Eco-Resilience: Games, Art, Science

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***Abstract*— Art, games and ecological science come together as a radical act of knowledge preservation in the work of the *Eco-Resilience Games* Group at Rensselaer Polytechnic Institute. Through the creation of VR and AR games, we are enabling people to experientially see, hear and touch plankton in new ways in order to understand their vital importance to freshwater ecology.**

Keywords—_environmental games; art and science; VR; AR; Plankton; Eco Resilience

Background

As we witness the current turning back of environmental protections[1], [2], [3], [4], there is a pressing need to inform the public about emerging ecological science and what steps we can do now to help the future.[5] *Eco-Resilience Games* seeks to give embodiment and a presence to plankton, some of the smallest players in this ecological assault, to help prevent them from being overlooked.

The sheer size of plankton ranging from < 0.2 µm (microns) or (0.0002 millimeters), to longer than 153 µm, and up to about 5,000 µm (5 mm) or about 0.2 inches make them challenging to know. Despite their small scale, they are responsible for life on our planet. Their numbers are in a delicate balance between zooplankton (animal plankton) and phytoplankton (plant plankton). This balance is being threatened worldwide.

The *Eco-Resilience Games* team, a trans-disciplinary group of artists, game designers, musicians, and programmers at Rensselaer Polytechnic Institute, started by Professor Kathleen Ruiz aims to make plankton known globally. The team is resonating creative artistic inquiry and practice with the evolving scientific research of *The Jefferson Project*, a partnership between Rensselaer Polytechnic Institute, IBM, and The Fund for Lake George. *The Jefferson Project* is creating revolutionary environmental monitoring and remediation methodologies that combines a network of sensors in and around Lake George in upstate New York measuring physical, chemical, and biological parameters.

[1] Friedman, Lisa. "E.P.A. Plans to Get Thousands of Pollution Deaths Off the Books by Changing Its Math," The New York Times, May 20, 2019 https://www.nytimes.com/2019/05/20/climate/epa-air-pollution-deaths.html?searchResultPosition=1

[2] The Editorial Board of the *New York Times*. "The Dirty Little Deals That Would Foul the Environment," *The New York Times,* Feb. 19, 2018 https://www.nytimes.com/2018/02/19/opinion/republican-environment-policy.html

[3] Hamblin, Jacob Darwin. "Access Denied: The Continuing Challenge to Environmental Sciences in the Trump Era", *Environmental History*, Volume 23, Issue 1, January 2018, Pages 164–171, https://doi.org/10.1093/envhis/emx128

[4] Lipton, Eric and Eder, Steve and Branch, John. "The Real-Life Effects of Trump's Environmental Rollbacks: 5 Takeaways from Our Investigation", A *New York Times* investigation shows how President Trump's deregulatory policies are starting to have substantial impact on those who experience them close up, *The New York Times,* Dec. 26, 2018 https://www.nytimes.com/2018/12/26/us/trump-environment-regulation-rollbacks.html

[5] Jain, Anab. "Why we need to imagine different futures," (TED2017) https://www.ted.com/talks/anab_jain_why_we_need_to_imagine_different_futures?utm_source=tedcomshare&utm_medium=email&utm_campaign=tedspread

Eco-Resilience Games seeks ways to expand this inquiry into a broader cultural understanding by creating artworks and virtual environments that will enable people to see and hear what the lake is telling us as a total entity, and lead us to a deeper wisdom about how and why we need to protect our waterways. Together, with our science colleagues, we are asking questions that no single discipline alone can ask. The team's explorations are resonating with Ruiz's artistic and scholarly research using multidimensional simulation media as a locus for expanding perception and empathy. Here specifically the challenge is relating to plankton. Using the phenomenological theories of Edith Stein and her description of empathy as "the experience of foreign consciousness,"[6] we reduce spatial distance and place the individual, and its pure "I" into the size scale of plankton and immerse the living body into the watery terrain that is home to plankton. The concept is akin to snorkeling at a microscopic size. One is oneself in these worlds, and can walk around, touch, and examine, but so too can the plankton! We are not invaders into each other's territory, but fellow explorers. Following Stein's idea that the position of the physical body is the zero point of orientation, and cannot be separated from the "givenness" of the spatial outer world, nor the spatial location of another being,[7] we are creating virtual worlds that enable close personal virtual "contact" where a sensation occurs with the realization of plankton as living creatures that share the same world. This results in an empathic projection where the "I" is able to see a new vantage point of orientation. The goal is to build a somewhat realistic world with scientifically and aesthetically correct models that has the actual behaviors, movements, and spawning rates and sound environments appropriate to the "real" ones, and where one can traverse the size scale of humans, fish, zooplankton and phytoplankton. Although this was technically and aesthetically very challenging, the discovery was that what was created was, to many, an astounding, joyful, engaging, and informative experience at the nexus of art, science and simulation media.

The following projects created by the *Eco-Resilience Games* group will be discussed here:

- *The World of Plankton* touch pool http://www.arts.rpi.edu/public_html/ruiz/WorldOfPlankton/WOP.htm
- *The Aquatic Messenger VR* https://sites.google.com/view/aquaticmessenger
- *Algae Bloom Dynamics* AR (in process)

1. What are plankton and why is freshwater ecology so important?
2. Yes, games, art, and science can work together to help enlighten people to change simple human behaviors that can help save the environment.
3. We will share what we have learned (in game design, platforms, hardware and streaming distribution options) by making games for successful museum exhibits and installations globally.
4. We will discuss evolving new AR/MR work and ideas for future projects

What are Plankton?

"Plankton" may not be a household word, but these little-known beings are vital to all life on earth. Many people seem to know something about plankton, but in an abstract and removed way that is far removed from a shared world experience. What are they? Plankton are communities of algae (phytoplankton) and animals (zooplankton) that are suspended in water and travel with the water currents. Phytoplankton give off oxygen when they use sunlight to turn carbon dioxide into sugars. Roughly half of the oxygen in our atmosphere was made by phytoplankton. Phytoplankton also form the base of aquatic food webs. All life in the ocean and in bodies of freshwater ultimately depends on algae for food. Phytoplankton provide a rich supply of food for zooplankton and other creatures that eat them in turn, such as larger zooplankton and fish. Small fish then, are eaten by birds and larger fish. Everyone ultimately depends on plankton to survive. However, if the delicate balance of phytoplankton and zooplankton is disrupted by nutrient pollutants such as chemical fertilizers or improper septic waste, nitrogen and phosphorus will abound. These very high nutrient conditions give rise to an overabundance of algae, resulting in algae blooms, which can create toxic conditions for fish and zooplankton. Road salts and industrial as well can make intolerant conditions that will upend the delicate balance of phytoplankton and zooplankton. When we learned about this through the research of our science colleagues on the Jefferson Project at the DFWI (Darrin Freshwater Institute), we realized that there is a fragile delicacy to nature that must be deeply respected. The projects of the Eco-Resilience Games Group engage users to learn about the long-term effects of nutrient pollution on lakes. Informing and educating the public about the importance of valuing and

[6] Stein, Edith. *Zum Problem der Einfühlung* (*On the Problem of Empathy*), translated by Waltraut Stein, Washington, D.C.: ICS Publications, 1989, 14.
Stein was a German Jewish philosopher born 1891 who studied with, and was assistant to, Edmund Husserl, known as the "father of phenomenology". Stein's major works include: *On the Problem of Empathy, Finite and Eternal Being, Philosophy of Psychology and the Humanities* and numerous works on spirituality. She became a Carmelite nun. She was killed at Auschwitz in 1942.

[7] Stein, Edith. *On the Problem of Empathy*, translated by Waltraut Stein, Washington, D.C.: ICS Publications, 1989, 61.

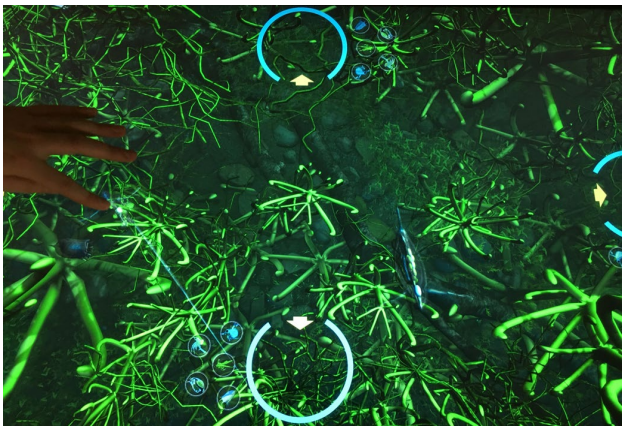
preserving fresh water is the key to enduring watershed protection. It is these personal, hands-on experiences that help people understand the causes of declines in lake health and how modifications of their personal behavior can help reverse human impacts on the watershed.

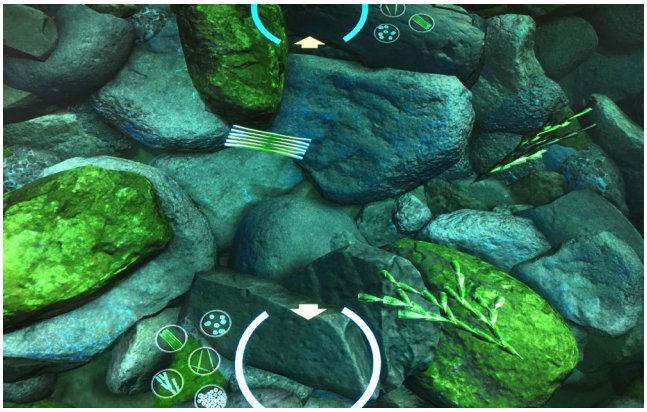
We also realized that our work is a "whole world" endeavor, as harmful algal blooms are occurring at a greater rate globally. Our *Eco-Resilience* team consists of people from many areas of the United States, China, the Caribbean, Europe, Central and South America. We all have seen declining conditions in freshwater resources firsthand in all of our countries.

I. World of Plankton

Immersing a user in a VR or AR environment akin to snorkeling with plankton as if they were fish-size or lager enables one to see, hear and touch the plankton in new ways—while also learning about them at the same time. This is a potent way to become more informed and activated about the very urgent issues of environmental ecology. [8] The *World of Plankton* is an interactive ecological art game installation currently on exhibit at the Innovation Playground at the ECHO, Leahy Center for Lake Champlain, in Burlington Vermont that takes visitors into the hidden realm of these microscopic freshwater organisms.

The installation has a virtual touch-pool aquarium with original art, animation, and composed music that allows up to four players to gather around a giant digital touch table to capture and explore zooplankton, phytoplankton and fish species. Also included are interactive plankton sculptures. The entire work is surrounded by a 32' mural.



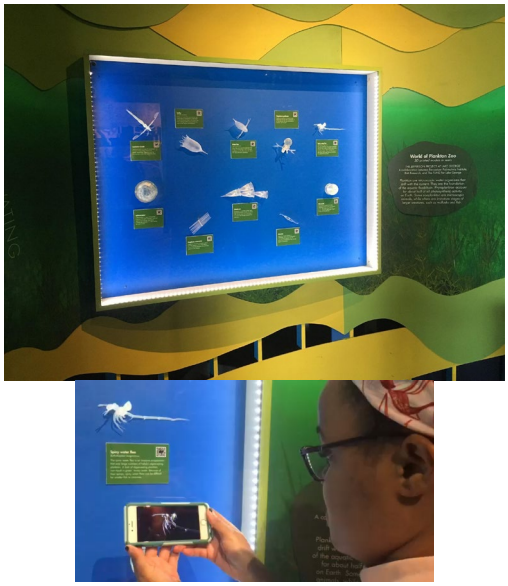


The *World of Plankton* submerges players in a virtual touch-pool aquarium, offering a hands-on exploration of the importance of fresh-water ecosystems. The idea of the team was to shrink the human game players to a size so small that we could almost snorkel with the plankton and get to know them more personally. What are these tiny creatures trying to tell us? What is each body of water as a whole trying to tell us?

[8] This work constitutes an attempt to highlight the potentials of simulation media for exploring non-colonizing approaches towards an understanding of "other," -- whether another person, animal or the environment.

Tactility and Multi-Modal Immersion

The *World of Plankton* touch pool exhibit also includes 3D printed sculptures of algae and zooplankton in resin (4-6" in size) so that visitors can see the magnificent detail of these fascinating organisms. Visitors can bring the plankton sculptures to life on their mobile devices by scanning QR codes found in the sculptures.



This activates original animation and composed music enabling both an aesthetic experience as well as stealth learning about their biology.

To create further immersion, the entire installation is surrounded by an original 32-foot digitally painted mural on canvas that inverts the size of fish and plankton. You essentially see, hear and touch plankton in new ways through art, music and sculpture, and learn about them all at the same time. We feel this is a potent way to become more informed and activated about the very urgent issues of environmental ecology.

In its first month, the exhibit has received tremendous interest from the public. Especially exciting was to learn that, not only are 5 year olds seamlessly interacting and learning with the installation, but the added layers of more in-depth information we designed into the project are being utilized by university faculty and student researchers before they go out on Lake Champlain for their fieldwork expeditions.

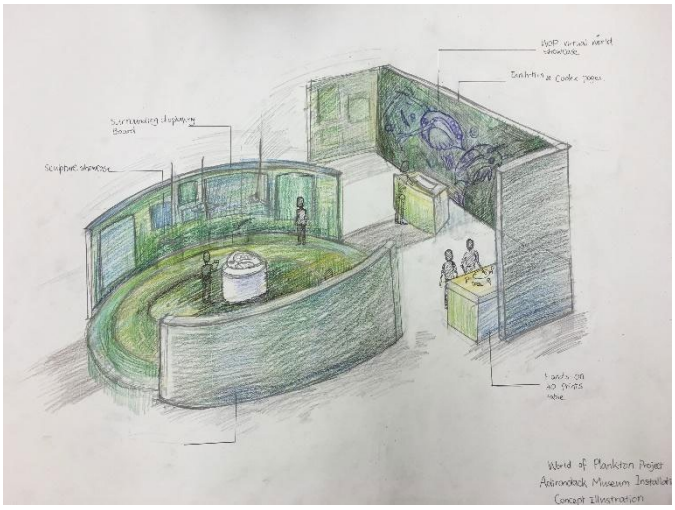
World of Plankton touch pool installation at Echo Museum: ECHO, Leahy Center for Lake Champlain 1 College St, Burlington, VT 05401 at the Innovation Playground and will re-open in the permanent collection in Fall 2019.

The Art and the Design

The *World of Plankton* touch pool installation includes an interactive virtual aquarium that helps to explain the role of plankton in freshwater ecology. The *World of Plankton* exhibit is comprised of a large touchscreen computer table that allows up to four people to view a lake food web—selecting animated algae, zooplankton, and fish—and learn about the role that each species plays in the lake ecosystem. The user can navigate at multiple scales, from microscopic algae to macroscopic fish. The media art of Ruiz[9] informs the work as the originator, designer, director and producer. Ruiz started the *Eco-Resilience Games Group,* establishing and creating and working with an amazing team of students and alumni in the arts, sciences, and game design programs at Rensselaer. Please see detailed info about team members at: https://sites.google.com/view/aquaticmessenger/team

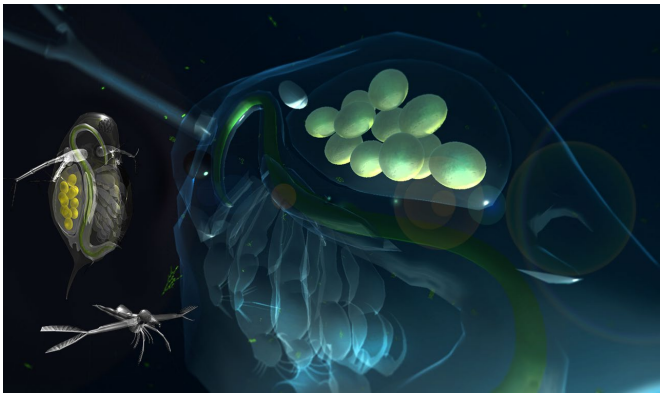
The group is developing original game design, two-and three-dimensional art, animation, music and sound design, and bringing it to life with artificial intelligence, and programming. Together we are committed to demystifying, engaging, educating and activating people about the importance of plankton. Especially in our current times where environmental protections and research funding budgets are being cut, we are "keepers" of the emerging environmental knowledge, giving tiny plankton a voice and a presence through virtual embodiment. We feel that using the virtual is a radical act of preservation and transmission of this vital knowledge as we help build a critical awareness about plankton.

[9] Ruiz, Kathleen, https://homepages.rpi.edu/~ruiz/



From ideation sketches to prototype sketches, resonating the creative ideas with our scientist colleagues on *The Jefferson Project* is integral to achieving scientific accuracy. Many times we need to visit the lab to see the plankton under the microscope or to go out to nature at the Darrin Freshwater Institute (DFWI) to experience various forms of plankton in its natural environment. Once our conceptualizations are approved, we move on to create the virtual organic 3D models, the textures, lighting and animation.

One particularly interesting situation arose when we were on a quest to observe natural movement of *Daphnia pulicaria* in order to animate our 3D models properly. When we looked at specimens under the microscope, we saw them flailing about in unusual ways with one armature or none, caught in a frightful state of being physically restrained or slowed down by chemical narcotizing. This reference was not going to help us in our study natural movement, so we utilized direct observation of samples within a freshwater tank in the lab and in the field. Although this is not the case for most plankton, thankfully these particular creatures were large enough for us to see with the naked eye.



2 and 3D level design based on bathymetric data and physical observations was made for the creation of the various levels or background scenarios. Physical observations for time-travel modules of *The Aquatic Messenger* were made using proxy data in geological investigations conducted by Kornecki and others. These data provided the information to reconstruct the water clarity, species composition, and even the on-shore representation of the included time periods.

The Science

Collaborative work by the Jefferson Project's research team inspires and informs content for the *World of Plankton* and *The Aquatic Messenger.* Biological and ecological investigations of road salt impacts[10], invasive species,[11] and pesticides[12] are studied in situ at Lake George, as well as in experimental mesocosms at the outdoor laboratory facility.

[10] Hintz, W. D. and Jones, D. K. and Relyea, R. A. "Evolved salt tolerance in zooplankton: Life history trade-offs, cross tolerance, and mitigation of salt-induced trophic cascades". *Philosophical Transactions of the Royal Society.* B 374: 20180012, 2019.

[11] Hintz, W. D., D. C. Glover, B. C. Szynkowski, and J. E. Garvey. "Spatiotemporal reproduction and larval habitat associations of non-native silver carp and bighead carp," *Transactions of the American Fisheries Society* 146:422-431, 2017.

[12] Relyea, R. A. "The interactive effects of predator stress, predation, and the herbicide Roundup®", Ecosphere 9:e02476, 2018.

Paleolimnological analysis at Lake George conducted by micropaleontologists and geochemists utilize proxies found in lake sediments. By taking a core of the sediment that has accumulated on the lake floor, these proxies provide a chronology of the lake's past and ultimately inspire the organisms and time periods participants experience in *The Aquatic Messenger*. As researchers analyze the core from the top down, they are observing the lakes conditions, marching back in time and illustrating present day and historical human impacts[13, 14] Because species have different preferences and tolerances for environmental parameters such as nutrient levels, salt concentrations, oxygenation, etc., the abundance, presence, or absence of species can be used to interpret past environmental conditions. Likewise, the size of sediments, stable isotope composition, pollen, and alga present in the sediment are combined to provide a detailed picture of the past.[14] For example, *Ambrosia,* more commonly known as ragweed, experienced a boom after deforestation of the surrounding watershed occurred for new settlers. This tree-removal provided the necessary real estate for these plants to flourish. This event is recorded in the lake sediments as an increase in ragweed pollen counts at a horizon in the core. This horizon occurs lake-wide.

Broad, regional geologic history is also employed, providing participants with an opportunity to experience deep time and thus a greater breadth of scale, temporally. Participants can experience the lake before its formation- ancient life that may have only been seen in artist renditions now are literally brought to life. Participants can swim with ammonites and the armored fish, *Dunkleosteus*.

The Programming

The projects are programmed in C# using the Unity game development platform in conjunction with other third party software and libraries in order to develop in virtual reality, and augmented reality. With the help of these libraries and plugins, we are able to put together a more personal, realistic, and impactful experience for the users. We aim to add networked and streamed multiplayer features in the near future.

Artificial Intelligence

AI is the soul of the creatures in the game. Players would not feel the game authentic if all the plankton moved frigidly and interact with players mechanically. Therefore, we spent a great deal of time observing how plankton moves in freshwater and analyzed their movements. Then, we used specific code to simulate the movement of plankton. The parameters of swimming and turning were particularly time consuming. In order to simulate the swimming of organisms, we divide complex actions into three states: swim, turn, and wait. Therefore, we use finite-state machine (FSM) to program the AI of swimming. Normally, all the organisms' FSM begin in wait state. After waiting for several seconds, their FSM transit to swim state. In swim state, the organisms burst forward for several seconds. After that, their FSM transit to wait state and continue looping forever. However, organisms need to turn around when they are about to bump into an obstacle. Therefore, we add a definite invisible ray in the front of each organism. At the beginning of the swim state, each organism will check whether the ray hits an obstacle. If the ray hits, it means that the organism will eventually hit the obstacle in this direction. Therefore, the organism needs to turn immediately, so its FSM transits to turn state instead and compels the organism to turn. Finally, in order to augment the variety of each organism, we add different base coefficients for each kind of organism. Some base coefficients control the duration of each state from respective FSM, while others help distinguish various species from all organisms. In swim state, a higher base coefficient provides stronger force to propel the fish forward in a greater distance, while lower base coefficient hinders the movement. Aside from base coefficients, random coefficients are also added to adjust the base coefficients for each fish slightly to provide more diversity among same groups of organisms. For the future improvement, we plan to make our code extensible. Therefore, we can add new functions easily in the future.

Hardware

Our creative and scientific exploration includes experiments in the following:

- Projected VR using keyboard & mouse, game controllers, joysticks
- Immersive and occlusive VR headsets such as the Oculus, and HTC Vive
- Immersive Touch Screen: Microsoft Surface and HDR monitors, Ideum touch pool
- Augmented Reality with mobile phones
- Mixed reality

Music and Sound

It is always one of our primary goals to present a realistic world of plankton in our simulation, so that is why auditory experience plays a crucial role in achieving the construction of high-level reality. We believe natural ambient environmental sounds, combined with gentle euphonic melodies create the best immersive mixtures. Different scenes in the gameplay have their own unique theme characteristics. By carefully adjusting the synergy of sounds from different instruments, we can emphasize various aspects of the player's mood and emotions from delightful refreshing journeys in ideal conditions to gloomy tonalities when the water is compromised. Spatialized sound effects are also elaborately developed. We adopt creative ideas to form a harmonic stereo surround with specific sounds at any

[13] Kornecki, K.M. and Katz, M.E. and Schaller, M. and McCarthy, F.M.G, and Stager, J.C. "Testate Amoebae and Other Microfossils of Lake George, NY: Understanding the Modern Analog," *Northeast GSA Meeting* Albany, New York, March 23, 2016.

[14] Kornecki, K.M., Schuler, M., Katz, M.E., Relyea, R., McCarthy, F.M.G., Schaller, M.F., Gillikin, D.P., Stager, J.C., Boylen, C., Eichler, L., and Nierzwicki-Bauer, S., "Calibrating Paleo-bio monitors in Lake George, NY sediments with modern geochemical and limnological measurements", *Geological Society of America National Conference*, Seattle, WA. October 22-25, 2017.

moment of the game ensuring an authentic, but exquisite gaming experience.

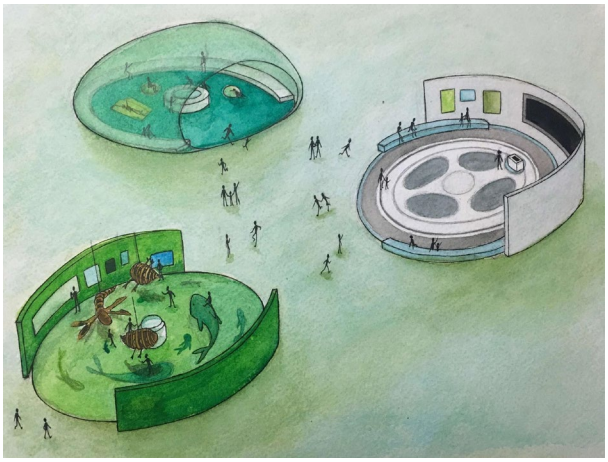
Global Distribution
With the important environmental message, we have, we aim to have exhibits in museums, galleries, schools and alternative spaces all across the world, as we want to reach to as many people as possible. This is why we created the *World of Plankton* Touch pool, as well as working on our current augmented reality projects. These projects are more hands on, and accessible to a global population.
We also recognize that the best way to deal with accessibility, would be being able to access our programs and games from home. We currently are working on releasing our *World of Plankton* VR and our *Aquatic Messenger* immersive VR via Steam, Google Stadia, or other global emerging distribution venues as a way to reach more people and receive more feedback. We are carefully assessing each of these distribution platforms as well as newly emerging distribution opportunities.

Future
Permanent installation of the *World of Plankton* at the ECHO, Leahy Center for Lake Champlain, in Burlington Vermont
Although this work was originally conceived as a 4-month exhibit, public interest has been so positive that we have been asked by ECHO to convert the temporary exhibit into a permanent exhibit that would inspire and educate the ECHO's more than 150,000 annual visitors. It is through the dedication of our Rensselaer team of students, alumni and faculty artists, programmers, and scientists that we were able to achieve this goal.

Pop up museums
We want the upcoming generations to be as excited as we are about the importance of the delicate balance of plankton and have designed the Pop-Up Plankton in response to this need. This STEAM initiative is aimed to entice and educate through immersive game simulation discovery experiences that are akin to snorkeling with giant plankton while revealing the secrets of this unseen world and collecting important knowledge along the way. Imagine being right there when a giant invasive Spiny Water flea (Bythotrephes longimanus) tries to devour an algae grazing Daphnia pulicaria!

The delicate balance of phytoplankton and zooplankton is in your hands and you could turn the tide from clear water to murky algae blooms. This agile, mini pop-up version of the game and installation will have a dynamic touch screen version of The World of Plankton with a cadre of physical plankton 3d print models that utilize RFID embedded technology to "spawn" your chosen zooplankton (animal) or phytoplankton (plant) such as in Skylanders® by Activision® or the Nintendo® game Amiibo®.
Additionally, the pop-up has an exciting augmented reality mural that comes to life with dynamic animations, and a special environmental career and opportunity info section. This version of the project is specifically designed to be an agile installation that can be installed and used in communities to involve and engage minority youth.

New Kinds of Learning Environments
Beyond learning at home via computer, or mobile touch devices, or home VR set ups, we envision a physical location much like the museums, art galleries and alternative spaces we have already exhibited our work at. But our vision here encompasses a space large enough to fully concentrate on the subject of plankton and its global importance in a three room experience that activates, transforms and stimulates participants about the delicate balance and nature of plankton and the threats to freshwater ecology worldwide.



An entryway filled with overhead, oversize plankton sculptures that lead to an inverted size scale of fish below would serve as an introductory space for participants to

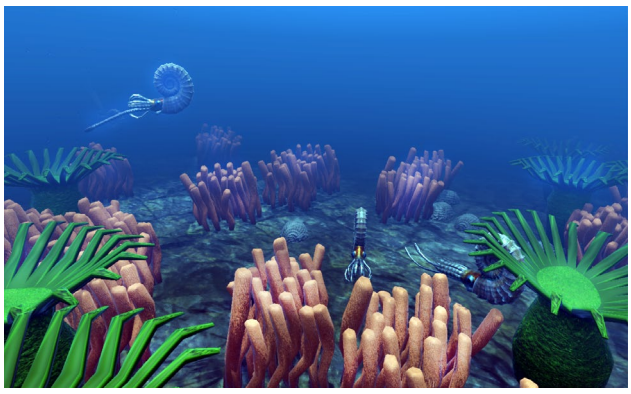
engage in AR experiences activated by specially designed murals that trigger animations, music and learning experiences. The next curved room would encompass a translucent dome where a central "campfire" interactive digital touch pool enables multiple players to interact and learn together. Their experience would be projected on the inside of the dome. People would be able to rest or lie down upon especially designed plankton pillows and peacefully see the gameplay and hear the trance-like music engaging them with the beauty and delicacy of plankton. The final room mimics the virtual reality world that participants can join. Their experiences are projected onto the wall for others to see and hear. The VR world enables time travel and size scale change so that users can experience the history of a single lake over deep time of the past, but also deep time of the future. Additionally, they can experience a sandbox vr world where the environmental decisions they make now and their repercussions are shown in the years 2060 and in 2100!

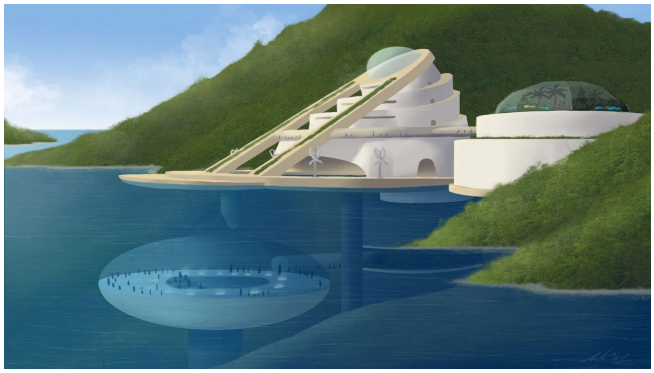
II. The Aquatic Messenger VR

The realization that there are creatures on earth that are relatively unknown, yet they are responsible for all the freshwater on the planet is a conceptual expansion that is quite challenging. Add to this that ancient forms of plankton from over 10,000 years ago are helping us understand the future of freshwater ecology and it may sound like a science fiction movie. However, these are the realities of real world plankton as experienced in *The Aquatic Messenger*, our next episode of our art/science educational underwater experience. The project is designed to inspire and engage youth 7 to 18 (and beyond) at the unseen micro-scale of phytoplankton and zooplankton in order to gain first-hand experience about the drama of underwater life and its serious potentials for environmental impact.
Enabling the exploration of the awesome wonders lying in our waters and resonating with the spirit of Galileo's *Starry Messenger* (*Sidereus Nuncius*), *The Aquatic Messenger* is a time travel VR work, exploring the microscopic and planktonic life indicators of freshwater ecology.

Created in conjunction with the micropaleontology and freshwater plankton research being done on *The Jefferson Project* and Darrin Fresh Water Institute (DFWI) at Lake George. Using advanced game and simulation technology, we are creating an artwork where these scientific discoveries will be revealed experientially. We feel that this work will have far reaching influence as it sets a new bar for excellence in VR game-art aesthetics and real-world science in educational environment projects.
Within the next year we aim to complete this immersive virtual reality project for distribution. Using experiments with HTC Vive, Microsoft Mixed Reality goggles, and other VR hardware, this work takes users back into deep time where they are immersed in a three-dimensional, underwater world of Lake George in upstate New York.

Users can explore a wide span of time, from the Cambrian Epoch 490 million years ago when the sea covered the lake, to the receding glaciers ~10,000 years ago, through the arrival of Native Americans, the arrival of European colonists, the present day, and what the future could be in 2060 and in 2100.

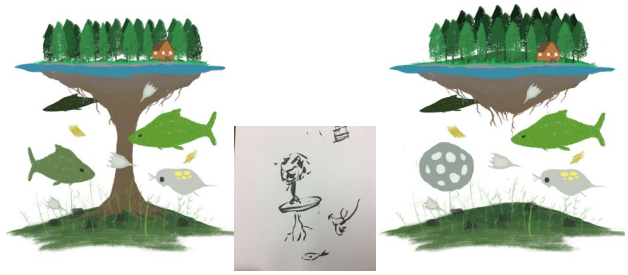




When completed, this game will allow users to experience historic human impacts, including the impacts of logging watersheds in the 1800s and the gradual increase in algal growth over the past three centuries due to increased nutrient inputs and global climate change. This work will offer a long temporal view of how humans have been contributing nutrient pollution.

III. ALGAE BLOOM DYNAMICS

We are also beginning a new mixed reality game-art simulation focused on eco-resiliency and the dynamics of harmful algal blooms (HABs). *Algal Bloom Dynamics* our new game that highlights the underlying causes of the current exponential increase in the frequency and magnitude of HABs in lakes around the world. In doing so, this effort is closely linked to the broad missions (of clean water, healthy ecosystems, thriving communities), with a particularly close link to creating an informed and involved public. By allowing the public to experience the lake from an underwater perspective and in a hands-on manner, our efforts promise to reach a very wide socioeconomic audience and will help to make the public more supportive of monitoring and mitigation efforts.



Algal Bloom Dynamics will allow users to personally experience a clear-water lake that begins to experience point and nonpoint inputs of phosphorus from human activities. As the nutrients continue to arrive in the system, underwater clarity will decline as the non-harmful algae begin to make the water green. Users will then see how further increases in dissolved nutrients, from both external inputs and the legacy of inputs residing in the lake benthos, stimulate the growth of toxic algal species. The harmful species of cyanobacteria emerge from the benthos, migrate up to the lake surface, and bloom at the surface. Given these blooms typically occur during days of unusually high air temperatures and no wind. We will also simulate the congregation of HABs when the wind begins to blow.

Primary sources of nutrient pollution in water bodies that will be experienced are:

1) Agricultural runoff
2) Storm water runoff
3) Wastewater (from failing septic tanks and ageing wastewater treatment plants)
4) Fossil fuels (nitrogen going into air and then coming down via precipitation)
5) Household waste (fertilizers, yard/pet waste, soaps/detergents)

For *Algal Bloom Dynamics* we are imagining an easy to use Mixed reality (MR) world– a form of technology that is not occlusive, yet is not simply overlays, but is a walkable and portable technology that enables anchoring of virtual objects to the real world and allows for the user to interact with the virtual objects. Our design process begins with a detailed discussion about the issues, the science, referencing, and the ecology. Then simple ideation sketches are made and refined.

We are imagining a table of headsets that people could simply come up to and use. The HABs topic lends itself to this technology in that the user will essentially experience the formulation of a HAB upon their current reality. Currently we are experimenting with mobile devices exporting from Unity 3D to the mobile development app Vuforia.

Transdisciplinary Thinking

What we are learning is that all of us working on the project, (whether we are from game design, the visual arts, music, computer science, cognitive science, biology, environmental science, micropaleontology, geology, etc.), are looking at the same thing, but from different points of view and when we come together, we ask questions and propose solutions in ways that none of us could do alone.

For instance, we have realized that while invasive species from other countries come here, other countries face invasive species coming from the United States. We are not outside of nature, but each a part of it globally. As we face the climate realities of today, it is critical to come together in profound new ways to understand each other in non-colonizing ways. Yes, we can give voice to tiny, unseen plankton and learn about their plight through game simulation. Yes, we can use this technology creatively to empathize and discover other people, different cultures, and huge ranges of complexities that will enable us to think in terms of openings of systems, contingencies, and new potentials of expression.

IV. CONCLUSION

The work of the *Eco-Resilience Game* team demonstrates the potential for using virtual worlds to inspire us to preserve our actual one.[15] Just as we gave voice to microscopic but mighty plankton, we can use this technology creatively to introduce people to new worlds, new perspectives, and new systems that will generate empathy and an enhanced desire for understanding. Heraclitus, the famous Greek philosopher, widely known for his flux doctrine revealing the interconnectedness of contrary states in life and in the world, is purported by Plato (B49a. *potamois tois autois)* to have said, "Into the same rivers we step and do not step, we are and are not." Heraclitus would have stepped into quite different types and numbers of planktonic life in the waters of 500 BC, compared to now. Today, through game art simulations like the *World of Plankton* and *The Aquatic Messenger*, and our evolving *Algae Bloom Dynamics* AR, the many kinds of interrelationships that contribute to formulating one's *weltanschauung*, or overall worldview perspective from which one sees and interprets the world, can now be enhanced.

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Kathleen is a media artist whose works highlight the importance and complexity of freshwater ecosystems, using art and science to build critical awareness about the environment. In her customary style, these works are manifested both digitally and in conjunction with physical interfaces and objects, and involve artistic and scientific real world fieldwork experiences. Her current research is centered on simulation, perspective, and empathy - exploring first-person experience, intentionality, and the possibilities for simulation media to approach a non-colonizing understanding. She is a co-creator of the GSAS program (Games and Simulation Arts and Sciences) and teaches courses in Advanced Digital Imaging, Experimental Game Design, and Vertical Studios in Integrated and Environmental Arts. rpi.edu\~ruiz

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