre-service geography teachers awareness of biodiversity preservation. Therefore, VFTs from two ecosystems in Berlin, Germany, have been exemplary created to demonstrate ecosystem biodiversity. The VFTs are created for university-based geography teacher education to raise awareness of biodiversity loss among students with a view to their later role as multipliers in schools. So, the research question of this work is, 'Can the use of Virtual Field Trips raise awareness of the threat to biodiversity'? This research question, along with the following hypotheses, is to be investigated with the help of a quasi-experimental study in a pre-post-study design. The hypotheses have been developed based on Kals et al., 1998 'model for explaining nature-protecting and nature-endangering dispositions and decisions. Accordingly, there are the first-order predictors: nature-related experience and interest variables, moral-related cognitions and moral-related emotions, which predict and explain the intermediate criteria (perceived responsibility and perceived usage rights). The intermediate criteria and the direct effects of the first-order predictors contribute to the willingness to protect or harm nature (Kals et al., 1998; Leske et al., 2009). The aim is, therefore, to investigate whether the individual components of biodiversity conservation awareness, based on the model of Kals et al., 1998, are influenced by the use of VFTs. The intrinsic motivation of the VFTs will also be investigated, as this also influences their actions.

## Hypotheses:

- Interest in biodiversity changes when VFTs are used.
- The perception of responsibility for protecting biodiversity is changing.
- Awareness of the threat to biodiversity is changing.
- The willingness to act to protect biodiversity is changing.
- The VFT promotes intrinsic motivation.

#### 1.1. Literature Review

Fiebelkorn & Menzel, 2013 conducted a comparative study on the biodiversity understanding of student biology teachers from Germany, an industrialised country, and Costa Rica, a biodiversity hotspot. Through in-depth interviews they wanted to identify the understanding of different aspects of biodiversity among these students. The study revealed a general lack of scientific understanding regarding biodiversity terminology, its distribution, and the implications of its loss. There were notable differences between the German and Costa Rican students. Costa Rican students show a lack understanding of global biodiversity issues and German students on local biodiversity. So, Fiebelkorn & Menzel, 2013 recommending that Costa Rican educators should learn more about global issues of biodiversity, while German educators should focus more on enhancing local biodiversity through direct engagement with local issues (Fiebelkorn & Menzel, 2013).

The integration of innovative technologies such as VR, Augmented Reality (AR) and Mixed Reality (MR) into environmental education presents promising avenues for enhancing understanding and engagement with biodiversity and climate change issues. Rambach et al., 2021 provide a comprehensive review of the literature and the use of these technologies. Several studies highlight the potential of VR to foster ecological awareness and enhance learning outcomes. For instance, Markowitz et al., 2018 explored the impact of immersive VR experiences on learning about marine science and the consequences of climate change. Across four studies, they found that immersive VR increased knowledge and greater interest in environmental issues (Markowitz et al., 2018). Similarly, Nelson et al., 2020 demonstrated the potential of VR to increase ecological awareness through immersive experiences by watching films about coral reefs in VR, which influenced participants' pro-environmental behavior, as measured by their willingness to donate to a charity organization (Nelson et al., 2020). Further, Thoma et al., 2023 examined the effectiveness of VR in raising climate change awareness through an immersive VR visualisation of the melting Swiss Aletsch glacier. Their findings indicate a significant increase in environmental awareness among participants exposed to the VR condition, in contrast to no change in the control group (Thoma et al., 2023).

The broader implications of using VR in education are further emphasized by Cho & Park, 2023, who suggest that these tools can significantly increase participants' interest, concern, and knowledge about environmental issues (Cho & Park, 2023). Additionally, Mentsiev et al., 2023 argue for the role of VR in sustainable development education, where it can simulate real-world scenarios, allowing students to engage with complex



environmental and social issues in a hands-on manner. This immersive approach not only enriches the educational process but also promotes social sustainability by making education more accessible and equitable (Mentsiev et al., 2023).

Research into the role of intrinsic motivation in relation to the learning effects of VR shows that VR not only promotes learning but also increases intrinsic motivation, leading to deeper and more sustainable learning outcomes. Several studies confirm this. A study by Makransky & Lilleholt, 2018 shows that immersion in VR experiences can generate strong intrinsic motivation to learn. The researchers found that VR-based learning environments promote a sense of presence and autonomy through their interactive and immersive structure, increasing learners' intrinsic motivation. This increased motivation leads to better learning performance and a deeper understanding of the content covered, including complex environmental topics (Makransky & Lilleholt, 2018). The study by Parong & Mayer, 2018 shows that VR-based learning environments that require active participation and interactivity significantly increase intrinsic motivation. In their research, they compared traditional learning methods with VR based methods and found that VR environment increased motivation to learn (Parong & Mayer, 2018). The self-determination theory by Ryan & Deci, 2000 can be cited as a motivational psychological basis. With this, the authors argue that intrinsic motivation is promoted by the fulfillment of the basic psychological needs for autonomy, competence and social integration. VR offers a unique opportunity to fulfill these needs by providing learners with a high degree of control over the learning environment (autonomy), challenging but manageable tasks (competence) and social interactions in virtual spaces (social connectedness). These characteristics make VR a particularly effective tool for increasing intrinsic motivation and therefore a better learning experience (Ryan & Deci, 2000).

#### 2. Materials and Methods

#### 2.1. Study Design

The present study examined a university course with a quasi-experimental longitudinal design. There were two data collection points, before and after the semester (October to March), and two main study groups of pre-service geography teachers. For better readability, the pre-service geography teacher is referred to as students in the following. The students are in the Bachelor's degree program, most of which are in the 3rd - 4th (48,1 %) and 5th – 6th (42,6%) semesters. Only 9,3 % of the participants are in the 7th – 8th semester. The study was conducted in a course consisting of four parallel courses. Structurally, they were, therefore, the same, and the content aspects can be adapted so that two of the four courses can receive an intervention as an experimental group and the other two as a control group receive none. The four parallel courses enable the largest possible number of students, with the same prerequisites, to be reached. The experimental group (EG) took part in the intervention, the Virtual Field Trip and the course with the theme of biodiversity. The control group (CG) also participated in the course but did not attend the VFT as an intervention. The courses of both study groups were a weekly course format. Both groups took the survey at the beginning (pre-test) and the end (post-test) of the lecture period. An overview of the study design is given in Figure 1.

The study was conducted in the winter semester of 2022/2023 at a university in North Rhine-Westphalia, Germany. The data analysis was performed with participants who answered the survey at both data collection points, the others who answered none or at one of the two points were excluded. The response rate of participants who completed the questionnaire in full at both points in time was low, so the following sample size results Ntotal = 54 (NEG = 35; NCG = 19), 20 of them are male and 34 females.

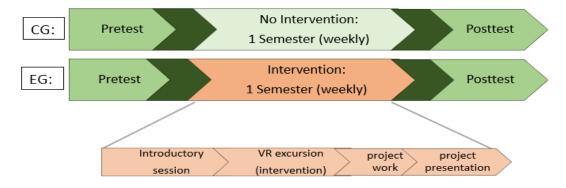


Figure 1. Overview study design.

#### 2.2 Project Content and Design

The aim of the VR ecosystems can be connected to biodiversity education, which enables people to 'Be aware of and understand the significance of biodiversity in their own environment as well as how they interact with it, and to be able to recognize how our actions have effects on it' (Navarro-Perez & Tidball, 2012).

The EG students participated in a biodiversity course using the example of two ecosystems in Berlin that were explored with a VFT. The example of Berlin was used because it represents two parks / green spaces used for leisure, so ecosystems where people interact. The advantage of using the VR was demonstrated for a course in North-Rhine-Westphalia where students were able two visit two ecosystems in two different seasons without the time, effort and costs of an excursion to these places at two times (Stainfield et al., 2000). The participants experience two different ecosystems in Berlin during the seminar in the winter semester. With the bird calls and the vegetation, they get the possibility of analysing the biodiversity exemplary with these aspects. At the beginning of the course, students receive theoretical input on the topic of biodiversity. On the following course days, they carry out the virtual excursion with head-mounted displays. They then analyse the vegetation, and bird calls at both locations in both seasons to determine the biodiversity using the Shannon-Weaver-Index, which was used because it takes into account the number of species and evenness (the distribution of species) and ensures therefore comparability (Tremp, 2005). To reduce the risk of cybersickness, which increases with time (Rebenitsch & Owen, 2021; Singla et al., 2019), it was decided to analyse the vegetation and bird calls outside of



VR. The biodiversity analysis is carried out with the help of a digital book in which the plants and bird calls occurring in VR are illustrated once again, and the procedure for the vegetation and biodiversity analysis is described (Heuke genannt Jürgensmeier et al., 2023). After the students have determined the vegetation and bird voices, a biodiversity index is calculated using the aspects of vegetation and bird species. A digital book was also created for this purpose, which explains the procedure and the biodiversity index. Both digital books were created with Book Creator app, 2021, Figures A1 and A2 in the Appendix show the content of both digital books, as an orientation what is included.

#### 2.3. Site selection and creation of VFT

The ecosystems to be mapped were inner-city areas, which must be publicly accessible so that necessary recordings for a virtual tour can be carried out. They had to be located within the same city to compare two different ecosystems with reasonably similar geographical conditions, these should be available so that the existing vegetation can be compared and is not influenced by other factors. This made it necessary to choose a larger city, and the decision was made in favour of Berlin as the capital of Germany as a motivating factor for the location of the excursion. Berlin also offers the opportunity to choose between different ecosystems thanks to its many green spaces and parks. So, after research into areas that are suitable for hosting a VFT, the choice initially fell on fallow land parks because they are close to nature but urban. Ultimately, the decision was made in favor of the 'Park am Nordbahnhof' and 'Thempelhofer Feld', the location of these is shown in Figure 2.

The 'Park am Nordbahnhof' was used as a long-distance train station until 1952, and in the early 1960s, German Democratic Republic border fortifications were erected there. In 2004-2009, the park was restored to its natural state, preserving the wild vegetation structures that had developed on the wasteland and bearing witness to Berlin's past (Grünberlin, 2024b). 'Tempelhofer Feld' was built as an airport complex during the National Socialist era and has had a varied history of different uses since then. Airport operations ceased in 2008, and the site was opened for recreational and leisure use in 2010 (Grünberlin, 2024a). Both areas thus offer a historical basis, which can be embedded in the VR tour with information and detailed photos, such as still existing railroad tracks or old training aircraft. This information can be used to discuss biodiversity in terms of past and present use in the different ecosystems. The choice of these parks also reveals two different uses: the 'Tempelhofer Feld' offers a wide range of sports and leisure activities in the large open spaces, and the 'Park am Nordbahnhof' has designated play and leisure areas and a boundary between the paths and green spaces. So, the analysed biodiversity in both ecosystems can be discussed under the intensity of human uses. At 5 ha (Park am Nordbahnhof) and 355 ha, the parks have different sizes, but even the smaller ones would be too big to show completely in VR, so only a section of each can be shown in the VFT (Grünberlin, 2024b; Senatsverwaltung für Mobilität, Verkehr, Klimaschutz und Umwelt, 2024).

The VFTs of these parks were created with 360° pictures of the ecosystems that were planned, recorded, and edited. First, a tour through the ecosystem has to be planned because not all the parks can be presented in VR. For each ecosystem, there is a spring and a summer tour with 20 locations at 'Tempelhofer Feld' and 18 locations at 'Park am Nordbahnhof', the maps in Figures 2, 3, & 4 provide an overview of the route and the respective locations in the VR tour. With these locations, both tours have a length of about 1 kilometer. A 360° picture was recorded in spring and summer at each planned location. These pictures were edited, which means people, license plates, and other objects were retouched. With these 360° images, a Virtual Tour was created using the VR Software 'VR Suite present 4D' (Trzaska, 2024). For a detailed description of all preparatory steps required to create a VFT, please refer to Heuke genannt Jürgensmeier et al., 2023.

To map and analyse biodiversity, it should be possible to analyse the vascular plants and bird species in the ecosystem in VR. To analyse the vegetation at both ecosystems, the vegetation was mapped in three randomly selected sites in spring and summer. To visualise the vegetation in VR, detailed images were taken of all mapped plants embedded in the VR tour at the corresponding locations as pictures that change size when pointing at it. To make it possible to record the bird calls in VR, they were recorded at both locations in spring and summer and embedded in the VFT as audio. This also creates background noise for the virtual tour, which can lead to a more immersive experience. The surveys were carried out simultaneously n spring and summer to ensure comparability between the two sites.

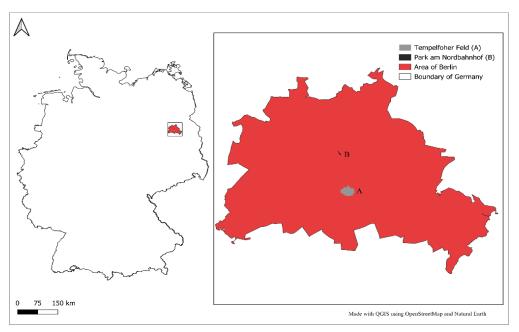


Figure 2. Overview map location of the VR ecosystems in Berlin.





Figure 4. Overview VR Tour Tempelhofer Feld (A).

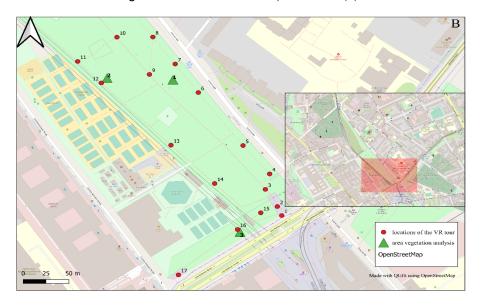


Figure 3. Overview VR Tour Park am Nordbahnhof (B).

## 2.4. Instruments and procedure

An online questionnaire (LimeSurvey GmbH, 2024) with the categories: interest in the subject of geography, interest in the topic of biodiversity, biodiversity in cities, perceived responsibility for the protection of biodiversity, awareness of threats, willingness to act to protect biodiversity and nature experiences from the EG and CG before and after the course was used. For these categories, scales were created with items based on the studies by Kals et al., 1998; Krapp et al., 2009; Leske et al., 2009; Menzel & Bögeholz, 2008, which deal with the willingness to protect biodiversity and environmental action. A six-point Likert-type scale was used from 1 to 6 (1 not true at all; 2 = mostly not true; 3 = somewhat not true; 4 = somewhat true; 5 = mostly true; 6 = completely true). These scales with examples of items are shown in Table A1 (A.2), in the original form (test language was German) and the translated version. The questions for the EG and CG were identical in the pre-test and post-test, with the expectation that the EG was asked to complete a scale on intrinsic motivation in the VFT in the post-test. The questions for the intrinsic motivation were adapted from the 'Short scale of intrinsic motivation (KIM)', which is a validated questionnaire on the topic (Wilde et al., 2009). As the motivational aspect of VR is to be investigated, the questions on intrinsic motivation relate to the VFT and, therefore, only carried out in the post-test and with the EG. To ensure anonymity, the pre-tests and post-tests are assigned to individuals using person-specific codes at the end of the questionnaire (Moosbrugger & Kelava, 2020).

# 2.5. Data analysis

All data were analysed using IBM SPSS statistics version 29, a statistic software to carry out extended statistical analyses (IBM Corp., 2023). The Cronbachs's alpha coefficient is calculated to assess the reliability of the scales, the scores are shown in section A.2. in the Appendix (Janssen



& Laatz, 2016). An acceptable value of Cronbach's alpha is > 0,7, which most of the values correspond to (Schecker et al., 2014; Schmitt, 1996). Since there is a close correlation between the number of items and Cronbach's alpha and the items have a high significance in terms of content, the number of items was not reduced to increase the alpha from the values that are not acceptable (Döring & Bortz, 2016; Rost, 2022; Streiner, 2003).

A test for normal distribution was performed, and it showed a normal distribution for most of the scales. Consequently, the Wilcoxon test for dependent samples and the Mann-Whitney-U for independent samples were therefore carried out first, as these do not assume a normal distribution (Janssen & Laatz, 2016; Rasch et al., 2021). Accordingly to Janssen & Laatz, 2016; Rasch et al., 2021 and based on the study by Winter & Dodou, 2010, who recommended the t-test for Likert-scale data after comparing the t-test with Mann-Whitney-Wilcoxon, we also performed the independent samples t-test to analyse the mean-value difference between the EG and CG in the pre-test and post-test, and the dependent sample t-test to analyse the pre-post-test means differences within the EG. The results of both test procedures differ only minimally, so we showed only the t-test results in the following.

To analyse the data on intrinsic motivation (Wilde et al., 2009), the total values within a scale were used, and then the mean values and standard deviation were calculated.

The first scale asks about 'Interest in the subject of geography' because interest is an important condition for learning (Hidi & Renninger, 2006). To analyse if the interest in the subject of geography has an influence on the other scales of the questionnaire, the Spearman correlation was calculated for both the EG and the CG in the pre and post-test to verify a correlation between interest in the subject of geography and the scales in the questionnaire. The post-test of the EC also checked whether there was a correlation between the motivation to use VR and the scales in the questionnaire. A coloured representation of the correlation table is chosen to display the results of the correlation. The figure was created with Excel by interpreting the correlation coefficient according to Cohen, 1988 (small = 0 - 0.30; medium = 0.30 - 0.50 and large > 0.50) and assigning corresponding colours to the values. The positive correlation is shown in orange-red tones. From a weak correlation in light orange to a strong correlation in dark orange. The negative correlation is shown from a weak correlation in light blue to a strong correlation in darker blue. The significant results with a level of 0.05 are marked with \* and those with a level of 0.01 with \*\*.

#### 3. Results

#### 3.1. Overview of the effects of the intervention

For a first overview, we examined the mean value difference for the independent and dependent samples of categories 1 to 7 of the questionnaire. All mean values and standard derivation are shown in Figure 5 and reported in Table 1. As can be seen in Figure 5, for the EG and CG at both test times some scales show high mean values. Independent of the differentiation between EG and CG, the highest mean values were recorded in subscales 4.2 'Perceived responsibility for the protection of biodiversity – external (economy)'; 4.3 'Perceived responsibility for the protection of biodiversity – external (state)' and in scale 5 'Awareness of threats'. Other scales that show relatively high mean values for the groups and test times are 1, 'Interest in the subject of geography', and all subscales of 6 to the 'Willingness to act to protect biodiversity'. The lowest mean values of all scales can be seen in scale 7, 'Nature experiences'.

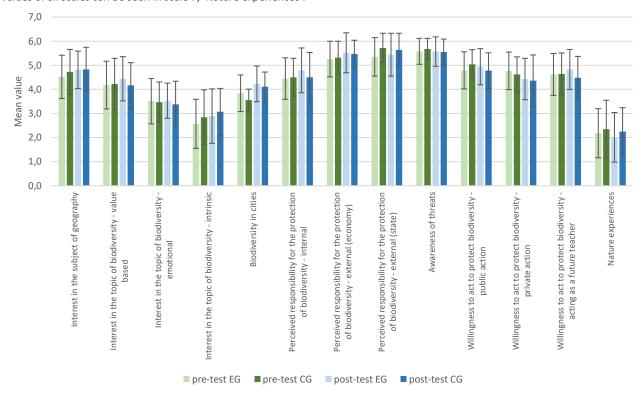


Figure 5. Mean values categories 1-7 of the EG and CG at pre- and post-test.



As seen in Table 1, the independent samples t-test revealed no significant differences, either in the pre-test or the post-test. In the first category, 'Interest in the subject of geography', the mean values of both groups and test times are in the range between 4.5 and 4.83 and have similar standard deviations. This can also be seen in the subcategories of category 2, 'Interest in the topic of biodiversity', where the mean values and standard deviations are also in similar ranges and, therefore, do not result in any significant differences in the t-test. There are larger differences in the third category, 'Biodiversity in cities', between the test times, which are subsequently relevant when considering the differences between the dependent group. There is a slightly greater difference in the mean values in subscale 6.1, between the CG and EG in the pre-test; t (52) = 1.21; p = 0.116; d = 0.34 and subscale 6.3 in the post-test; t (52) = -1.45; p = 0.077; d = 0.41, although this does not lead to a significant value in the t-test. Overall, category 7, 'Nature experiences' has the lowest mean values with high standard deviations, but there are also no significant differences in the mean values.

In contrast, the dependent sample t-test revealed significant differences for three scales in the questionnaire. After the intervention (M = 4,81; SD  $\pm$  0,78), EG students show a significantly higher interest in the subject of geography, t (34) = 4.73; p<0.001; d = 0.80, than before (M = 4.52; SD  $\pm$  0.90). According to Cohen, 1992, this has a high effect size. In the more specific category of 'Interest in biodiversity', however, there was no significant difference in any subcategory in the EC before and after the intervention. Before the intervention, the EG students show significantly less knowledge of biodiversity in cities (M = 3.84; SD  $\pm$  0.76) than after the intervention (M = 4.23; SD  $\pm$  0.74); t (34) = 2.99; p = 0.005; d = 0.51. This result also has a high effect size (Cohen, 1992)The third scale, where a significant difference can be reported, is the private action for the willingness to act to protect biodiversity. Here, the willingness is higher before the intervention (M = 4.77; SD  $\pm$  0.78) than after (M = 4.43; SD  $\pm$  0.86); t (34) = 2.99; p = 0.005; d = 0.50, with a high effect size (Cohen, 1992).

Table 1. Mean values (M) and standard deviations (SD) categories 1-8 of the EG and CG at both measurement times (pre-test, post-test).

| Category                              | Subcategory                   | Pre-test           |       |                    |       | Post-test          |       |                    |       |
|---------------------------------------|-------------------------------|--------------------|-------|--------------------|-------|--------------------|-------|--------------------|-------|
|                                       |                               | EG                 |       | CG                 |       | EG                 |       | CG                 |       |
|                                       |                               | М                  | SD    | М                  | SD    | М                  | SD    | М                  | SD    |
| Interest in the subject of geograph   | у                             | 4.52 <sup>ab</sup> | ±0.90 | 4.73 <sup>aa</sup> | ±0.93 | 4.81 <sup>ab</sup> | ±0.78 | 4.83ªª             | ±0.92 |
|                                       | value-based                   | 4.18 <sup>aa</sup> | ±0.99 | 4.22ªª             | ±1.07 | 4.44 <sup>aa</sup> | ±0.92 | 4.17ªª             | ±0.94 |
| Interest in the topic of biodiversity | emotional                     | 3.51ªª             | ±0.94 | 3.47 <sup>aa</sup> | ±0.84 | 3.53 <sup>aa</sup> | ±0.73 | 3.38 <sup>aa</sup> | ±0.96 |
|                                       | intrinsic                     | 2.57 aa            | ±1.02 | 2.84ªª             | ±1.14 | 2.89ªª             | ±1.13 | 3.07ªª             | ±0.97 |
| Biodiversity in cities                |                               | 3.84 <sup>ab</sup> | ±0.76 | 3.56ªª             | ±0.45 | 4.23 <sup>ab</sup> | ±0.74 | 4.11 <sup>aa</sup> | ±0.61 |
| Perceived responsi-                   | internal                      | 4.45 <sup>aa</sup> | ±0.86 | 4.50ªª             | ±0.79 | 4.79ªª             | ±0.93 | 4.50ªª             | ±1.03 |
| bility for<br>the protection of       | external (economy)            | 5.26ªª             | ±0.74 | 5.32 <sup>aa</sup> | ±0.68 | 5.52 <sup>aa</sup> | ±0.83 | 5.4 <b>7</b> ªª    | ±0.57 |
| biodiversity                          | external (state)              | 5.35ªª             | ±0.80 | 5.72ªª             | ±0.61 | 5.44ªª             | ±0.89 | 5.64ªª             | ±0.69 |
| Awareness of threat                   | S                             | 5.58ªª             | ±0.54 | 5.68ªª             | ±0.44 | 5.57ªª             | ±0.61 | 5.55ªª             | ±0.54 |
| Willingness to act                    | public action                 | 4.79ªª             | ±0.77 | 5.04ªª             | ±0.61 | 4.94ªª             | ±0.75 | 4.78 <sup>aa</sup> | ±0.74 |
| to protect                            | private action                | 4.77 ab            | ±0.78 | 4.62ªª             | ±0.73 | 4.43 ab            | ±0.86 | 4.36ªª             | ±1.07 |
| biodiversity                          | acting as a future<br>teacher | 4.62ªª             | ±0.87 | 4.64ªª             | ±0.87 | 4.83ªª             | ±0.83 | 4.48 <sup>aa</sup> | ±0.89 |
| Nature experiences                    |                               | 2.18 <sup>aa</sup> | ±1.02 | 2.35ªª             | ±1.20 | 2.01ªª             | ±1.03 | 2.25ªª             | ±0.99 |
|                                       | interest/enjoyment            | -                  | -     | -                  | -     | -                  | -     | 3.29               | ±1.26 |
| Motivation<br>through VR              | perceived choice              | -                  | -     | -                  | -     | -                  | -     | 4.94               | ±1.06 |
|                                       | Pressure / tension            | -                  | -     | -                  | -     | -                  | -     | 4.07               | ±0.72 |

 $<sup>^{\</sup>mathrm{aa}}$  no significant different t-test at level 0.05

 $<sup>^{\</sup>mathrm{ab}}$  significant different t-test at level 0.05

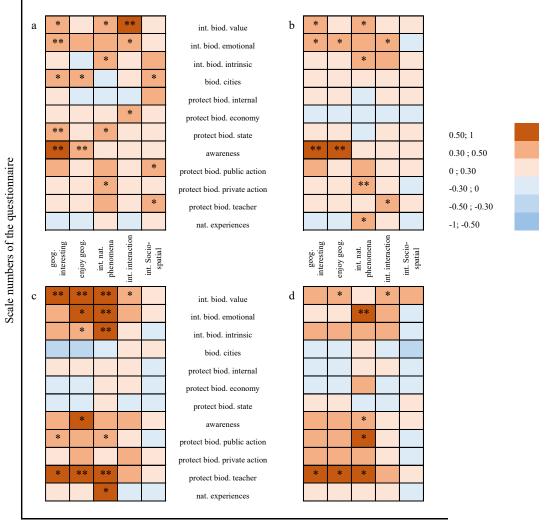


#### 3.2. Motivational Aspects of Virtual Reality

This section presents the results of intrinsic motivation through VR, which were collected using the KIM (Table 1). The scale 'perceived choice' (M = 4.94) achieves the highest value, with almost 5 on a scale of 1-6. The 'pressure/tension' is rated as quite low (M = 4.07). Here, a high mean value means low pressure because the items have been recorded, and all scales have a positive meaning with a high number of Likert scale items. 'Interest/enjoyment' (M = 3.29) has a medium value and, with  $\pm 1.26$ , the highest standard deviation of the three scales, which means that there were the greatest differences in the answers to the questions on this scale.

#### 3.3. Correlations with Interest in the Subject of Geography

To check whether there is a correlation between the variables of the scale 'interest in geography' and the scales of the questionnaire, the Spearman correlation has been calculated in the pre- and post-test for both the EG and CG. The results are shown in Figure 6. All detailed values are included in Tables A2 and A3 in the appendix. The abbreviations for the scales used in the figure are listed in Table 2.



Questions of scale 1 'Interest in geography'

**Figure 6.** Spearman-correlation between interest in geography and measurement; a: pre-test of the EG; b: post-test of the EG; c: pre-test of the CG; d: post-test of the CG; \*correlation is significant at level 0.05; \*\*correlation is significant at level.

When comparing the EG in the pre-and post-test, so Figure 6a with Figure 6b, scale 2 'Interest in the topic of biodiversity' mostly shows moderate correlations at both test times, with significant values in all subscales. For the value-based interest, there is a positive correlation to the questions 'I find the subject geography interesting' and 'I am particularly interested in natural phenomena in geography'. The latter also shows a positive correlation with intrinsic interest. The emotional interest shows significant positive correlations with questions 'I find the subject geography interesting' and 'What interests me most about geography is the interaction between people and environment'. The correlations of scale 3 'Biodiversity in cities' with the questions only show significant moderate correlations in the pre-test. Scale 4 reveals changes, with the pre-test showing moderate and significant correlations across all subscales, whereas the post-test displays negative correlations particularly in subscale 4.2 'Perceived responsibility for the protection of biodiversity- external (economy). Scale 5, 'Awareness of threats' has a nearly identical result in the correlations with significant values to questions 'I find the subject geography interesting' and 'I enjoy the subject geography' at both test times. The pattern of the correlations in the three subscales of scale 6 is nearly identical between the pre and post-test of the EG, with significant



moderate correlations between 'Willingness to act to protect biodiversity-public action' and 'I find the subject geography interesting' and 'I am particularly interested in natural phenomena in geography'. 'Nature experiences' has slight negative correlations to questions 'I find the subject geography interesting' and 'I enjoy the subject geography' at both test times, with a significant moderate positive correlation for 'I am particularly interested in natural phenomena in geography' in the post-test.

In the CG (Figure 6c and Figure 6d), Scale 2 'Interest in the topic biodiversity' shows mainly positive correlations at both test times, with significant values between the emotional interest and 'I am particularly interested in natural phenomena in geography' and between the value-based interest and "I enjoy the subject geography' and 'What interest me most about geography is the interaction between people and environment'. 'Biodiversity in cities' and 'Perceived responsibility for the protection of biodiversity' have a mix of negative and positive correlations with slight, non-significant values. Scale 5 'Awareness of threats' shows positive correlations at both times, with moderate significance in different questions. The correlations of the 'Willingness to act to protect biodiversity' are mainly moderate positive with strong significant correlations for 'acting as a future teacher' at both test times.

Comparing the pre-tests of the EG and the CG, Figure 6a and Figure **6**c, scale 2 'Interest in the topic of biodiversity' shows significant values in both groups, with higher correlations in the CG. 'Biodiversity in cities' (scale 3) differs between groups, the EG shows slight negative and moderate positive correlations, while the CG shows mostly negative correlations. These differences can also be seen in the three subscales of 'Perceived responsibility for the protection of biodiversity'. Scale 5 'Awareness of threats' shows similar positive correlations in both groups with a significant value for 'I enjoy the subject geography'; EG,  $\rho = 0.499$ ,  $\rho = 0.002$ ; and CG,  $\rho = 0.512$ ,  $\rho = 0.025$ . For the 'Willingness to protect biodiversity', there are positive correlations in both groups, with different significant values. Scale 7 shows different results between the groups.

Comparing the post-test of the EG and CG, 'Interest in the topic of biodiversity' (scale 2) reveals similar moderate positive correlations with no common significant values. The scales 3 'Biodiversity in cities' and 4 'Perceived responsibility for the protection of biodiversity' show only non-significant values for both groups. Scale 5 'Awareness of threats' shows positive correlations with significant values in both groups, though none overlap. 'Willigness to act to protect biodiversity' shows positive correlations with significant values in all three subscales, but again, there is no overlap between the groups. There is one significant value on scale 7 'Nature experiences' for the EG with a moderate correlation.

**Table 2.** Questions and scales meaning for Figure 4 and Figure 5.

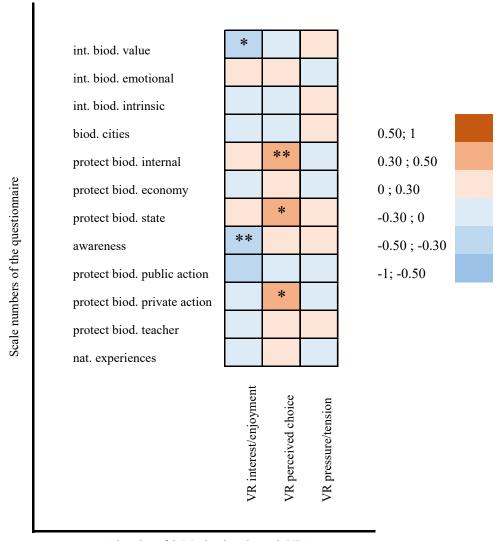
| Scale/question number | Meaning  | Abbreviation                 |
|-----------------------|--|------------------------------|
| 1.1                   | 'I find the subject geography interesting'   | geog.interesting             |
| 1.2                   | 'I enjoy the subject geography'  | enjoy geog.                  |
| 1.3                   | 'I am particularly interested in natural phenomena in geography'                               | int. nat. phenomena          |
| 1.4                   | 'What interests me most about geography is the interaction between people and the environment' | int. interaction             |
| 1.5                   | 'I am particularly interested in socio-spatial structures and processes in geography'          | int. socio-spatial           |
| 2.1                   | Interest in the topic of biodiversity – value-based  | int. biod. value             |
| 2.2                   | Interest in the topic of biodiversity - emotional  | int. biod. emotional         |
| 2.3                   | Interest in the topic of biodiversity - intrinsic  | int biod. intrinsic          |
| 3                     | Biodiversity in cities   | biod. cities                 |
| 4.1                   | Perceived responsibility for the protection of biodiversity - internal                         | protect biod. internal       |
| 4.2                   | Perceived responsibility for the protection of biodiversity – external (economy)               | protect biod. economy        |
| 4.3                   | Perceived responsibility for the protection of biodiversity – external (state)                 | protect biod. state          |
| 5                     | Awareness of threats   | awareness                    |
| 6.1                   | Willingness to act to protect biodiversity – public action                                     | protect biod. public action  |
| 6.2                   | Willingness to act to protect biodiversity – private action                                    | protect biod. private action |
| 6.3                   | Willingness to act to protect biodiversity – acting as a future teacher                        | protect biod. teacher        |
| 7                     | Nature experiences   | nat. experience              |
| 8.1                   | Motivation through VR – interest/enjoyment   | VR interest/enjoyment        |
| 8.2                   | Motivation through VR – perceived choice   | VR perceived choice          |
| 8.3                   | Motivation through VR – pressure/tension   | VR pressure/tension          |



#### 3.4. Correlations with Motivation through VR

Figure 7 shows the Spearman correlation between motivation (scale 8) and the questionnaire scales in a colour matrix. All detailed values are included in Table A4 in the A.4.

Overall, there are a few medium and strong correlations; when there is one, it is usually significant. There are two significant negative correlations overall, both relating to 8.1: 'Motivation through VR – interest/enjoyment', one with 2.1: 'Interest in the topic of biodiversity – value based', p = 0.-343, p = 0.044; and the other with scale 5: 'Awareness of threats', p = 0.-.366, p = 0.031. The other three significant correlations are positive, and all occur in subscale 8.2. These correlate with subscales 4.1: 'Perceived responsibility for the protection of biodiversity – internal', p = 0.449, p = 0.007, 4.3: 'Perceived responsibility for the protection of biodiversity – external (state)', p = 0.406, p = 0.016; and 6.2: 'Willingness to act to protect biodiversity – private action'. The third subscale of motivation, 'pressure/tension', shows no significant correlations, and according to Cohen, 1988, there are only weak correlations in both, the positive and negative areas.



Subscales of 8 'Motivation through VR'

**Figure 7.** Spearman-correlations between motivation through VR and measurement of the EG in the post-test; \*correlation is significant at level 0.05; \*\*correlation is significant at level 0.01 (own figure, created with Excel).

#### 4. Discussion

The results of the independent samples t-test showed that there are no significant differences between the mean values in the comparison between the EG and CG, both in the pre-and the post-test. This can also be expected for the pre-test, as all participants have the same prerequisites. In the post-test, it can be expected that the mean values of the EC differ significantly from those of the CG, as they experienced the VFTs, carried them out, and engaged intensively, but this is not the case. This is not in line with the studies by Markowitz et al., 2018; Nelson et al., 2020; Thoma et al., 2023 mentioned at the beginning, but this is consistent with some studies on the learning outcomes of VR, where immersive VR had a small effect on learning outcomes (Coban et al., 2022; Hamilton et al., 2021; Makransky et al., 2021). If the mean values of the results are now taken into account, it can be seen that these are already high in the pre-test and, therefore, cannot change significantly in a positive direction. This can be seen, for example, for variable 5: 'awareness of threats' in both groups (EG: 5.58; CG: 5.68). This is also noticeable in the three variables



on the scale 6: 'Willingness to act to protect biodiversity'. A critical factor that may have contributed to these findings is the ceiling effect, which occurs when participants' pre-test scores are already near the maximum possible score, leaving little room for improvement in the post-test. The high mean values observed in the pre-test indicate that the participants already had a well-developed understanding of the topics (Austin & Brunner, 2003; Wang et al., 2009). This ceiling-effect likely constrained the potential for the VR intervention to produce measurable improvements, as the scores could not significantly increase from an already high baseline.

We analysed the correlations of interest in the subject of geography because interest is an important condition of learning (Hidi & Renninger, 2006) and so we can now add the results of the correlation to these results It is noticeable that there are some significant correlations. First of all, for both test groups, predominantly moderate and strong correlations can be recognised on scale 2 at both the first and second test time points. This suggests that the interest in biodiversity, which is measured on scale 2, plays a significant role for both groups. In particular, significant correlations can be observed in subscales 2.1 and 2.2, which indicate that interest in the topic of biodiversity is value-based and emotional, and the associated values are strongly related to the interest in the subject of geography. Through the interest in their subject and the correlating interest in the topic of biodiversity, it can be assumed that the participants have specialist knowledge in these areas (Hidi & Renninger, 2006). A specific example of a strong correlation can be found between subscale 2.1 ('Interest in the topic of biodiversity – value based') and questions 1,2, and 3 to the interest in the geography of the CG in the post-test. The significant correlations between these variables could indicate that interest in biodiversity values is strongly related to the participant's attitude toward the topic. This is consistent with the theory of the value-based model, which states that individual values and beliefs can influence a person's behaviour and attitudes (Schwartz, 2012). Knowledge about environmental problems, such as the decline in biodiversity, can be seen as a prerequisite for pro-environmental action. According to Gifford & Nilsson, 2014, consciously acting environmentally friendly is unlikely if people are unaware of the problem and possible positive measures. With interest in the subject of geography, the perquisite of understanding the aspects of the environment's health and how they are interconnected can be taken for granted (Fauville et al., 2020). The high mean values, which are already shown in the pre-test, can thus be attributed to the interest and associated knowledge in the subject of geography and thus on topics of biodiversity, which can already lead to environmentally friendly behaviour. After all, it '[...] is unlikely to knowingly be concerned about the environment or deliberately act in pro-environmental ways if one knows nothing about the problem or potential positive actions' (Gifford & Nilsson, 2014).

A specific example of a strong correlation can be found between subscale 2.1 ('Interest in the topic of biodiversity — value based') and questions 1,2, and 3 to the interest in the geography of the CG in the post-test. The significant correlations between these variables could indicate that interest in biodiversity values is strongly related to the participant's attitude toward the topic. This is consistent with the theory of the value-based model, which states that individual values and beliefs can influence a person's behaviour and attitudes (Schwartz, 2012). Furthermore, the results show that the correlations in scales 3 and 4 are predominantly weak and exhibit both positive and negative correlations. This could indicate that other factors outside of scale 2 play a lesser role for the groups studied or that the constructs measured in these scales are less clear.

The results show that there are no significant differences between the EG and CG after the VR excursion, which could be attributed to the fact that the participants are all geography students. They all show a high level of interest in the subject of geography, which already leads to a high level of interest in the topic of biodiversity and a willingness to act to protect it. This illustrates the importance of interest in learning content for learning success and underlines the role of teaching and educational institutions in promoting this interest (Krapp et al., 2009) because when students can pursue their personal interests during learning, they try harder (Makransky et al., 2019).

Notably, the intervention led to significant increases in interest in geography among the EG students and improved knowledge of biodiversity in cities. These findings are consistent with previous research indicating that immersive Virtual Reality '[...] can potentially be efficient in promoting the various dimensions of environmental literacy [...]' (Fauville et al., 2020). The dimensions of environmental literacy are knowledge, dispositions, competencies, and environmentally responsible behaviour (Fauville et al., 2020).

The emotions, engagement, and motivation of individuals are linked with each other and represent all important aspects of learning (Allcoat & Mühlenen, 2018; Pintrich, 2003). So, it is useful to supplement the results with those on the motivation of the EC by VR. Looking at the mean values of the KIM, the high mean value of 'perceived choice' indicates a strong sense of autonomy among the participants. According to Deci & Ryan, 1993, autonomy, the feeling of being able to make your own decisions, is an important aspect of intrinsic motivation and engagement. A high value in this category indicates that the participants felt free in their decisions and actions, which can lead to increased motivation and satisfaction according to self-determination theory (Deci & Ryan, 1993). The relatively high mean value in the recorded scale for 'pressure/tension' shows that the participants experience low pressure/tension. This is consistent with the fact that less external pressure and less perceived tension can promote self-determination. Low pressure is associated with higher intrinsic motivation, as learners are more likely to perceive their activities as self-detected (Deci & Ryan, 1993). The mean value of 'interest/enjoyment' is in the medium range of the scale, which indicates that the participants experienced a moderate level of interest and enjoyment during the VFT. However, the relatively high standard deviation shows that the participants perceived these aspects very differently. This highlights the importance of recognising individual differences, as interest and enjoyment are important for the intrinsic motivation that drives sustained engagement and learning (Deci & Ryan, 1993). This shows that the VFT positively affects student motivation, which is consistent with some previous studies. Lee et al., 2010 say in their research that 'VR features were a significant antecedent to motivation' (Lee et al., 2010) and that VR software is motivating.

A look at the results of the correlation analysis between motivation and the questions from the questionnaire shows that there are negative significant correlations between motivation through VR and the value-based interest in biodiversity and the awareness of threats. This is contrary to the assumption of the self-determination theory, as the increase in interest and enjoyment means a decrease in the value-based interest in the topic of biodiversity and awareness of threats instead of an increase because of a higher intrinsic motivation (Deci & Ryan, 1993).

On the other hand, three positive significant correlations appear in subscale 8.2 and are associated with the perceived responsibility for biodiversity protection and the willingness to protect biodiversity in private action. These can show that learners who perceive themselves as capable and autonomous in their actions are more motivated to act to protect biodiversity. This can be underlined by the argumentation of Deci & Ryan, 1993, that the promotion of self-determination and perceived competence are decisive factors for the engagement and motivation of learners

To summarise, this study shows that using a VFT for biodiversity analysis cannot directly raise awareness of the threat to biodiversity. The interest in biodiversity, the perception of responsibility for protecting biodiversity and the awareness of threat to biodiversity did not change significantly after the VFT. The private willingness to act to protect biodiversity decreases significantly after the intervention, although the willingness here still can be regarded as high. The results of the KIM show that the VFT promotes the students' intrinsic motivation. This is consistent with the study of Makransky et al., 2021, which reports that immersive VR results in enjoyment and presence but makes no difference in learning



outcomes. It underlines the results of studies that compared immersive VR with traditional methods, where VR always had motivational outcomes but no consistent results regarding the learning outcomes (Makransky et al., 2021). In our case, it is not a learning outcome in the form of declarative knowledge, but the motivational effects of VR also predominate here. However, these findings also prompt a critical look at the limitations of VFTs in education, particularly when it comes to translating motivation into meaningful learning outcomes or behavior change. Despite high intrinsic motivation, the decreasing willingness to engage in biodiversity conservation suggests that while VFts can captivate students and pique their interest, they may not be sufficient to foster the deep understanding and engagement necessary to protect the environment effectively. This shows that the high potential of VR in education, which is also the case in the studies listed at the beginning, is not confirmed, and therefore, the focus of the advantage of VR in education is on the motivational aspect.

So, promoting intrinsic motivation can effectively increase interest and attitudes towards biodiversity in some aspects. Integrating VR into education can offer great potential regarding intrinsic motivation, which underlines VR's main advantage in education.

The lack of significance in the differences between the EG and CG may also be attributed to several limitations inherent in the study design. One critical factor could be the ceiling effect. In this study, the participants, who were pre-service geography teachers with a strong existing interest in environmental issues, likely started a high level of awareness and knowledge about biodiversity, which may have minimized the impact of the VFT. In addition to the ceiling effect, there are other potential limitations related to the sensitivity of the measurement instruments used. The scales employed to assess relevant factors, such as awareness, responsibility, and willingness to act, might not have been sensitive enough to detect subtle differences between the groups. Also, the timing of the post-test could have been chosen differently, for example, directly after the intervention and not at the end of the semester. For a future study, a follow-up test several weeks after the post-test could also be considered to check the intervention's long-term effect. Also, it could be interesting to do a pre-test, an immediate post-experience post-test, and an end-of-semester post-test. Another explanation could lie in the nature of the VFT itself, and factors could be optimised in the VFT.

#### 5. Conclusions

Due to the alarming decline in biodiversity, educational strategies are needed to promote awareness and, thus, action to protect biodiversity. This study investigated the potential of VFTs as an innovative educational tool in university-based geography teacher education to raise awareness of biodiversity loss.

Overall, the results show no significant differences between the EG and CG after the intervention in the form of the VFT. However, existing interest in geography and the associated environmental topics plays a decisive role in the development of environmental awareness and the willingness to act to protect biodiversity. It can be seen that the participants in the VFT find it intrinsically motivating, as they perceive a high degree of perceived choice, moderate interest/enjoyment, and only a little pressure when carrying out the VFT. This can be linked to some significant differences found in the EG between the pre-and post-test and the correlations between motivation through VR with questionnaire items. This can be related to the fact that intrinsic motivation can foster the engagement and motivation of learners.

It can be seen that even during the pre-test, all participants had a high level of awareness and willingness to protect biodiversity, which may be because all students are geography students. So, it seems sensible to carry out the study again in the future and to do so with a sample that does not already have previous experience with the topic, like the geography students.

Furthermore, the results of the study can emphasize the importance of intrinsic motivation and interest in environmental issues as key factors for educational success. In addition, the study can illustrate the potential of VR technologies for enriching environmental education in terms of the enhanced motivational aspects. The effectiveness of an intervention like the VFT in fostering a deep understanding and commitment to biodiversity conservation is likely to depend on the extent to which they complement and enhance, rather than replace, existing education.

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# A. Appendix

# A.1. Example Digital Book



Figure A1. Contents of the Digital Book 1.



Figure A2. Contents of the Digital Book 2.



# A.2. Questionnaire item details

Table A1. Questionnaire item details.

| Scale   |                                | Number of<br>items | Example of an original item   | Item translation  | Cronbachs α (pre/post) |  |
|---|--------------------------------|--------------------|---|---|------------------------|--|
| 1. Interest in the subject of geography           |                                | 5                  | Am Fach Geographie interessieren mich besonders die Naturphänomene.                                       | I am particularly interested in natural phenomena in geography.                   | .723 / .731            |  |
| 2. Interest in the topic of biodiversity          | 2.1 value-based                | 4                  | Wenn ich ehrlich sein soll, ist mir das<br>Thema Biodiversität eher gleichgültig.*                        | To be honest, I don't really care about biodiversity.*                            | .774 / .662            |  |
|   | 2.2 emotional                  | 5                  | Die Beschäftigung mit dem Thema<br>Biodiversität wirkt sich positiv auf meine<br>Stimmung aus.            | Dealing with the topic of biodi-<br>versity has a positive effect on my<br>mood.  | .605 / .503            |  |
|   | 2.3 intrinsic                  | 4                  | In meiner Freizeit beschäftige ich mich nur<br>ungern mit dem Schutz von<br>Ökosystemen.*                 | In my free time, I am reluctant to get involved in the protection of ecosystems.* | .806 / .777            |  |
| 3. Biodiversity in cities                         |                                | 5                  | Die Biodiversität in Städten ist nicht schützenswert.*  | Biodiversity in cities is not worth protecting.*                                  | .361 / .445            |  |
| 4. Perceived responsibility for the protection of | 4.1 internal                   | 4                  | Ich persönlich bin nicht für den Schutz der<br>Biodiversität verantwortlich.*                             | I am not personally responsible for protecting biodiversity.*                     | .792 / .678            |  |
| biodiversity                                      | 4.2 external (economy)         | 4                  | Die Wirtschaft ist für den Schutz von<br>Ökosystemen verantwortlich.                                      | The economy is responsible for protecting ecosystems.                             | .726 / .821            |  |
|   | 4.3 external (state)           | 4                  | Die Politik ist für den Schutz der<br>Biodiversität verantwortlich.                                       | Politics is responsible for the protection of biodiversity.                       | .792 / .678            |  |
| 5. Awareness of threats                           |                                | 6                  | Die Zerstörung von Ökosystemen wird zu einem immer größeren Problem.                                      | The destruction of ecosystems is becoming an ever greater problem.                | .744 / .871            |  |
| 6. Willingness to act to protect biodiversity     | 6.1 public action              | 3                  | Ich würde eine Unterschriftenliste zum<br>Schutz von gefährdeten Arten<br>unterzeichnen.                  | I would sign a petition for the protection of endangered species.                 | .43 / .359             |  |
|   | 6.2 private action             | 5                  | Ich würde mich in Naturschutzgebieten<br>auch außerhalb der ausgewiesenen Wege<br>aufhalten.*             | I would also stay outside the des-<br>ignated paths in nature re-<br>serves.*     | .473 / .578            |  |
|   | 6.3 acting as a future teacher | 5                  | Als zukünftige Lehrperson würde ich über<br>den Lehrplan hinaus über das Thema<br>Biodiversität sprechen. | As a future teacher, I would talk about biodiversity beyond the curriculum.       | .706 / .653            |  |
| 7. Nature experiences                             |                                | 5                  | Ich halte mich gerne draußen in der Natur<br>auf.   | I like to spend time outdoors in nature.  | .805 / .722            |  |
| 8. Motivation through<br>VR                       | 8.1 interest/enjoyment         | 3                  | Die Virtuelle Exkursion hat mir Spaß gemacht.   | I enjoyed the Virtual Field Trip.   | - / .926               |  |
| (post-test)                                       | 8.2 perceived choice           | 3                  | Ich konnte die Virtuelle Exkursion selbst steuern.  | I was able to control the Virtual<br>Field Trip myself.                           | -/.917                 |  |
|   | 8.3 pressure/tension           | 3                  | Bei der Virtuellen Exkursion fühlte ich   | I felt tense during the Virtual   | - / .793               |  |

# A.3. Correlations Interest in geography

TableA2. Correlations (spearman-correlation) between Interest in geography and measurement of the EG in pre- and post-test (N=35).

|  |                                     |         | 'I find the subject geogra-<br>phy interesting' |        | 'I enjoy the subject<br>geography' |        | 'I am particularly inter-<br>ested in natural phenom-<br>ena in geography' |        | "What interests me<br>most about geography<br>is the interaction be-<br>tween people and the<br>environment" |       | 'I am particularly in-<br>terested in socio-<br>spatial structures<br>and processes in ge-<br>ography' |        |
|--|-------------------------------------|---------|---|--------|------------------------------------|--------|--|--------|--|-------|--|--------|
|  |                                     |         | Pre   | Post   | Pre                                | Post   | Pre  | Post   | Pre  | Post  | Pre  | Post   |
|  |                                     | ρ       | 0.424*  | 0.344* | 0.231                              | 0.242  | 0.492*   | 0.346* | 0.559**  | 0.234 | 0.213  | 0.074  |
| Interest in the topic<br>of biodiversity | valu<br>e-<br>bas<br>ed             | p-value | 0.011   | 0.043  | 0.183                              | 0.162  | 0.003  | 0.042  | <.001  | 0.177 | 0.218  | 0.674  |
| erest in the to<br>of biodiversity       | emo<br>tion<br>al                   | ρ       | 0.441**   | 0.373* | 0.317                              | 0.361* | 0.323  | 0.31   | 0.382*   | 0.39* | 0.155  | -0.067 |
| sst in<br>biodi                          | emo<br>tion<br>al                   | p-value | 0.008   | 0.027  | 0.064                              | 0.033  | 0.059  | 0.069  | 0.023  | 0.021 | 0.373  | 0.704  |
| ofl                                      | ı                                   | ρ       | 0.196   | 0.272  | -0.057                             | 0.103  | 0.393*   | 0.369* | 0.286  | 0.322 | 0.307  | 0.053  |
| <u>=</u>                                 | in-<br>trin-<br>sic                 | p-value | 0.26  | 0.114  | 0.745                              | 0.556  | 0.019  | 0.029  | 0.096  | 0.059 | 0.073  | 0.761  |
| o  | Bio-<br>di-<br>di-<br>sity<br>in in |         | 0.396*  | 0.296  | 0.372*                             | 0.171  | -0.011   | 0.195  | 0.216  | 0.097 | 0.383*   | 0.286  |
| iğ ip                                    |                                     |         | 0.018   | 0.085  | 0.028                              | 0.325  | 0.95   | 0.262  | 0.212  | 0.58  | 0.023  | 0.096  |



|  | ibil-<br>ion<br>in-<br>nal   | ρ              | 0.049              | 0.043            | -0.042  | 0.063  | -0.126 | -0.152  | -0.025 | 0.041  | 0.323  | 0.136  |
|--|--|----------------|--------------------|------------------|---------|--------|--------|---------|--------|--------|--------|--------|
| onsib<br>ectic<br>ity  | in-<br>ter-<br>nal   | p-value        | 0.78               | 0.807            | 0.811   | 0.718  | 0.471  | 0.382   | 0.885  | 0.817  | 0.058  | 0.436  |
| seived responsibil-<br>for the protection<br>of biodiversity | ex-<br>ter-<br>nal<br>(eco<br>no<br>my)  | ρ              | 0.223              | -0.292           | 0.196   | -0.064 | 0.111  | -0.148  | 0.352* | -0.172 | 0.139  | -0,011 |
| /ed r<br>the  <br>biodi                                      | g n g n te   | p-value        | 0.198              | 0.089            | 0.33    | 0.715  | 0.525  | 0.397   | 0.038  | 0.324  | 0.427  | 0.95   |
| Perceived responsibility for the protection of biodiversity  | ex-<br>ter-<br>nal<br>(stat<br>e)  | ρ              | 0.456**            | 0.107            | 0.176   | 0.263  | 0.342* | -0.054  | 0.224  | 0.099  | 0.15   | 0.221  |
| 9 ÷  | ex-<br>ter-<br>nal<br>(stat<br>e)  | p-value        | 0.006              | 0.54             | 0.312   | 0.126  | 0.044  | 0.76    | 0.195  | 0.57   | 0.391  | 0.202  |
| Awa<br>re-<br>ness<br>of<br>thre<br>ats                      |  | ρ              | 0.622**            | 0.504**          | 0.499** | 0.55** | 0.001  | 0.142   | 0.034  | 0.154  | 0.049  | 0.282  |
| Ą  | Awa<br>re-<br>nes<br>of<br>thre<br>ats   |                | <.001              | 0.002            | 0.002   | <.001  | 0.998  | 0.415   | 0.844  | 0.378  | 0.778  | 0.101  |
| 0 >  | publ<br>ic<br>ac-<br>tion  | ρ              | 0.322              | 0.307            | 0.184   | 0.181  | 0.307  | 0.313   | 0.278  | 0.275  | 0.354* | 0.263  |
| act t<br>ersit   | pu<br>ac<br>tic  | p-value        | 0.06               | 0.073            | 0.291   | 0.297  | 0.073  | 0.067   | 0.106  | 0.11   | 0.037  | 0.127  |
| Willingness to act to<br>protect biodiversity                | pri-<br>vate<br>ac-<br>tion  | ρ              | 0.202              | 0.273            | 0.254   | 0.27   | 0.35*  | 0.461** | 0.218  | 0.198  | 0.201  | -0.1   |
| gnes<br>ct bi  | pr<br>va<br>ac<br>tic  | p-value        | 0.245              | 0.113            | 0.141   | 0.117  | 0.039  | 0.005   | 0.208  | 0.254  | 0.248  | 0.568  |
| /illin<br>rote   | act- ing as a fu- ture teac  | ρ              | 0.183              | 0.039            | 0.021   | 0.251  | 0.319  | 0.227   | 0.282  | 0.341* | 0.362* | 0.164  |
| ≶ 0  | as in the fact that the fact t | p-value        | 0.292              | 0.826            | 0.907   | 0.145  | 0.062  | 0.189   | 0.101  | 0.045  | 0.033  | 0.346  |
| - L  | ex-<br>pe-<br>ri-<br>enc<br>es   | ρ              | -0.078             | -0.025           | -0.274  | -0.033 | 0.18   | 0.425*  | -0.034 | 0.157  | 0.061  | -0.225 |
| ž  |  | p-value        | 0.657              | 0.888            | 0.111   | 0.852  | 0.3    | 0.011   | 0.845  | 0.369  | 0.726  | 0.193  |
| * correlat   | ion is significant at level  | 0.05; ** corre | elation is signifi | cant at level 0. | 01      |        |        |         |        |        |        |        |
|  |  |                |                    |                  |         |        |        |         |        |        |        |        |

**Table** *A3.* Correlations (spearman-correlation) between Interest in geography and measurement of the CG in pre- and post-test (N=19)

|                                 |                   |         | 'I find the su<br>raphy int |        | 'I enjoy the<br>ogra |        | 'I am particularly inter-<br>ested in natural phenom-<br>ena in geography' |         | 'What interests me<br>most about geography<br>is the interaction be-<br>tween people and the<br>environment' |        | 'I am particularly<br>interested in socio-<br>spatial structures<br>and processes in<br>geography' |        |
|---------------------------------|-------------------|---------|-----------------------------|--------|----------------------|--------|--|---------|--|--------|--|--------|
|                                 |                   |         | Pre                         | Post   | Pre                  | Post   | Pre  | Post    | Pre  | Post   | Pre  | Post   |
|                                 | value-based       | ρ       | 0.614**                     | 0.434  | 0.728**              | 0.482* | 0.720**  | 0.099   | 0.472*   | 0.472* | 0.08   | 0.437  |
| to be a section by a            | value-pased       | p-value | 0.005                       | 0.063  | <.001                | 0.036  | <.001  | 0.688   | 0.041  | 0.041  | 0.743  | 0.061  |
| Interest in the topic of biodi- | amatianal         | ρ       | 0.384                       | 0.227  | 0.519*               | 0.273  | 0.651**  | 0.619** | 0.433  | 0.45   | 0.023  | -0.157 |
| versity                         | emotional         | p-value | 0.105                       | 0.351  | 0.023                | 0.258  | 0.003  | 0.005   | 0.064  | 0.053  | 0.925  | 0.522  |
| versity                         |                   | ρ       | 0.305                       | 0.344  | 0.470*               | 0.326  | 0.775**  | 0.341   | 0.143  | 0.309  | -0.125   | -0.041 |
|                                 | intrinsic         | p-value | 0.204                       | 0.149  | 0.042                | 0.173  | <.001  | 0.154   | 0.559  | 0.199  | 0.612  | 0.867  |
| Dia di caratt                   |                   | ρ       | -0.324                      | -0.031 | -0.325               | -0.01  | -0.133   | 0.008   | 0.257  | -0.14  | 0.098  | -0.312 |
| Biodiversity in cities          |                   | p-value | 0.176                       | 0.899  | 0.175                | 0.969  | 0.588  | 0.972   | 0.289  | 0.567  | 0.689  | 0.193  |
| Perceived re-                   | internal          | ρ       | 0.089                       | -0.092 | 0.105                | -0.119 | 0.23   | 0.161   | 0.211  | 0.011  | -0.04  | -0.037 |
|                                 |                   | p-value | 0.716                       | 0.707  | 0.669                | 0.628  | 0.343  | 0.511   | 0.387  | 0.965  | 0.871  | 0.882  |
| sponsibility for                | external          | ρ       | -0.198                      | -0.049 | -0.119               | -0.023 | 0.236  | 0.344   | 0.09   | -0.018 | -0.191   | -0.131 |
| the protection                  | (economy)         | p-value | 0.415                       | 0.842  | 0.629                | 0.927  | 0.33   | 0.149   | 0.716  | 0.941  | 0.434  | 0.594  |
| of biodiversity                 | external          | ρ       | -0.174                      | 0.095  | -0.033               | 0.103  | 0.088  | -0.033  | -0.187   | -0.029 | -0.206   | 0.143  |
|                                 | (state)           | p-value | 0.477                       | 0.7    | 0.894                | 0.675  | 0.719  | 0.892   | 0.443  | 0.908  | 0.398  | 0.56   |
| Awareness                       | £ 41 4-           | ρ       | 0.388                       | 0.304  | 0.512*               | 0.349  | 0.455  | 0.486*  | 0.365  | 0.201  | 0.094  | 0.008  |
| Awareness                       | or tiffeats       | p-value | 0.1                         | 0.205  | 0.025                | 0.143  | 0.05   | 0.035   | 0.124  | 0.41   | 0.703  | 0.974  |
|                                 | public action     | ρ       | 0.471*                      | 0.314  | 0.382                | 0.33   | 0.482*   | 0.564*  | 0.081  | 0.296  | -0.177   | -0.091 |
|                                 | public action     | p-value | 0.042                       | 0.191  | 0.107                | 0.168  | 0.037  | 0.012   | 0.741  | 0.218  | 0.469  | 0.712  |
| Willingness to                  | private ac-       | ρ       | 0.3                         | 0.398  | 0.431                | 0.431  | 0.286  | 0.359   | 0.33   | 0.183  | 0.109  | -0.021 |
| act to protect                  | tion              | p-value | 0.213                       | 0.092  | 0.065                | 0.066  | 0.236  | 0.131   | 0.365  | 0.453  | 0.658  | 0.931  |
| biodiversity                    | acting as a       | ρ       | 0.510*                      | 0.506* | 0.656**              | 0.513* | 0.673**  | 0.547*  | 0.397  | 0.414  | 0.153  | 0.005  |
|                                 | future<br>teacher | p-value | 0.026                       | 0.027  | 0.002                | 0.025  | 0.002  | 0.015   | 0.092  | 0.078  | 0.532  | 0.984  |
| Noture                          | orionoos          | ρ       | 0.158                       | 0,216  | 0.245                | 0.18   | 0.510*   | 0.253   | -0.204   | 0.021  | -0.253   | -0.078 |
| Nature exp                      | eriences          | p-value | 0.517                       | 0.374  | 0.312                | 0.46   | 0.026  | 0.296   | 0.401  | 0.932  | 0.296  | 0.75   |

# A.4. Correlations Motivation through VR

Table A4. Correlations (spearman-correlation) between motivation through VR and measurement of the EG (post-test) (N=35).

|   |                         |   |                      | Motivation through VR |                    |
|---|-------------------------|---|----------------------|-----------------------|--------------------|
|   |                         |   | Interest / enjoyment | Perceived choice      | Pressure / tension |
| 1   | value-based             | ρ | -0.343*              | -0.063                | 0.014              |
| Interest in the topic of biodiversity                               | emotional               | ρ | 0.016                | 0.282                 | -0.164             |
| piodiversity  | intrinsic               | ρ | -0.155               | -0.045                | 0.166              |
| Biodiversity ir   | n cities                | ρ | -0.052               | -0.052 -0.173         |                    |
| Daraniyad raspansibility  | internal                | ρ | 0.105                | 0.449**               | -0.126             |
| Perceived responsibility<br>for the protection of bio-<br>diversity | external (econ-<br>omy) | ρ | -0.072               | 0.077                 | -0.117             |
| ulversity   | external (state)        | ρ | 0.14                 | 0.406*                | 0.236              |
| Awareness of  | threats                 | ρ | -0.366*              | 0.142                 | 0.061              |
|   | public action           | ρ | -0.333               | -0.084                | -0.092             |



| Willingness to act to pro-<br>tect biodiversity   | private action                | ρ | -0.058 | 0.424* | -0.063 |  |  |  |
|---|-------------------------------|---|--------|--------|--------|--|--|--|
|   | acting as a future<br>teacher | ρ | -0.026 | 0.277  | 0.217  |  |  |  |
| Nature expe   | Nature experiences            |   | -0.041 | 0.009  | -0.061 |  |  |  |
| * correlation is significant at level 0.05; ** correlation is significant at level 0.01 |                               |   |        |        |        |  |  |  |

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