Virtual Reality Immersion – An Eco-consciousness Machine

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1.0 Introduction

The feeling of driving through Texas to reach the remote Devils River was an (IRL) immersive experience all on its own – driving home a significant point of pride in the Texas landscape, a love for the plants, terrain, people, species, history, and future alike. The arrival to the lodging along the Devils River, stepping out onto the edge of the decking created a feeling of being in another world, yet knowing it is just another place on Earth, struck a new nerve of eco-consciousness. Prior to visiting, the research and facilitation team knew stewarding the watershed is/was/would be/will be/has always been truly vital to the health of the environment and local habitats. After arriving, the deep sense of presence, an arrival to self via these beautiful vistas, the transcendental experience of being a small piece to the massive puzzle, was deeply moving, and instilled a deeper sense of responsibility for this watershed.

One issue arose during the development of the State of the Devils River Watershed Report: how can this innate understanding of the importance of stewarding this resource and habitat be shared with those that do not have the means to frequent the area? One potential solution may lie within modern technological advances through VR. The IRL immersive experience of place, belonging, and presence within the Devils River watershed begs the question: Through the concept of presence, can Virtual Reality experiences support the development and integration of a stewardship mindset through learning, understanding, and a sense of presence?

2.0 Literature Review: Fostering stewardship mindset through Virtual Reality

As populations increasingly move toward urban and digital environments, the experience of the outdoors and natural environments is not only becoming less accessible due to urban sprawl, but it is also becoming a leisure activity for the affluent rather than a wholesome experience for all. This divergence of human experience from our natural spaces increases a lack of awareness, understanding, and connection to environmental concepts and reduces the capacity for urban populations to develop a deep, stewardship mindset: “The limiting of immersive and kinesthetic learning explorations and authentic meaning-making is problematic to biocultural conservation efforts and the formation of eco-consciousness” (Dussler et al., 2023, p. 1). This particular problem was highlighted during an interview with Dell Dickinson, a legacy landowner along the Devils River, and several conversations with Dani Miller, the communications manager for the Devils River Conservancy, during the 2024 development of the State of the Devils River Report which was published in 2025. During this experience, it became clear that through virtual reality

(VR), the development of an immersive-edutainment experience could bridge gaps in the relationship between urban mindsets and environmental stewardship mindsets.

VR has been recognized as a tool for education by means of entertainment via immersive experiences (Mulders et al, 2020). The hypothesis is that VR may be a transformative tool for fostering a stewardship mindset as it relates to care and reverence for natural environments by offering alternative access to immersive, environmental edutainment experiences. This literature review synthesizes research on how VR can support the cultivation and communication of environmental stewardship ideals by effectively *increasing* rather than "limiting...immersive and kinesthetic learning explorations" and "authentic meaning-making" to facilitate "the formation of eco-consciousness" as Dussler et al. (2023, p. 1) outline in their article, while focusing on mechanisms of edutainment such as presence, experiential learning, perspective-taking, and immersive storytelling.

2.1 Enhanced Engagement via Immersive Learning

Much evidence has been collected to indicate that "edutainment" platforms can greatly increase student engagement and enhance comprehension and application outcomes, as noted in my own previous research which can be accessed here. When diving into the literature regarding VR-specific educational outcomes, particularly for environmental learning, the findings are aligned. For instance, Sahabuddin and Makkasau (2024) found that by simulating consequential circumstances such as environmental degradation, VR evoked emotional responses resulting in positive shifts in environmental attitude and adjusted behavior (Positive Environmental Behaviors or PEBs as the authors distinguished). Similarly, Fauville et al. (2021) found in their study on participatory research that VR, when used in combination with other teaching methods, could enhance empowerment of students to change behaviors by simulating impacts of their daily behaviors on oceans and through visualizing chemical bonds and reactions which are unseen to the naked eye. Participating educators in this study confirmed "empowerment, perspective-taking and visualization as the three principal avenues through which virtual reality [may result in PEBs]" (Fauville et al., 2021, p. 1).

2.2 Immersion, Environmental Edutainment, Presence, and Empathy in Virtual Reality

The inherent visual and auditory immersion within VR augments a sensation and experience of deep presence—a feeling of truly "being there" in a simulated environment or world. More specifically, *presence.* Presence being the "unmediated" experience of being immersed (Lombard and Ditton, 1997). Immersion being the sensorial exclusion of the exterior world (Cummings and Bailenson, 2015, p. 6). The emotional responses evoked from such visceral experiences have the capacity to influence PEBs and reduce impacts from IRL visitors. Su et al. (2024, p. 9) found in their study on the relationship between VR tourism (VRT) and environmentally focused behaviors that "[t]he sense of ecological presence evoked by VRT scenarios significantly affected biospheric values, personal norms, and environmental self-

identity" ultimately resulting in more positive PEBs from tourists. This study also finds that a powerful conceptualization of VR can be “ecological presence” (Su et al., 2024 p. 2, 9). Additionally, utilizing VR as a mechanism for immersion within environmental or historical sites, the need for tourists’ physical presence at each site was reduced, resulting in lower maintenance costs and reduced ecological impacts (Esmi & Hashemi, 2025). They also note that these experiences can positively impact tourist behaviors toward environmental stewardship if they visit the site after a VR experience of the location beforehand.

2.3 Perspective-Taking and Lasting Mindset Changes

Through immersive narrative, VR offers the option to create first-person perspectives on memory and passing time. The opportunity to proverbially and virtually walk in another’s shoes allows audiences to explore vastly differing realities, potential outcomes, and consequences of choices and behaviors. Seeing these narratives take shape from that first-person perspective through VR may help cultivate a sense of responsibility for environmental stewardship. Abouata Amlashi, E., & Adiloglu, F. found in their study of ethics in VR narrative immersion that this medium “[allows] for a deeper engagement with ethical...complexities” (2025, p. 1361). These findings can be directly applicable to environmental stewardship through immersive ecological dilemmas in various immersive augmented “natural” settings. Gruenewald, T., & Chen, C. found in their study of narrative VR content’s ability to share and receive memories that the medium of VR ultimately expands creator tools for narrative development, “such as the immersive first-person perspectives...that have a particular relevance for sharing a memory,” which are not found in other media types such as books, flat films, etc. (2025, p. 1323). By offering immersive first-person memory experiences of place, these findings could be applied to environmental experiences and memories of displacement or changing environmental conditions over time.

2.4 Embodiment and Heurism Drive Positive Outcomes

Pi et al found in their study of VR climate scenarios’ influence on immsersants’ real-world behaviors that through immersive, simulated experiences of climate changing over the course of three generations, the abstract and complex issue of climate change was made more tangible. This unique function of VR resulted in an effect of the scenario on the carbon footprint response of participants, even 6 weeks after the VR exposure, irrespective of condition. Additionally, increases were found in participants’ perceived influence on climate action and engagement in pro-environmental behaviors, with the embodied group showing a more pronounced response in the short term. Similarly, Shin, M., & Lee, H. found in their study regarding 360 pro-environmental campaign messaging that not only does the sense of presence created by immersive technology increase the positive reception of environmental campaigning, but the ability to more heuristically engage with these messages through these 360 experiences can have more lasting positive results.

VR's unique combination of presence, experiential learning, and perspective-taking makes it a potent tool for cultivating and communicating a stewardship mindset. By immersing users in meaningful scenarios, enabling authentic interactions, and facilitating reflection on values and consequences, VR can help individuals and organizations develop the confidence and commitment needed for responsible leadership and environmental care.

VR can empower individuals to engage in stewardship practices by instilling a sense of presence, creating immersive learning experiences, providing meaningful perspective-based and heuristic dilemma processing, and more. Each of these sources identify ways in which immersive content can positively influence audience attitudes toward and understanding and perceptions of ecological concepts and stewardship, resulting in lasting mindset shifts and positive environmental behaviors.

3.0 Conceptual Framework: Virtual Reality, Presence, and Stewardship

Central to the conveyance and development of a stewardship mindset, or “eco-consciousness" as Dussler et al. describe it, is not just immersion, but a true sense of presence within the environment established through interactivity, heuristic elements and self-guided exploration, and general use of one’s own senses. Understanding presence, how it is established within the context of VR, and evaluating its contributions to positive environmental attitudes and behaviors – similar to that of the experience of arriving at the Devils River–is key to evaluating the validity of the research question.

3.1 Presence and Immersion in VR

A conceptual framework for understanding presence in the context of virtual reality, presence and experience on empathy, memory, comprehension, retention, learning, and action/application will be imperative for determining if VR is an effective method for influencing stewardship mindsets for those not affiliated with environmental work already. Drawing from the work of Cummings and Bailenson (2015) as well as Lombard and Ditton (1997), we can begin to define the experience of presence. This definition will then be used to examine immersive experiences’ effects on learning, empathy, and thus potential for shifts in mindset toward stewardship.

Presence as defined by Lombard and Ditton (1997) is the illusion of “nonmediation” such that a consumer is so immersed that they no longer recognize or experience the technological contributors to an experience, and thus act and respond in such a way as if the technological contributor did not exist – hearing aids or prescription lenses were their examples of choice (Lombard and Ditton, 1997). As Cummings and Bailenson (2015, p. 6) note, there are two types of presence: spatial and social. For the purposes of this research, we will focus mainly on spatial (as environmental) presence as noted to be “the superordinate feeling of being located within a virtual space” and its role in fostering stewardship mindsets (Cummings and Bailenson, 2015, p. 6). When learning about environments that differ from one's local environment, or even when

learning environmental concepts in a classroom, there are limitations to experiencing these concepts in action. This can create a sense of separation from the concepts or consequences, which can create difficulties for both instructors and students to ground their knowledge without experiencing natural phenomena where they occur. Offering real-time, immersive learning opportunities for knowledge application or for experiential learning within a spatial area has been shown repeatedly to increase retention, comprehension, and application, and a sense of presence within these natural landscapes instills a deeper level of understanding, care, and sense of relationship with the environment, thus creating longer lasting positive behavioral outcomes.

In VR this illusion of nonmediated presence can be achieved via immersion – a general shutting out of the exterior world via sensorial satisfaction combining both the technological stimulation of sensorial presence and crafting psychological phenomena "representing the extent to which an individual experiences the virtual setting as the one in which they are consciously present" (Cummings and Bailenson, 2015, p.3). In other words, the experience of presence in VR is dependent upon the degree to which immersion is achieved, thus actively crafting belief in the experience rather than "willingly suspending disbelief" (Gruenewald and Chen, 2025, p.1315).

Presence is deeply connected to immersion within VR experiences. Being immersed is ultimately an overwhelm of the senses such that one forgets they are within a simulation. When these senses are overwhelmed to the correct degree, a feeling of presence can be achieved. The experience of immersion within VR is dependent upon several factors, namely visual input (responsive user tracking for realistic simulation of three-dimensional [spatial] perspective), audio input (the illusion of spatiotemporal audio created by volume changes if "nearby" or "farther away"), and interactivity (the agency provided to the user/immersant to pick up objects, make choices, and otherwise engage with the setting, characters, narrative, etc.) (Cummings and Bailensen, 2015, pp. 26-27), By utilizing immersive tools to effectively transport an immersant's consciousness to a virtual reproduction of an environment, (theoretically) a sense of presence may be instilled.

3.2 Empathy: Realism and Perspective-Taking

Plausibility and place illusion both contribute to a sense of presence and can impact empathy by crafting an illusion of perspective. Plausibility (such that the immersant is able to believe simulated events are truly happening) and place illusion (such that an immersant feels "there" in the virtual environment) go hand-in-hand in crafting a sense of realism within the world of immersive technologies (Slater et al., 2022, p. 1). This plausibility and sense of place contribute to conceptual presence within a VR environment. Plausible presence within a virtual place ultimately results in a sense of perspective–either as amorphous witness or voyeur (as experienced in *IT: Float* [SunnyBoy Entertainment, 2017]), embodied bystander (as experienced in *Traveling While Black* [Williams and Nadarajah, 2019]), or as first-person actor and receiver (as experienced in *The Party* [Majumdar and Guardian News and Media, 2017]).

Herrera et al. (2018) describe VR as allowing "users to vividly and viscerally experience any situation as if it were happening to them from any perspective" and argue crafting a *first-person* perspective within an immersive VR experience can be used as a driver of empathy. While the validity of VR as an empathy machine is under critique (Hassan, 2020, p. 208) the general consensus of the MC5339 course students (course discussion, October 16, 2025) seems to be that though it is a fraught argument, VR is still a *more* successful medium for developing empathetic responses (via its affordance of first-person perspective-taking) than other flat storytelling media due to the unique tools available in immersive media.

VR perspective-taking (VRPT) was found by Herrera et al. (2018, p. 1) to result in "more positive, longer-lasting attitudes" in participants that had experienced homelessness within a VR-simulated experience than those that had not experienced the VR simulation, and that participants from the immersed group were more likely to take supportive action outside of the experience than other groups. These findings show that while VR may not directly craft empathy, positive and empathetic outcomes can certainly be influenced by VR experiences.

3.3 Stewardship: Eco-Consciousness, Place-based Learning, and Interactivity

Utilizing valuable education and learning research, some educational theories can be applied within the VR worlds and may connect VR immersive experiences to environmental educational and thus stewardship mindset outcomes through presence theory within VR Place-based learning (PBE) is described by Yemini, Engel, and Simon (2025) as prioritizing "experiential, community-based, and contextual learning in order to inculcate students with a sense of civic identity and engagement" by utilizing ethical/empathetic decision-making to ground a sense of common good as valuable.

Dussler et al. (2023, p.1) use PBE to argue that eco-consciousness and a stewardship ethic can be fostered via immersive "eco-phenomenological, personally relevant experiences." In this case, the perspective is that of the observer, usually IRL, thus grounded within your own kinesthetic and sensory experience, rather than an augmented experience from the perspective of a nonhuman stakeholder (i.e. bugs, deer, water droplets, etc.). They also posit that "Informal [or unconventional] science programs serve a vital function in connecting a variety of learners to scientific knowledge in personally meaningful contexts (Dussler et al., 2023, p. 513)." These arguments are made specifically referring to IRL nature experiences, though considering the affordance of VR to mediate a sense of presence within simulated natural environments, this could be similarly applied to VR explorations of virtually recreated natural environments (VRNE) via place illusion. Furthermore, Talgorn and Ullerup (2023, p. 1) define stewardship as "empathy for the Planet as a holistic relationship with human and nonhuman stakeholders" and call for participatory storytelling to be utilized as an engaging tool for fostering such empathy. The affordances of VR offer the opportunity to perhaps utilize the medium to craft a first-person perspective of a nonhuman stakeholder–ultimately crafting a sense of empathy or empathetic

response toward the nonhuman stakeholder taking Talgorn and Ullerup's call to action to another level of participatory.

Han (2025, p. 1) found in their study on gamification and interactivity (generally within more flat media) that "Learners' academic performance improved significantly in [an] interactive environment." By connecting the nature experience, or VRNE, to this sense of presence and the affordances within VR technology to provide heuristic interactivity, the possibilities of VR enhancing learner engagement become evident. Ahn, Nowak, and Bailensen (2022, p. 11), however, recognize there are limitations of spatial learning within VR, particularly given such issues as cybersickness and negative effects on information recall. However, the question here arises, if the focus is less on specific information recall, and more on empathetic mindset shifts, are these limitations still relevant?

By crafting a sense of presence through plausibility and place illusion via immersive tools, and through the principles of environmental and interactive education, a use-case for VR to influence stewardship mindsets via virtually recreated natural environments arises. While limitations exist, this medium does pose an experientially rich environment in which to explore, expand one's world via virtually immersive platforms, and to safely engage with potential outcomes in decision-making scenarios. An argument could certainly be made that nothing will beat the IRL experiences for grounding a sense of environmental responsibility, however, this method may be viable for bringing natural experiences to those that may not have the means to travel to an IRL natural area.

4.0 Methods + Case Studies

Nature-based Virtual Reality experiences vary widely from 360 footage spliced together with no narration, to weather and climate simulators, to interactive gardening and bug games, and infinitely more. Each of these experiences has the potential to create a sense of presence and enhance both learning and connection, thus fostering a stewardship mindset. Interchanging stewardship mindset with the eco-consciousness term from Dussler et al., ultimately defined as "the formation and expression of a vital ecological selfhood [as] a catalyst to care for natural spaces (Dussler et al., 2023, p. 508)," we can determine the degree to which each of the following case studies may be able to foster such a mindset shift. As Dussler et al., argue, immersive learning (in their research context, it is meant within physical environments, though here we will apply the concept to VRNE) can indeed develop the relationship of students with their environments and craft an appreciation for natural environments – resulting in stewardship mindsets through achieving eco-consciousness with a sense of deep presence. Presence theory in Virtual Reality necessitates immersion and a number of other tools, yet this feeling of presence can intensify that connection to nature and result in an eco-consciousness experience, likely influencing a feeling of connection with natural environmental components – thus enhancing a

sense of responsibility, appreciation for, and dedication to stewarding real, natural resources and environments.

To explore this sense of presence, place-based immersive learning, and the degree to which VR experiences may be able to achieve a similar eco-conscious mindset, several case studies will be evaluated. Table 1 is a chart of evaluated experiences and criteria developed from tools and concepts established in the literature review. For the purpose of this research, only freely accessible games were evaluated; accessibility and barriers to entry will be discussed in the findings and recommendations for future study.

Table 1. *Virtual reality case studies and evaluation criteria for presence and stewardship mindset*

VR Experience	Ocean of Light Dolphins VR	Embrace German Nature	Sea Level Rise Explorer
Platform	Media Player	Meta Horizon App	Meta Horizon App
Cost	Free	Free	Free
Experience Type	Passive 180 Video	Interactive Action/Adventure	Narrative + Interactive Simulation
Barriers to Entry?	Minimal (Free, non interactive, narrated, no closed captioning, less than 1hr long)	Moderate (free, some instructional narration, non-intuitive controls, instructions did not always work in practice, activities less than 1 hr long)	Minimal (free, instructional narration, multiple lanugages, closed captioning, less than 1 hr long)
Scenario	180 degree film of free diver with dolphins, narrated by the free diver.	Multimple scenarios available - VR exhibition of Germany tourist destinations and activities (activity selected for evaluation: spalunking)	West Palm Beach at 2022 sea level, two other storm scenarios, and future green infrastructure scenarios
Established Perspective	Amorphous voyeur	Amorphous interactive bystander	Amorphous interactive bystander
Sensory Engagement	Auditory, visual, no kinesthetic engagement	Auditory, visual, high kinesthetic engagement	Auditory, Visual, minimal kinesthetic engagement
Heuristic Engagement	N/A - passive consumption	High - personal choice for activity selection, low instructions, high problem solving	Minimal - active influence on scenario examples, only three static scenarios provided
Dilemma Presented?	N/A - passive consumption	No dilemma presented other than solving the hand and footholds.	Sea level rise in west palm beach - mitigation strategies, consequences without mitigation were presented
Presence Achieved?	Yes - despite not being interactive with the surroundings, and the video being only 180 degrees rather than 360, the depth of field and quality of visuals felt like I was there underwater with them	Yes - sensory satisfaction of spatiotemporal audio, high kinesthetic engagement, clear visuals and height adjustment for realistic perspective.	Yes - multiple angles, initial intro to the space and narrative orientation
Degree of Presence (1-5)	4 - graphics clearly real-world footage, visual + auditory senses were satisfied, kinesthetic engagement was not part of this experience	4 - graphics clearly digital modelling, visual, auditory, and kinesthetic senses were satisfied in a relatively realistic manner	3 - graphics clearly digital modelling, table model was not in focus (headset was adjusted to confirm it was graphics not user error)
Intuitive Navigation + Controls?	N/A	Moderate - instructions provided, though not all instructions functioned properly	High - plus instructions
Notes	Despite the lack of any interactivity of this experience, the quality of the visuals created a sense of presence within the environment. Though the perspective was non-interactive voyeur, the narration was clearly directed to the immersant, thus bringing in the voyeur and making the narrator more of a guide - similar to a deep-sea safari experience. Ultimately this indicates an expansion of reality as another tool for effective communication about the natural world.	The landing spot within the exhibition is confusing - there are so many choices laid out in such a variety of ways that it removes the immersant from the experience somewhat initially. The spelunking experience did achieve a sense of presence, and excitement for visiting the caves of Germany. It also created a sense of understanding what spelunking may look like for those unfamiliar - offering a relativley safe space to explore this type of engagement with a natural environment prior to IRL experience. There were no notes about the rock formations or the natural surroundings.	Effectively demonstrated sea level rise from multiple angles and perspectives, and offered positive environmental behavior solutions to mitigate effects of sea level rise and to harness this natural phenomenon to the community's advantage. Used audio recordings of community members to articulate the area's impact on the community and what the loss of the area would mean to them, without instilling a sense of despair, and ended on a positive outlook for disaster mitigation and created a sense of agency to positively influence strategies and planning.

The types of VR experiences explored include a passive-consumption 180° video (*Ocean of Light Dolphins VR*), an action/adventure game (*Embrace German Nature*), and an interactive demonstration (*Sea Level Rise Explorer*). Several descriptive data points were gathered in Table 1, though the evaluative criteria were whether navigation and controls were intuitive, established perspective type, degree of sensory and kinesthetic engagement, degree of heuristic engagement, introduction of dilemma presentation, and thus degree of presence achieved. Other observations regarding potential contributing factors outside of the establishment of presence to the overall end of influencing stewardship mindsets were also noted.

4.1 Ocean of Light Dolphins VR

Ocean of Light Dolphins VR is a 180° immersive video of a free diver exploring the ocean with dolphins. The free diver, Ashleigh Baird, narrates the experience, both explaining dolphin cultural norms and the benefits and challenges of free diving with them. The technical coding of this experience does not allow for screenshots or recordings, so no visuals will be provided from inside the experience. Ultimately, despite the limitations of the 180° video, a plausible sense of presence and "being there" was achieved and drove a new-found appreciation for dolphins. The high quality of the graphics was imperative for creating such a plausible experience and developing a feeling of nonmediated presence. However, this feeling could easily be interrupted by looking too far to one direction – anything outside of the main frame of video content was a black abyss, reminding the immersant of the technology behind the experience.

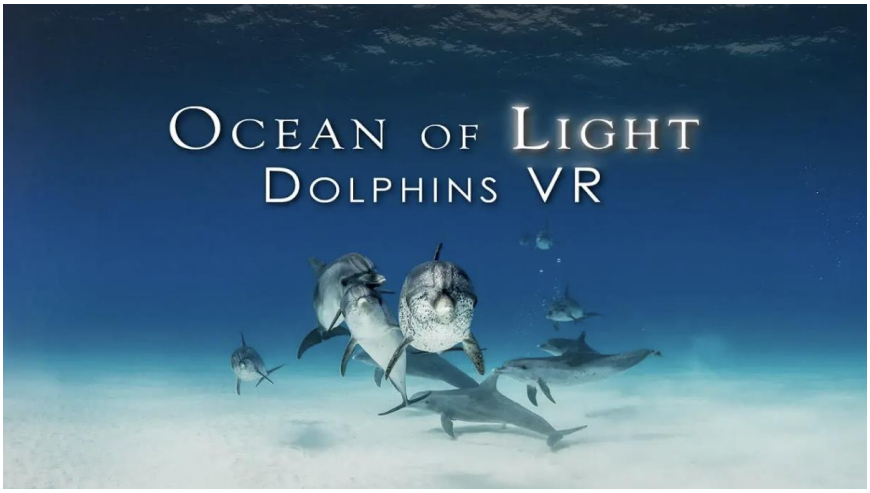

***Figure 1**. Still image of title sequence from Ocean of Light Dolphins VR (source).*

This method of carefully crafting a 180° immersive video is relatively effective in this research context, though the limitations of the visual boundaries present complexities in maintaining a sense of nonmediated presence. Despite the limitations, it is a clear demonstration of the power of VR technology as an expansion tool for educators – safely immersing learners in a natural

habitat that would otherwise be inaccessible and relatively life-threatening without proper training and gear. Training is both time consuming and expensive, not including gear, travel, and guides for an IRL experience of a similar nature. This type of semi-immersive (albeit passive) content presents an opportunity to create a similar yet more immediate and less expensive experience, ultimately making this option more accessible.

The question arises, "Is the passive consumption of 180° video significantly different than consuming this type of content passively via flat media or near immersive media such as iMax?" When considering the affordance of perspective-taking even within a limited scope of vision, motion tracking of the user's head movements and subsequent visual adjustments (Bujić et al., 2025, p. 1) actively craft a more interactive and lesser-mediated experience than when consumers are able to see and hear IRL contexts such as a frame, other seats in an auditorium, etc. This visual exclusion of the IRL context and motion tracking-created perspective-taking contributes greatly to the psychological plausibility of the sense of presence, thus enhancing the experience further than a flat version of the same content.

Could passive consumption of this type of VR content contribute to PEBs in immersants? The feeling of being there contributes to an attachment to or deeper appreciation of the natural habitat in which the sense of presence is established. Through presence, and thus attachment, empathy for surroundings, animals, etc. can be developed, ultimately achieving what is described as place-based attachment. This phenomenon has been extensively investigated by conservation researchers in regard to community science (usually volunteers from local communities to support conservation needs and efforts, see Texas Stream Team for what community science can look like). Newman et al. define place-based attachment or "the power of place" as "actions motivated by the emotional, cultural and material connection that many people have for the place in which they live, sometimes expressed as 'love' or 'attachment to place' (Newman et al., 2017, p. 56)." Ultimately, this type of attachment and love of place can lead to PEBs, and thus a shift toward not just a stewardship mindset, but a stewardship ethic and action in those experiencing such a connection.

4.2 Embrace German Nature

Embrace German Nature is an immersive gaming experience centered around nature tourism opportunities in Germany. The initial spawn site of this VR experience offers a variety of virtual nature tourism experiences to select from. The spelunking option was selected for evaluation in this particular research context, as one of the action/adventure features presented. To enter the spelunking game, the immersant places their hands as designated on a rope leading to the top of a rock formation – then the screen fades to black, and the immersant spawns inside a cave. Once in the cave, a disembodied narrator provides verbal instructions on controls for climbing the rope through the cave and up to a simulated vantage point.

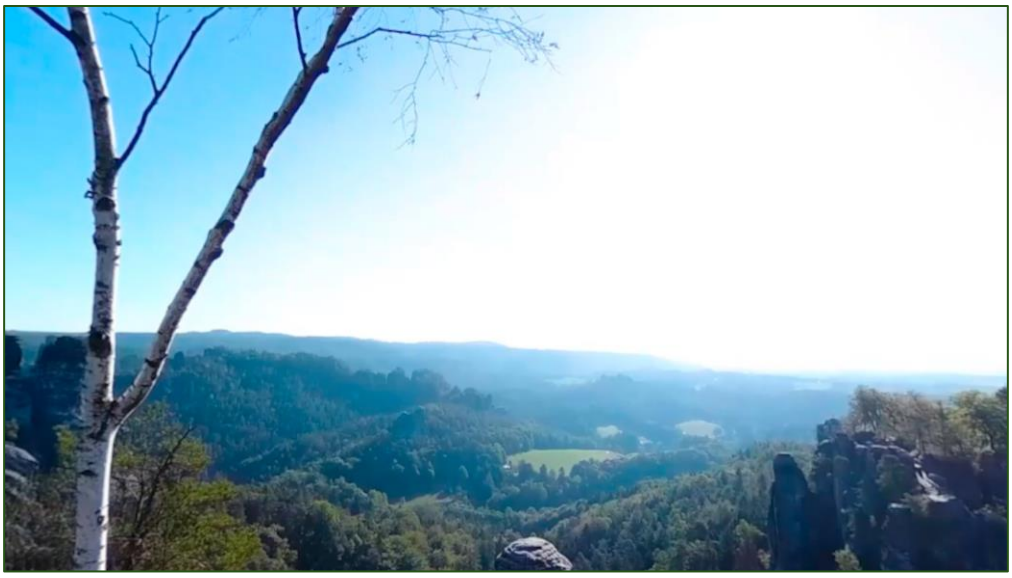

Figure 2. *Simulated vantage point,* Embrace German Nature *spelunking experience*

Despite there being basic verbal instructions for controls, some exploration and discovery was required in order to navigate the virtual cave. Trial and error with virtual "hand holds" and placement, along with facings and taking risks to hold the virtual rope without knowledge around whether it will hold weight or let the immersant fall and force a respawn, all contribute to heuristic problem solving while engaging in kinesthetic experience of the virtual space. The immersant is required in this experience to stand, stretch, "grab," and reach in all directions. The combination of heuristic discovery, independent problem solving, and kinesthetic involvement and challenge results in a deep sense of presence – the outside world completely shut out.

Figure 3. *Hand holds and climbing,* Embrace German Nature *spelunking experience*

Not only is a sense of presence a significant outcome of this virtual exercise, but the feeling of accomplishment when the course is completed arises, as well. Independent problem solving, physical release of endorphins from exertion, along with the fantastic vista presented at the end of the rope, all work in tandem to craft a connection to this game. These positive associations are likely contributors to a positive outlook on spelunking or drive an interest in visiting the locale this experience was designed around, similar to the outcome found in Pi et al.'s study on climate scenarios effects on participants behaviors.

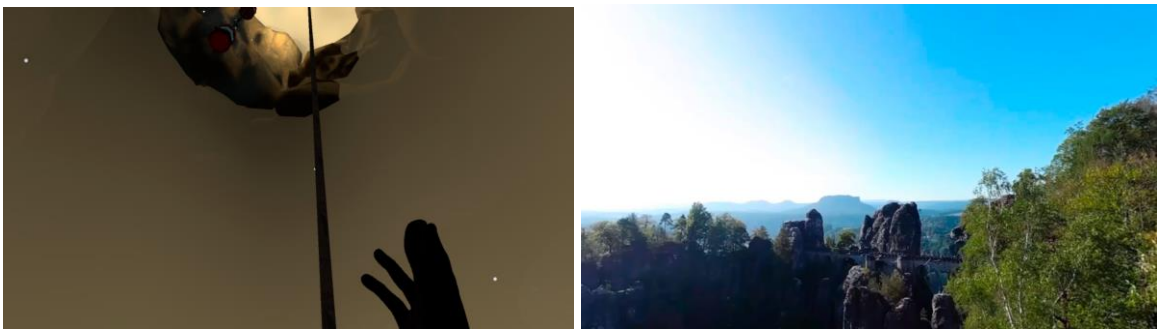

Figure 4. *End of rope and fantastic vista,* Embrace German Nature *spelunking experience*

One aspect that did not arise was a discussion of the natural environment itself. The experience was within a digital recreation of a natural environment, though the narration did not discuss any of the rock formations, the geographical location or significance, or what sort of species may be found in that area. This creates a challenge to argue its significance within the stewardship mindset framework, however the mere fact that a positive engagement can be experienced through heuristic discovery and reward within a simulated natural environment may be enough to override the lack of direct discussion.

4.3 Sea Level Rise Explorer – West Palm Beach

Sea Level Rise Explorer is an immersive model and simulator of sea level rise in West Palm Beach. The spawn site (Figure 5) is a digital recreation of one of the waterfront parks in the area, and straight ahead is a table with a scale model and a screen above it. Upon approach, a disembodied narrator discusses the value of the park in the community, sea level complications, and some of the concerns and considerations associated with it. Then the narration guides the immersant through instructions on ways to influence the simulation via the model on the table (Figure 7). Once the scale model simulations have been explored, the immersant is taken on a "blimp" ride to view the location and simulation from a different angle (Figures 6 and 8). After a few different sea level rise scenarios are displayed, the immersant is taken to a new screen to see a positive outlook future scenario that incorporates storm infrastructure and green infrastructure to protect the area (Figure 9).

Figure 5. *Spawn point at Osprey Park,* Sea Level Rise Explorer

This VR experience of rising sea levels was a relatively seamless experience for the immersant. It offered multiple languages at the start of the experience, an option for closed captioning, and both verbal instructions and highlight indicators for recommended actions. These facilitation tools reduced the feeling of mediation by keeping the immersant engaged and by not introducing complications to pull the immersant out of the experience.

Figure 6. *Two examples of self-location methods,* Sea Level Rise Explorer

The digital modeling was an effective tool despite being out of focus. This poor image quality contributed to an increased sense of experience mediation, but the other sensory inputs such as sound, visual simulation, and interactivity were enough to override the distracting image quality and develop a sense of presence. To help ground a sense of presence and location identification, the blimp ride provided another perspective and supported a feeling of understanding of place and self-location within the digital recreation, as depicted in Figure 6.

Figure 7. *Interactive scale model flooding simulation,* Sea Level Rise Explorer

Both by crafting some empathy through the testimonials of community members looking at the simulation along with that sense of place and perspective, this simulation uses both presence and empathy to achieve what is described as place-based attachment. This phenomenon has been extensively investigated by the conservation community in regard to community science (usually volunteers from local communities to support conservation needs and efforts, see Texas Stream Team for what community science can look like). Newman et al. Define place-based attachment or "the power of place" as "actions motivated by the emotional, cultural and material connection that many people have for the place in which they live, sometimes expressed as 'love' or 'attachment to place' (Newman et al., 2017, p. 56)." Ultimately, this type of attachment and love of place can lead to PEBs, and thus a shift toward not just a stewardship mindset, but a stewardship ethic and action in those experiencing such a connection.

Figure 8. *Blimp ride to view flooding effects from above,* Sea Level Rise Explorer

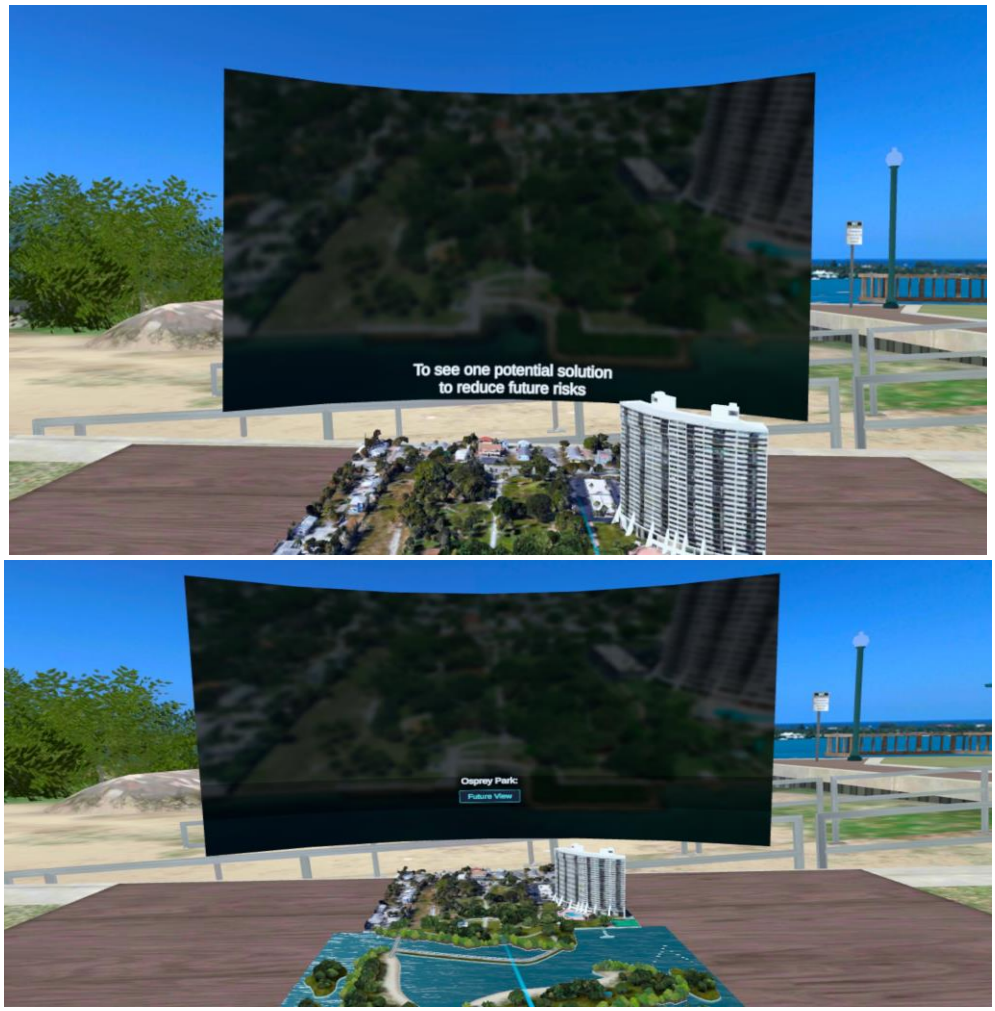

Figure 9. *Demonstration of green stormwater infrastructure flooding mitigation,* Sea Level Rise Explorer

This simulation is unique in that it is able to effectively communicate emotionally and politically loaded concepts without enhancing despair and by offering positive outcomes through solutions. Through the sense of presence and connection to the value of the area within the simulation, watching the negative consequences of unmitigated sea level rise and then seeing a solution to provide not only resilience but a positive outcome with increased communal amenities such as a fishing pier and added greenery and walk paths, as shown in Figure 9, is likely to leave the immersant with a positive mindset around mitigation and stewardship strategies via green stormwater infrastructure. The call to action at the end, shown in Figure 10, of the simulation is to learn more about these concepts via their website and communicate with the local government about preferences for sea level rise mitigation strategies.

Figure 10. *Final call to action, creating path for real-world agency and influence,* Sea Level Rise Explorer

5.0 Discussion, Findings, Considerations and Recommendations

Virtual Reality is a technology in flux and early stages in its development timeline. Technological limitations such as image quality, coding challenges, and sensory experiences certainly exist, creating challenges to craft a fully seamless and unmediated experience of place and presence. Other limitations for accessibility arise within this technology such as cost, language, closed captioning, battery life, etc.

Some of these environmental scenarios have clear directives, instructions, navigation, narration, argument, and present clearly that which should be taken away from the experience. Others are less self-explanatory and require a little reflection or would do well to be revisited for added enrichment. At this point in the technological stage, little can be done regarding visual quality in most digitally recreated environments, but narration seems to be a strong component for driving stewardship narratives within these experiences.

5.1 Findings

Ocean of Light Dolphins VR, *Embrace German Nature*, and *Sea Level Rise Explorer* are three very distinct experiences within the environmental sector of the VR worlds. Each media type offers its own affordances, benefits, and challenges. Each production team navigated these with varying degrees of success, but still with some room for improvement. The experimental nature of VR experiences in this era of the technology leads one conclusion to be that VR is not yet a perfect system for crafting a true sense of presence, but it is an effective tool in that it is more capable of augmenting presence and thus influencing stewardship mindsets than other flat media.

VR is less a tool for creating true presence or reality, and more a tool for expanding beyond the IRL reality and increasing access to the next best thing. By expanding experience beyond

realistic perspective – such as nonhuman stakeholder perspective-taking or transforming a classroom into a dolphin swim experience – and by creating a close-enough "nature" experience, PEB, eco-consciousness, and stewardship mindset shifts are still more likely to be achieved through this sense of augmented presence than flat media experiences could. As Dussler et al. express generally throughout their article, surrounding or immersing folks in a natural setting, and offering guided heuristic exploration within an ecological space, creates a sense of responsibility for the environment around them. With the theories of both presence and place-based attachment, VR experiences are able to augment this place immersion to a high *enough* degree to influence positive environmental behavioral outcomes.

5.2 Considerations and Recommendations

This study was limited to three case studies of varying types of media within VR experiences. VR is a vast and ever-growing and changing playscape. To create more conclusive findings and test these concepts in more depth, future research should focus on a more extensive corpus of study. A randomly selected qualitative and quantitative study should be conducted to gauge preexisting PEB levels in participants and PEBs after experiencing different types of VR nature experiences. This study was also limited to no-cost case studies. Future research should explore barriers to entry such as cost, and whether that has an impact on either the quality of the experiences or stewardship mindset outcomes.

Further research may be done to explore the differences in eco-consciousness outcomes between VRNE experience types. Comparing and contrasting 360° and 180° video impacts, or passive-consumption VR content vs interactive gaming experiences in the context of science communication and eco-consciousness outcomes could support more informed educational content design and selection for educators. Deeper exploration of information recall vs empathetic response on stewardship action-taking may also be a favorable line of study.

This research clearly supports use-cases for VRNE as a stewardship and education tool. Continued exploration of the psychological benefits, experiential design components, research and educational application, and other general use-cases for VRNE as a tool for eco-consciousness development in immersants will be vital as ecological crises continue to emerge and evolve.

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