Claws of Change: An Embodied Educational VR Experience for Visualizing the Effects of Ocean Climate Change Through Time Travel

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Figure 1: Various elements found in the Claws of Change experience where users embody a time-travelling American Lobster. Elements include a clock with a button to change the time period, images of the shell degrading under future ocean conditions with high ocean acidification, and locomotion that involves users using their claws to swim forward.

Abstract

Claws of Change is an immersive virtual reality educational experience that places learners in the body of an American lobster exploring the Atlantic Ocean. Participants travel through time to witness the effects of climate change using a novel claw-based swimming locomotion system that strengthens embodiment. The experience aims to foster empathy for marine life through non-human perspective-taking and environmental storytelling. A pilot study in a university sustainability classroom found the experience engaging, easy to learn, moderately immersive, and effective for climate education. Future work will improve accessibility, locomotion, environmental interactions, and educational content.

Index Terms: Virtual Reality (VR), Embodied Learning, Perspective-taking, Climate Change Education, Locomotion Design, Ocean Warming, Acidification, Simulation.

1 Introduction

Communicating the impacts of climate change on marine ecosystems remains a significant challenge, as many environmental changes occur gradually and are difficult for learners to observe directly [10]. For example, increasing ocean acidification is a serious challenge for marine biology, as lobster shells become more susceptible to its corrosive effects [6]. To address these challenges, we developed Claws of Change, a VR experience that places learners in the embodied perspective of an American lobster inhabiting the Atlantic Ocean off the coast of Nova Scotia. Participants explore the environment across three time periods (2025, 2050, and 2100) to observe the long-term impacts of climate change on marine ecosystems. Two VR platforms (desktop and head-mounted display - HMD - VR) were supported to improve accessibility by providing a pathway for those who are uncomfortable with or unable to use HMD VR [12].

Claws of Change is an immersive, free-roam narrative of 5-10 minutes that allows learners to experience the science of climate change. This study focuses on animal embodiment, storytelling, and the mechanics of time travel to present data in an immersive and empathetic way. Additionally, a novel locomotion technique was developed that allows users to swim using "their claws" to propel themselves through the environment, adding an extra challenge and game mechanic. The project was designed as a lightweight, accessible prototype that can be integrated into existing post-secondary sustainability curricula (Figure 1).

1.1 Motivation

Through the Proteus Effect [14], whereby people change their behaviour according to their virtual appearance, we aim to enhance engagement and emotional response to the effects of ocean warming, acidification, and human-discarded objects on lobster physiology, behaviour, and surrounding biodiversity.

2 Related Work

Several similar VR applications explore creature perspectives and coastal education.

2.1 Climate Change Education in VR

Markowitz et al. introduced immersive VR "field trips" as a tool for climate change education, demonstrating that short VR experiences can effectively support learning and knowledge retention [9]. Similar to Claws of Change, participants observed the long-term impacts of ocean acidification from the perspective of a marine organism. However, while their experience presents a gradual 40-year environmental transformation, Claws of Change employs distinct

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Figure 2: Three clock 3D models with labelled years for user interaction.

time jumps between future scenarios to create a more immediate and emotionally impactful comparison of climate outcomes.

2.2 Embodiment and Locomotion

Krekhov et al. explored animal embodiment in VR through a variety of animal avatars (rhino, bird and scorpion) and investigated how avatar characteristics contribute to the illusion of virtual body ownership (IVBO), the sensation that a virtual body belongs to the user [9]. The authors' research suggests that IVBO can enable "novel, engaging player experiences that cannot be realized in non-VR games" and suggests that future research should examine factors such as "locomotion, altered or additional body parts, and appeal" in greater detail [9]. The design of Claws of Change further explores IVBO in post-secondary settings through additional interactions, swinging your claws to swim, rather than relying on traditional joystick-based movement.

2.3 Narration and Immersive Visuals

Dyakugha et al.'s work places users in a realistic coastal underwater environment, where they engage with cultural stories by collecting healing seaweed while under the guidance of a narrator. Similar to Claws of Change, users interact through actions that reinforce the accompanying audio narrative and encourage reflection on environmental change, rather than relying solely on passive observation. The authors report that participants found the combination of immersive visuals and interactions enhanced their retention of the narrated educational content [5]. Dyakugha et al. conclude that future studies should extend this approach through longitudinal evaluation, expanded content, and integration into formal educational settings, a goal also pursued by Claws of Change.

3 Prototype Design

Claws of Change is an educational VR experience developed in Unity (version 6000.3.2f1) for the Meta Quest 3, allowing users to embody a lobster and explore a simulated marine environment. The player's virtual claws replace the Meta Quest controllers, reinforcing non-human embodiment while interacting with the environment.

The experience consists of a central lobby connected to two underwater caves, each representing a different future climate scenario. Time-travel clocks (Figure 2) allow users to transition between 2025, 2050, and 2100. The lobby contains a clock returning users to the 2025 environment, while each cave contains clocks for 2050 and 2100. The left cave depicts a pessimistic future with limited climate mitigation, whereas the right cave represents an optimistic future where climate action reduces ocean warming and acidification.

As users travel through time, changes in lighting, water colour, textures, wildlife, debris, and environmental audio illustrate the predicted effects of climate change on the Atlantic Ocean and the possible health of the lobster. These five environments encourage direct comparison of alternative climate futures.

An optional scavenger hunt further promotes exploration by encouraging users to identify environmental changes and collect marine debris. Progress is displayed as a checklist on the user's right claw, and the experience remains open for continued exploration after all objectives have been completed.

3.1 Educational Design

The educational design of Claws of Change supports diverse learning preferences and aligns with principles of Universal Design for Learning (UDL) [12]. The experience presents information through visual, auditory, and kinesthetic methods.

- **Visual Learning**: Environmental storytelling communicates climate change through changes in water quality, lighting, wildlife, debris, and the lobster avatar across time periods, encouraging learners to compare environmental conditions.
- **Auditory Learning**: Narrated information points provide scientific explanations about climate change and marine ecosystems, allowing learners to receive educational content while exploring.
- **Kinesthetic Learning**: Learners reinforce concepts through direct interaction, including collecting shells and debris and activating time travel using lobster-inspired movements.

3.2 Embodied Lobster Interaction

Users propel themselves through the environment with their virtual claws, fostering a deeper understanding of the challenges of navigating the large hub as a small creature. The user must first hold out their hands, then hold the trigger buttons of the Meta Quest controllers, then pull back and away, similar to the breaststroke swimming motion. Also, many rocks, shells, and discarded human objects on the map can be picked up with their claws as grips.

Users who experience discomfort or difficulty with the swimming system can switch to joystick-based movement, allowing them to navigate the environment in any direction at a similar speed. This option also creates a tunnel-vision effect in the user's peripheral field of view, helping mitigate potential motion sickness. For the desktop version, controls were adapted; users navigate the environment using standard WASD keys and mouse input.

4 Methodology

To evaluate the educational effectiveness and user experience of Claws of Change, the prototype was introduced as part of a post-secondary sustainability course with approximately 25 enrolled students. Students were provided access to the experience through a head-mounted display (HMD) version using Meta Quest 3, and limited to the claw-based swimming locomotion technique. Participation in the evaluation survey was voluntary and anonymous. Due to the exploratory nature and limited sample size, the study was not designed to statistically compare desktop and VR conditions. Instead, collected responses were analyzed to identify trends and areas for future improvement.

No ethics approval was required, as the research relied exclusively on the secondary use of anonymous information collected for course improvement, and the processes of data linkage, recording, or dissemination of the results did not generate identifiable information.

4.1 Participants

Participant demographic information, including age, previous virtual reality experience, and prior knowledge of climate change and sustainability topics, was not collected as part of this pilot evaluation. Therefore, participant differences in technological familiarity or previous sustainability knowledge could not be controlled for. Approximately 25 students had access to the prototype; three participants completed the voluntary post-study survey (n = 3).

4.2 Procedure

A Google Form was available for voluntary completion, through which participants completed the iUXVR questionnaire [3]. The questionnaire comprises seven-point Likert-like statements divided into five components: usability, sense of presence, aesthetics, VR sickness, and emotions for the Meta Quest 3 experience. The student's choice of locomotion technique input method was not recorded. Additionally, five short-form questions were included to gather comments regarding climate change learning, lobster embodiment, sustainability awareness, and suggestions for future improvements.

1. *Can you briefly explain your answer on learning about climate change?*
2. *Can you briefly explain your answer on learning about lobsters?*
3. *Does this experience change your understanding of sustainability?*
4. *Can you briefly explain your answer on perception change?*
5. *Can you explain your thoughts on the use of virtual reality for learning and/or this experience?*

Because this study relied exclusively on anonymous secondary data collected for course improvement purposes, no ethics approval was required. The collected responses contained no identifiable participant information.

4.3 Presence and Embodiment Survey Results

Below are the results from the seven-point [4] questionnaire (ratings between Completely disagree and Completely agree). These findings should be interpreted as preliminary observations regarding usability, comfort, and user experience. Usability results presented in this section represent only participants who used the VR version, all VR participants experienced the same lobster swimming locomotion system using Meta Quest 3 controllers.

4.3.1 Motion Sickness and Discomfort

Participants reported low to moderate levels of discomfort and motion sickness while using the experience. Dizziness received the highest average rating (4.7/7), while nausea (3.0/7), eye strain (3.3/7), or headaches (3.3/7) remained relatively low. These results suggest that the unique swimming locomotion and head movement may have introduced mild motion-related discomfort for some users. Participants' VR experience levels and selected platforms were not recorded; additional studies with larger participant groups are required to determine whether discomfort was related to locomotion design, VR familiarity, or other factors.

4.3.2 Usability

Participants reported that the experience was generally understandable and that they were able to navigate the environment. The strongest usability result was the feeling of control within the virtual environment (6.0/7), suggesting that participants were able to understand and interact with the system. Confidence ratings were lower (3.7/7), indicating that some participants may have required additional time to adapt to the lobster's unconventional locomotion system and underwater scavenger-hunt interactions.

4.3.3 Presence and Immersion

Participants reported moderate levels of presence and immersion throughout the experience. Ratings indicated that users felt engaged with the virtual environment and found the underwater world visually compelling. The highest ratings were associated with the excitement and realism of the virtual environment, suggesting that environmental design contributed positively to participant engagement. Lower ratings were observed for statements related to replacing reality and forgetting that they were using an HMD, indicating that the experience created a sense of presence while participants did remain aware of the virtual nature of the environment.

Figure 3: Experience screenshot featuring the front entrance of a cave area.

4.4 Narrative and Themes Survey Results

The qualitative responses from the five open-ended survey questions were analyzed using thematic analysis [2]. Responses were reviewed and grouped into recurring themes.

- **Climate Change**: Participants described that the experience helped them visualize climate change impacts over time, particularly through observing ocean degradation and changes in ocean conditions. Responses indicated that information about ocean acidification and pH levels was memorable, with one participant noting that the degraded ocean environment contributed to an emotional connection with the experience.

- **Learning About Lobsters**: Participants identified learning about lobster migration patterns, climate-related impacts, and shell-wasting disease. However, one participant noted that the experience covered broader environmental themes and could include more focused information about lobster biology and conservation.

- **Empathy and Sustainability**: Participants reported that they increased their understanding of ocean pollution and the challenges of mitigation. One participant noted they would like to see, in future work, how precisely humans contribute to the environment.

4.5 Limitations

This pilot study was limited by the small sample size (n = 3) and lack of participant demographic information. Future studies should include larger participant groups, recorded user backgrounds, and defined locomotion conditions to better evaluate the relationship between interaction methods, comfort, and learning outcomes.

4.6 Discussion

Participant feedback highlighted opportunities to strengthen the educational structure of Claws of Change. One of the most frequently reported strengths was the opportunity for open exploration and free-play discovery, rather than following a fixed sequence of learning objectives. Qualitative responses suggested that the time-travel mechanic effectively communicated long-term environmental change by allowing learners to observe environmental degradation over time, while participants also described increased awareness of ocean pollution and climate change impacts.

These findings align with previous research on non-human embodiment and environmental education. Similar to Pimentel and Kalyanaraman, Claws of Change uses species-specific locomotion and environmental storytelling to encourage empathy for marine life through body transfer (BT) [11]. Participants' reflections also support Ahn et al.'s findings that embodied virtual experiences can strengthen learners' connection with nature when used alongside traditional educational materials [1]. Rather than replacing classroom instruction, the VR experience provided a vivid perspective that complemented sustainability concepts introduced in the course.

4.7 Areas for Improvement

Participants suggested improvements to interaction design and gameplay. While the claw-swimming locomotion was viewed as innovative, it required additional onboarding, and participants requested clearer navigation cues and indicators for interactive objects. They also recommended expanding the experience with additional scavenger-hunt objectives, ocean-cleanup activities, and environmental challenges, such as predator encounters to invoke more intense negative feelings.

5 Future Work

Although the initial prototype demonstrated the potential of embodied virtual reality for climate change education, there are several opportunities to expand both the educational takeaways and the gameplay.

5.1 Mobile

A mobile and AR version of Claws of Change could improve accessibility by allowing learners to experience the educational content without dedicated VR hardware. Such a deployment could support homework activities and reduce logistical challenges associated with sharing head-mounted displays in classroom settings.

5.2 Additional Interactions

Future iterations will expand environmental interactions and storytelling by introducing additional marine life, lobster social behaviours, and visible human activities such as fishing vessels and traps. Additionally, more embodied controls for the lobster, such as exploring how to transfer human movement to lobster movement and further exploring the embodied connections suggested by earlier VR studies on homuncular flexibility [13], could help create a stronger connection between users and the lobster, potentially fostering greater empathy. Future versions could investigate more advanced locomotion techniques, including the ability to swim backwards, or more visual "scuttling" behaviour.

5.3 Expanded Educational Design

Future iterations could further strengthen the educational framework by incorporating established pedagogical models such as Kolb's Experiential Learning Cycle [7] and Bloom's Revised Taxonomy [8]. Student feedback suggested that some learners were uncertain about the intended learning outcomes, indicating that reflective activities and decision-making scenarios could better reinforce climate change concepts while encouraging learners to apply, analyze, and evaluate environmental issues. Student feedback suggested that some learners were uncertain about the intended learning outcomes, indicating that an additional concluding reflection or decision-making activity could help reinforce key educational messages.

6 Conclusion

Claws of Change, as a prototype experience, explored how embodied virtual reality can support climate change education by placing learners in the role of an American lobster experiencing environmental change across multiple time periods. The prototype combined claw-based swimming locomotion, environmental storytelling, and interactive exploration to encourage engagement with concepts such as ocean warming, acidification, pollution, changes in migratory patterns and shell disease. The results of our classroom pilot evaluation suggest that the participants found the experience pleasant, visually engaging and effective in increasing awareness of the impacts of climate change on marine ecosystems. The feedback we received also identified opportunities to further refine locomotion comfort and environmental interactions, and to expand the educational content. Overall, this work demonstrates the potential of immersive and accessible VR/Desktop experiences to foster empathy for non-human life and support environmental education through VR immersive learning.

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