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The Role of Ecosystem Restoration in Combating Climate Impact

BIOS4YOU AR 2.0

BIO-INSPIRED STEM TOPICS FOR ENGAGING YOUNG GENERATIONS THANKS TO THE USE OF AUGMENTED REALITY

Project Number: 2023-1-DE03-KA220-SCH-000126516

KIT Karlsruher Institut für Technologie · ktu kaunas university of technology · Università degli Studi di Palermo · CEIPES · Eduact

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Image 1. The Role of Ecosystem Restoration in Combating Climate Impact

General topic of the learning path	Climate Change and Its Impact on Biodiversity
Specific name of the learning unit	The Role of Ecosystem Restoration in Combating Climate Impact
Age of the target users	14-18 years
Requirements for the learner	1. Basic understanding of environmental science concepts (e.g.,ecosystem, climate). Basic literacy and numeracy skills. Basic ICT skills. 2. Access to a computer or tablet with internet connectivity. 3. Willingness to engage with digital tools (AR apps, CoSpaces Edu). 4. No prior coding or AR development experience required, as CoBlocks is beginner-friendly.
Description of the learning unit	This learning unit provides a comprehensive introduction to climate change and the critical role of ecosystem restoration as a nature-based solution. It is divided into three sections: "Explore" introduces foundational concepts of climate change, ecosystems, and restoration. "Execute" delves into bio-inspiration, showcasing how natural processes inspire solutions and how Augmented Reality (AR) can visualize these processes and impacts, supported by real-world examples and practical activities. "Enhance" justifies the pedagogical benefits of AR, offering examples of useful AR applications and practical integration strategies. The unit culminates in a hands-on exercise where students use a gamified AR experience in Delightex to strengthen their understanding and engagement with the topic.

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Subject: Parties involved	Environmental Science, Biology, Geography, Digital Literacy/Computer Science, Art & Design, Social Studies (community action), Mathematics (data analysis in restoration), Language Arts (research, communication)
Keywords	Climate Change, Ecosystem Restoration, Nature-Based Solutions, Carbon Sequestration, Biodiversity, Ecosystem Services, Bio-inspiration, Biomimicry, Environmental Education, Sustainability, Reforestation, Wetland Restoration, Soil Regeneration, Digital Literacy, Augmented Reality (AR), Gamification.
Key qualifications, skills and knowledge that can be acquired	Qualifications (Mindset/Attitude): • Environmental awareness. • Proactive and innovative thinking towards environmental challenges. • Appreciation for nature's role in sustainable solutions. • Motivation to participate in climate action. Skills: • **Critical Thinking:** Analyzing environmental problems and proposing solutions. • **Problem-Solving:** Applying bio-inspired concepts to environmental challenges. • **Digital Literacy:** Navigating and utilizing AR applications. • **Scientific Inquiry:** Interpreting data and observing natural processes (virtual or real). • **Communication:** Explaining complex environmental concepts and presenting restoration ideas. Knowledge: • Understanding different types of ecosystems and their services. • Understanding of the causes and impacts of climate change. • Familiarizing with various ecosystem restoration methods. • Recognising the way ecosystem restoration combats climate impact (carbon sequestration, resilience). • Recognising bio-inspired solutions derived from nature. • Understanding the potential and applications of Augmented Reality in environmental education.
Resources and didactic aids used	Resources: • Textbooks/Scientific articles • Case studies • Internet resources • Free AR platforms (Delightex) • AR-compatible devices (smartphones/tablets)
Assessment criteria and evaluation	• **Participation:** Engagement in discussions and activities throughout the unit. • **Activity Completion:** Execution of practical AR exercise • **Concept Map/Mind Map:** Creation of a visual representation linking climate change, ecosystems, restoration methods, and bio-inspired solutions.

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Introduction

Climate change ranks among the most urgent issues of our era, affecting ecosystems, economies, and communities globally. While minimizing greenhouse gas emissions is essential, another impactful approach exists in nature: restoring ecosystems. This learning unit will familiarize you with the crucial role that rehabilitating damaged ecosystems has in reducing climate change, boosting biodiversity, and creating resilient communities. We will examine essential ideas, uncover motivating real-life instances, and investigate how advanced technologies such as Augmented Reality (AR) can enhance our comprehension and involvement with this important subject. By the conclusion of this unit, you will possess a basic comprehension of ecosystem restoration and its capacity as a nature-based approach to addressing climate effects

1. Explore – Foundations of Ecosystems and Climate Impact

1.1 What are Ecosystems?

An ecosystem is a community of living organisms (plants, animals, and microbes) interacting with their nonliving environment (e.g. air, water, soil, sunlight). Ecosystems can be as large as a forest or as small as a pond.

- **Types of Ecosystems:**
  - **Terrestrial:** Forests, grasslands, deserts, tundras, mountains.
  - **Aquatic:** Freshwater (rivers, lakes, ponds, wetlands) and Marine (oceans, coral reefs, estuaries).
- **Ecosystem Services:** Healthy ecosystems provide essential benefits to humans, often called "ecosystem services":
  - **Provisioning:** Food, water, timber, fiber.
  - **Regulating:** Climate regulation, flood control, disease regulation, water purification, air quality regulation.
  - **Cultural:** Recreation, aesthetic beauty, spiritual enrichment.
  - **Supporting:** Nutrient cycling, soil formation, primary production.

1.2 What is Climate Change?

Climate change refers to long-term shifts in temperatures and weather patterns. These shifts may be natural, but since the 1800s, human activities have been the main driver of climate change, primarily due to the burning of fossil fuels (like coal, oil, and gas), which produces heat-trapping gases (Regoto et al., 2022).

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- **Greenhouse Effect:** Certain gases in the Earth's atmosphere trap heat, much like the glass walls of a greenhouse. This natural process keeps our planet warm enough to support life. However, human activities are increasing the concentration of these gases (e.g. carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O)), intensifying the greenhouse effect and leading to global warming (https://science.nasa.gov/climate-change/faq/what-is-the-greenhouse-effect/)

The key impacts of greenhouse effect are rising global temperatures, more frequent and intense heat waves, melting glaciers and ice sheets, rising sea levels, changes in precipitation patterns (leading to more severe droughts or floods), and increased frequency of extreme weather events.

1.3 What is Ecosystem Restoration?

Ecosystem restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. The goal is to return the ecosystem to a healthy, resilient, and self-sustaining state, often resembling its historical condition or at least a functional state that provides essential services.

- **Common Restoration Methods:**
  - **Reforestation/Afforestation:** Planting trees on deforested land (reforestation) or on land where there was no forest previously (afforestation).
  - **Wetland Restoration:** Bringing back the natural hydrology and vegetation of drained or degraded wetlands.
  - **Coastal Restoration:** Protecting and rebuilding coastal habitats like mangroves, salt marshes, and coral reefs.
  - **Soil Regeneration:** Practices that rebuild healthy soil, such as no-till farming, cover cropping, and composting.
  - **River Restoration:** Restoring natural river flows and habitats, often by removing dams or re-meandering straightened sections.

➢ Ecosystem restoration projects are occurring around the world: https://obaines.github.io/frontiers_restoration/restoration_map.html

1.4 How Does Ecosystem Restoration Combat Climate Impact?

Ecosystem restoration is a powerful nature-based solution to climate change.

- **Carbon Sequestration:** Healthy ecosystems, particularly forests, wetlands, and oceans, act as "carbon sinks" by absorbing large amounts of carbon dioxide from the atmosphere and storing it in biomass (trees, plants) and soil.

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    - *Example:* A growing forest continuously pulls CO2 from the air through photosynthesis. Peatlands and mangrove forests are particularly effective carbon sinks, storing vast amounts of carbon in their soils.
- **Building Resilience:** Restored ecosystems are more resilient to the impacts of climate change. For example:
    - Healthy wetlands and coastal ecosystems can absorb storm surges and reduce flood damage.
    - Diverse forests are more resistant to pests and diseases, which can be exacerbated by changing climates.
- **Biodiversity Protection:** Climate change poses a significant threat to biodiversity. Restoration efforts often focus on restoring habitats, which in turn supports a wider variety of plant and animal species, making ecosystems healthier and more stable.
- **Water Regulation:** Restored forests and wetlands improve water infiltration, reduce soil erosion, and regulate water cycles, which can mitigate the impacts of droughts and floods.

2. Execute – The Role of Augmented Reality in Ecosystem Restoration

Nature has evolved incredibly efficient and sustainable solutions over billions of years. Bio-inspiration (also known as biomimicry) is the practice of looking to nature for inspiration to solve human problems. When it comes to environmental solutions, nature offers a masterclass in resilience, resource efficiency, and circular systems.

An Augmented Reality (AR) application can profoundly enhance the learning experience for sustainable water management by making abstract concepts tangible and providing immersive, interactive engagement. The main objective of this training unit is to equip learners with knowledge and practical insights into innovative water recycling and conservation techniques. An AR app can support this by:

2.1 Specific features and types of AR Tools

An AR application for this purpose would be more than just a visualization tool; it would be a dynamic platform for discovery, design, and problem-solving. Key features and tools could include:

- **3D Model Visualization:** Allowing students to interact with 3D models of urban water infrastructure, green roofs, or permeable pavements, seeing how components fit and function together. Making the movement of water (e.g., groundwater flow, greywater recycling paths within a building) visible and understandable.

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- **Interactive "What If" Scenarios:** Users could manipulate variables (e.g., rainfall intensity, population density) and see the AR-projected impact on water runoff or availability.
- **Simulations:** Placing students virtually within different urban settings to observe the impact of various water management strategies (e.g., seeing how a green roof absorbs rainfall vs. a traditional roof).

2.2 Real studies and practical exercises

Many educational initiatives globally integrate bio-inspiration and hands-on activities to teach about environmental sustainability. AR was meaningfully integrated into these experiences.

A study on an AR application used in an aquarium in Kastoria, Greece, ("Exploring the Aquarium") aimed to enhance natural heritage education, foster participation, and support the ecological restoration of aquatic ecosystems (Evagelou et. al., 2025). Students considered the application easy to use and fun. They recognized that the information obtained via the application improved their knowledge of freshwater organisms, and additionally, they stated their plan to use a similar application with a different theme in the future. This shows AR's potential to make abstract environmental impacts and restoration benefits tangible.

Another case study explored how student teachers used the AR app Seek by iNaturalist as a pedagogical tool in a biology course module focused on learning about plants. The study aimed to understand their experiences during an excursion designed for plant identification and learning. During the excursion, student teachers actively used the Seek by iNaturalist app on their mobile devices to practice identifying various plants. The app's image recognition capabilities provided instant identification and information. The findings indicated that using Seek increased the student teachers' awareness, interest, and engagement with plants. The easy accessibility of the app encouraged them to use it in their spare time, fostering a deeper connection to nature by helping them learn plant names and understand their importance in ecosystems (Cederqvist & Thorén Williams, 2023). This directly translates to how they, as future educators, can leverage AR for effective environmental education and biodiversity learning with their own students.

These examples demonstrate how AR can transform traditional learning activities into immersive, data-rich, and highly interactive experiences, bridging the gap between theoretical knowledge and practical application, and empowering students to engage with real-world environmental issues.

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3. Enhance – AR for Deeper Learning and Engagement

3.1 Examples of Useful AR Apps and Tools

Various AR tools can significantly enhance the learning experience for ecosystem restoration by providing immersive and interactive ways to explore complex environmental concepts. Here is an example:

Delightex (CoSpaces Edu):

Delightex allows users to create interactive 3D virtual worlds and then experience them in augmented reality or virtual reality. It features a drag-and-drop interface and a visual block-based coding language (CoBlocks), making it highly accessible for students and teachers with no prior coding experience. It offers a free version with core functionalities. Students can design and build their own virtual ecosystems, simulate environmental changes, and visualize restoration efforts. Its creative freedom empowers students to become content creators, not just consumers.

3.2 Practical Suggestions for Integration into the Learning Experience

Gamified learning environments or interactive 3D virtual worlds can challenge students to explore.

Exercise: "Restore our Ecosystem" AR App

"Restore our Ecosystem" AR App uses an **AR escape-room style scene in Delightex** to engage with ecosystem restoration. Students enter a virtual degraded environment and are challenged to **restore it by placing appropriate virtual elements** (e.g., trees, pollinator plants, water features). Along the way, they must **answer related quiz questions** that connect ecological functions to their choices. Correct actions and answers earn them points, while mistakes provide immediate feedback, making the experience both **gamified and educational**.

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Image 2. “Restore our Ecosystem” AR App

By thoughtfully integrating AR into the curriculum, educators can create dynamic, immersive learning experiences that not only strengthen students' connection to ecosystem restoration but also empower them with the knowledge and tools to become active participants in environmental stewardship.

Conclusion

Restoring ecosystems goes beyond merely returning nature; it focuses on creating a healthier, more robust future for everyone. As discussed in this unit, from the essential processes of climate change to the motivating concepts of bio-inspiration, revitalizing our natural environment is an effective, nature-driven approach to the climate emergency. Technologies such as Augmented Reality improve our capability to comprehend, visualize, and interact with these essential concepts, converting abstract notions into concrete, interactive experiences. By gaining insights from nature, engaging in restoration activities, and utilizing creative tools, you can be a part of the solution, helping to create a world where both people and nature flourish. The fate of our Earth relies on our united efforts, and each tree planted, each wetland rejuvenated, and every sustainable method embraced moves us nearer to a harmonious and flourishing planet

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Phase	Description
Explore	- Research and Discovery: Introduce students to the concept of ecosystem restoration and its role in mitigating climate impacts, such as reducing CO_2 levels, preventing soil erosion, and improving biodiversity.
	- Content Development: Provide engaging content including visuals, animations, and case studies showing degraded ecosystems and successful restoration projects.
	- Needs Analysis: Assess students' prior knowledge of ecosystems, ecological functions, and climate challenges to tailor AR activities and quiz difficulty.
Execute	- Curriculum Implementation: Connect theoretical concepts of ecosystem restoration to practical actions in AR. Students learn how planting trees, pollinator plants, or creating water features can restore ecological balance and mitigate climate effects.
	- Interactive Exercises: Using the AR escape-room style scene in Delightex, students enter a virtual degraded ecosystem and strategically place virtual elements to restore it. Quiz questions guide their decisions and provide immediate feedback on ecological choices.
	- Feedback Collection: Students reflect on their restoration strategies, share designs with peers, and discuss the ecological outcomes and climate impact.
Enhance	- AR Integration: Use the AR app to visualize the results of restoration actions in real time, showing how ecosystems recover and interact.
	- Interactive Learning: Students earn points for correctly restoring elements and answering related quiz questions. Badges reward mastery of restoration techniques and climate-smart decisions.
	Gamified Content: - **Leaderboards**: Track individual or team progress based on design performance, quiz results, and creative application of green infrastructure.
	AR-Based Assessments: Replace traditional tests with interactive evaluations, such as completing AR restoration challenges, demonstrating understanding of ecosystem functions, and showing how restoration mitigates climate impacts.

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