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Ecosystem at risk: climate change impact

BIOS4YOU
AR 2.0

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

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General topic of the learning path	Climate Change and Ecosystem Sustainability
Specific name of the learning unit	Ecosystem at Risk: How Climate Change Affects Nature
Age of the target users	14-18 years
Requirements for the learner	Students should have a basic understanding of ecology and climate change. They should be able to read short scientific texts, work in groups, and express their ideas in simple written and spoken English. Interest in nature and sustainability is recommended.
Description of the learning unit	This learning unit helps students understand how climate change affects different ecosystems: terrestrial, freshwater, and marine. Students explore real examples of climate impacts such as rising temperatures, biodiversity loss, extreme weather events, and ecosystem tipping points. The unit combines reading, discussion, short videos, quizzes, and interactive digital activities. A key element of the unit is an Augmented Reality (AR) quiz planned to be created in Delightex. Although the AR activity will be developed later, the unit already prepares students for it through clear explanations, interactive tasks, and reflection activities. Students learn about nature-based solutions and discuss how ecosystems can become more resilient. The unit encourages critical thinking, teamwork, and connections between global climate issues and local environments.
Subject: Parties involved	Students, Science teachers (biology / environmental science), ICT or digital learning specialists
Keywords	Climate change, ecosystems, biodiversity, resilience, adaptation, tipping points, sustainability, nature-based solutions, AR in education

Key qualifications, skills and knowledge that can be acquired	- Understanding how climate change affects ecosystems - Awareness of ecosystem services and interconnections - Ability to work with simple scientific information - Critical thinking and problem-solving - Collaboration and discussion skills - Digital literacy and experience with interactive tools
Resources and didactic aids used	Short adapted texts based on IPCC and scientific reports Infographics and simple ecosystem diagrams Short educational videos (e.g. YouTube / National Geographic clips) Interactive quiz (Wordwall) Reflection worksheets Group project materials Planned AR activity in Delightex (to be created later)
Assessment criteria and evaluation	- Participation in discussions and activities - Accuracy and completeness of AR-based biodiversity observations - Reflective writing on resilience strategies - Group presentation on nature-based solutions - Final quiz or digital report summarizing key threats and solutions

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Introduction:

Climate change represents one of the most serious global challenges of the 21st century. Scientific research shows that increasing global temperatures, melting glaciers, rising sea levels, stronger storms, and changing precipitation patterns are already affecting natural and human systems worldwide (Hoegh-Guldberg et al., 2018; National Academy of Sciences, 2019). These environmental changes influence not only human societies but also plants, animals, and the ecosystems on which life on Earth depends. Ecosystems are strongly interconnected with the atmosphere and the oceans. Forests, soils, wetlands, and oceans play a crucial role in regulating the climate by absorbing carbon dioxide, storing carbon, and influencing weather patterns (Bardgett & Caruso, 2020). Because of these close connections, even relatively small climatic changes can lead to significant ecological impacts. When one part of an ecosystem is disturbed, the effects may spread to other species and processes, creating cascading changes across the system (Bennett et al., 2016).

Human activities are the main driver of current climate change. The burning of fossil fuels, deforestation, intensive agriculture, and industrial processes increase greenhouse gas emissions, which trap heat in the atmosphere and lead to global warming and ocean acidification (Hoegh-Guldberg et al., 2018). As temperatures rise, many species face difficulties adapting to new conditions, resulting in changes in distribution, population decline, and loss of biodiversity.

Scientists warn that exceeding a global temperature increase of 1.5°C above pre-industrial levels significantly raises the risk of reaching ecosystem tipping points (Lenton et al., 2019). A tipping point is a critical threshold beyond which an ecosystem may shift rapidly into a new and often irreversible state. Examples include coral reef collapse, large-scale forest dieback, and disruptions to freshwater systems (Turner et al., 2020). Once these tipping points are crossed, ecosystem recovery becomes extremely difficult or impossible.

Understanding the impacts of climate change on ecosystems is essential for developing effective mitigation and adaptation strategies. Scientific evidence highlights the importance of protecting ecosystems and promoting nature-based solutions to strengthen ecosystem resilience and reduce long-term environmental

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risks (Nicholls et al., 2018; Molotoks et al., 2020). By studying these processes, learners gain a clearer understanding of why climate action and sustainable environmental management are necessary to safeguard both natural systems and human well-being for future generations.

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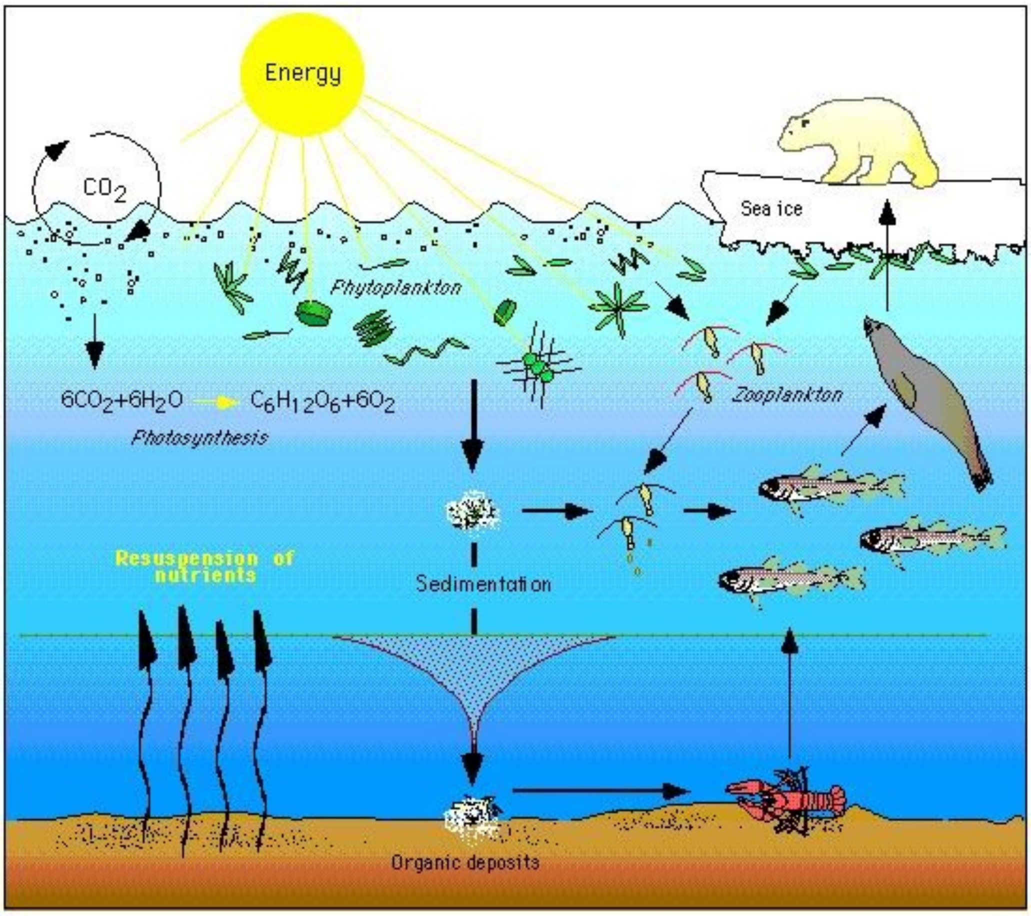
1: Explore

Climate change trajectories and tipping points

Climate change affects ecosystems by altering key physical and biological processes that regulate energy flow, carbon cycling, and species interactions. Scientific evidence shows that rising global temperatures and increasing concentrations of atmospheric carbon dioxide influence both terrestrial and marine ecosystems, often reducing their stability and resilience (Hoegh-Guldberg et al., 2018; National Academy of Sciences, 2019).

Figure 1. Energy flow and carbon cycling in a marine ecosystem.



As illustrated in **Figure 1**, solar energy drives photosynthesis in phytoplankton, which form the foundation of marine food webs. Through photosynthesis, phytoplankton absorb carbon dioxide from the atmosphere and convert it into organic matter,

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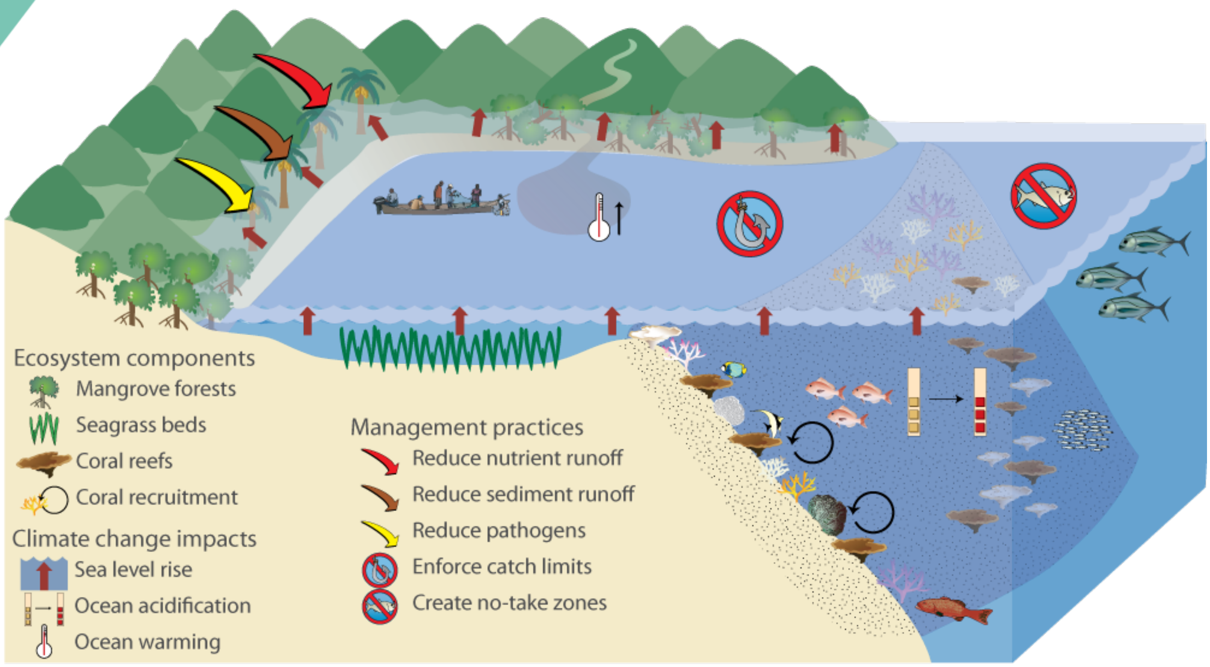
supporting higher trophic levels and contributing to climate regulation. Carbon and nutrients move through the ecosystem via trophic interactions, sedimentation, and nutrient recycling. Climate change can disrupt these processes by increasing water temperatures, altering ocean circulation, and reducing nutrient availability (Bardgett & Caruso, 2020).



Conceptual diagram illustrating climate change impacts on ecosystem components and management practices.
Diagram courtesy of the Integration and Application Network (ian.umces.edu), University of Maryland Center for Environmental Science. Source: Kaufman L and Tschirky J 2010. *Living with the Sea*. Science and Knowledge Division, Conservation International, Arlington, VA, USA.

Figure 2: Ecosystem tipping points and abrupt change.

Figure 2 highlights trophic interactions within ecosystems and illustrates how climate-related stressors increase ecosystem vulnerability. Rising temperatures, ocean acidification, and habitat changes affect primary producers first, but the impacts spread through food webs via cascading effects. When phytoplankton productivity declines, zooplankton, fish, and top predators may also decline. These interconnected responses demonstrate that ecosystems do not respond to climate change in isolation, but as complex systems with strong internal dependencies (Bennett et al., 2016).

The broader consequences of these changes are illustrated in **Figure 3**, which presents a **climate cascade in catchment systems**. This figure shows how climate drivers such as temperature increase and altered precipitation affect multiple ecosystem components simultaneously. Changes in rainfall and temperature influence soil moisture, water flow, salinity, vegetation, and species movement across terrestrial, freshwater, and coastal ecosystems. These linked processes can lead to unexpected outcomes, such as increased flooding, habitat loss, and reduced water quality (Turner et al., 2020).

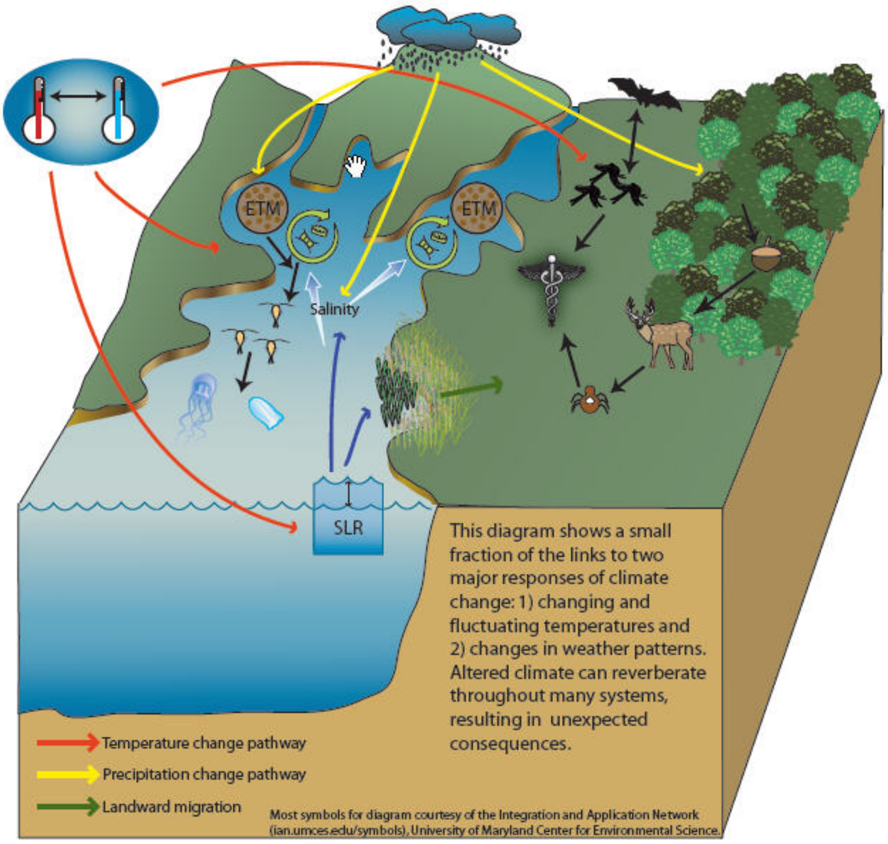


Figure 3. Climate cascade in catchment systems.

Together, Figures 1–3 demonstrate how climate change impacts move from **physical drivers** (temperature and precipitation) to **biological responses** (changes in productivity, species interactions, and migration). These cascading effects increase the risk of **ecosystem tipping points**, where gradual environmental change leads to rapid and potentially irreversible ecosystem shifts (Lenton et al., 2019).

In addition to climate change, ecosystems are affected by other human pressures, including pollution, land-use change, and overexploitation of natural resources. The interaction of these stressors further reduces ecosystem resilience and makes recovery more difficult (Harrison, 2020).

Understanding these interconnected processes is essential for developing effective mitigation and adaptation strategies. Scientific research highlights the importance of nature-based solutions, ecosystem restoration, and adaptive management to strengthen resilience and reduce climate-related risks across ecosystems (Nicholls et al., 2018; Molotoks et al., 2020).

Questions

1. How does climate change affect energy flow and carbon cycling in ecosystems, according to the text?
2. Why do cascading effects increase the risk of ecosystem tipping points?

Climate Change Threats and Challenges to Ecosystems

Climate change poses a wide range of threats to ecosystems across the globe. Rising temperatures, altered precipitation patterns, and the increasing frequency of extreme weather events are among the most visible impacts of climate change. These environmental changes affect ecosystems differently, depending on their location and structure (National Academy of Sciences, 2019).

Terrestrial ecosystems are experiencing shifts in growing seasons, changes in species distribution, and increasing biodiversity loss. Many plant and animal species are forced to migrate to new areas or adapt to changing conditions, while others face population decline or extinction. Freshwater ecosystems, such as rivers and lakes, are also highly vulnerable. Higher water temperatures, changes in precipitation, and pollution affect water quality and flow regimes, placing stress on aquatic organisms. Marine ecosystems face additional pressures, including ocean warming, ocean acidification, and coral bleaching, which threaten biodiversity and ecosystem services (National Academy of Sciences, 2019).

Ecosystem responses to climate change are complex due to strong interdependencies among species. When one trophic level is affected, the impacts can spread through the food web, creating cascading effects. Research shows that climate change often interacts with other human pressures, such as habitat destruction, pollution, and overexploitation, which further intensify ecosystem degradation (Bennett et al., 2016).

In addition, ecosystems may reach critical thresholds or tipping points, where gradual environmental change leads to sudden and potentially irreversible shifts in ecosystem structure and functioning (Lenton et al., 2019). These risks highlight the urgent need for both climate change mitigation and adaptation strategies. Without significant reductions in greenhouse gas emissions, ecosystems and the services they provide to human societies are at risk of profound and long-term disruption.

Questions

1. What are the main climate change threats faced by terrestrial, freshwater, and marine ecosystems?

2. Why do interactions between climate change and other human pressures intensify ecosystem degradation?

Opportunities for Ecosystem Resilience

Despite these challenges, scientific research identifies pathways to strengthen ecosystem resilience, defined as the ability of ecosystems to resist, adapt to, and recover from environmental change. One important approach is the use of nature-based solutions (NbS), which combine ecosystem protection, restoration, and sustainable management with climate mitigation efforts (Nicholls et al., 2018).

Examples of nature-based solutions include the restoration of wetlands, which enhances carbon sequestration and reduces flood risk, and reforestation projects, which absorb carbon dioxide while providing habitats and migration corridors for wildlife. These approaches offer multiple benefits for both ecosystems and human communities.

Adaptive management strategies are also essential for addressing the dynamic nature of climate change impacts. Such strategies involve continuous monitoring of ecosystems and adjusting conservation practices based on observed changes and scientific evidence (Turner et al., 2020). Engaging local communities and stakeholders further

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strengthens resilience by combining scientific knowledge with local experience and traditional ecological understanding.

International cooperation plays an important role in ecosystem protection by supporting the exchange of best practices, knowledge, and financial resources for large-scale restoration projects (Molotoks et al., 2020). In addition, education and awareness initiatives are crucial for promoting sustainable behaviour. By improving understanding of the links between human activities and ecosystems, societies can be encouraged to adopt more sustainable practices.

Questions

1. What are nature-based solutions, and how do they help strengthen ecosystem resilience?
2. Why are adaptive management and community involvement important in responding to climate change?

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Conclusion

This learning unit highlights the importance of understanding how climate change affects ecosystems through interconnected physical and biological processes. Scientific evidence shows that climate-related threats, combined with other human pressures, increase the risk of ecosystem degradation and irreversible change. At the same time, research demonstrates that effective mitigation, adaptation, and nature-based solutions can enhance ecosystem resilience and reduce long-term risks (Harrison, 2020).

Addressing the challenges posed by climate change requires coordinated action across scientific disciplines, policy sectors, and societies. Policymakers, scientists, educators, and the public must work together to develop and implement strategies that both reduce climate impacts and protect ecosystem functioning. Through informed decision-making and collective action, it is possible to safeguard ecosystems and the essential services they provide for future generations.

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2: Execute

After completing the reading and discussion activities in Section 1: Explore, students move from theoretical understanding to practical application through an Augmented Reality (AR) activity designed in Delightex Studio. The main purpose of this stage is to apply knowledge about climate change trajectories, ecosystem tipping points, and environmental threats in an interactive and meaningful way.

The AR quiz, developed specifically for this learning unit, is structured as a mission that tests students' understanding of how climate change affects different ecosystems. Instead of simply recalling information, learners are guided by virtual ecosystem guardians—symbolic characters such as a whale representing marine ecosystems, a coral representing reef systems, and a rainforest tree representing terrestrial ecosystems. Each guardian introduces its ecosystem, explains a real-world climate-related challenge (for example, coral bleaching, sea-level rise, or biodiversity loss), and presents a multiple-choice question.

The quiz questions are directly based on the scientific content explored in Section 1. They focus on key issues such as the importance of limiting global warming to 1.5°C, the differences in risks between 1.5°C and 2°C warming scenarios, ecosystems that are especially vulnerable to climate change, cascading effects caused by disruptions at one trophic level, and strategies to strengthen resilience through nature-based solutions (NbS).

Students complete the quiz individually on their digital devices. Correct answers allow them to progress to the next ecosystem, while incorrect answers activate supportive feedback that encourages reflection and reconsideration. This step-by-step structure creates a sense of journey through terrestrial, freshwater, and marine ecosystems, helping students understand their interconnections and the global scale of climate risks while working with clear and manageable tasks.

The AR activity is followed by a guided reflection session. During this stage, students discuss which parts of the quiz they found most challenging, explain how they approached problem-solving, and relate global climate examples to local environmental contexts they are familiar with. This reflective component ensures that

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the AR activity functions not only as an assessment tool, but also as a catalyst for deeper discussion, critical thinking, and collaborative learning.

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3: Enhance

Integrating the Delightex AR quiz into the learning unit enhances the learning process by shifting students from passive content consumption to active and experiential learning. Instead of reading information and answering questions in a static format, students interact with virtual characters and environments that support deeper engagement with scientific concepts.

One key advantage of AR integration is improved visualisation of complex processes. Concepts such as ecosystem tipping points, cascading effects, and climate-driven changes are often difficult to understand through text alone. Presenting these ideas through ecosystem guardians and interactive AR elements provides a clearer and more memorable learning context, helping students connect abstract climate processes with concrete visual representations.

Student motivation and engagement are also significantly increased. The AR quiz is designed as a mission in which students progress step by step through different ecosystems. This structure creates a sense of curiosity and achievement, as learners unlock new challenges and move forward based on their responses. Compared to traditional quizzes, this interactive format reduces assessment anxiety and encourages active participation.

The AR activity also supports critical thinking and application of knowledge. Because all tasks are directly based on the scientific content explored in Section 1, students are required to recall, analyse, and apply information rather than rely on guessing. The reflection stage further strengthens learning by encouraging students to explain their reasoning, link quiz content to broader ecological concepts, and consider how similar challenges appear in real-world contexts.

In addition, the AR quiz promotes collaboration and inclusivity. Although students complete the mission individually, the shared reflection and discussion that follow provide opportunities for peer learning and comparison of problem-solving strategies. The use of visual and interactive elements supports different learning styles and makes scientific content more accessible to a wider range of learners.

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Phase	Description
Explore	- **Research and discovery:** Students examine adapted IPCC materials and selected scientific articles to understand current evidence on climate change impacts on ecosystems. Key concepts include tipping points, ecosystem services, and resilience
	- **Content development:** Learners collaboratively summarise scientific information using visual materials such as infographics, maps, and diagrams related to terrestrial, freshwater, and marine ecosystems.
	- **Needs analysis:** The teacher assesses prior knowledge through short questionnaires and guided discussion in order to adapt content to students' level and interests.
Execute	- **Curriculum implementation:** Lesson content is delivered through presentations, guided readings, and AR-based activities. Ecosystem models and real-world examples are used to visualise climate threats.
	- **Interactive exercises:** Students use AR applications (e.g. *Seek by iNaturalist* and *Google Arts & Culture – Expeditions*) to explore biodiversity, observe species, and simulate environmental changes.
	- **Feedback collection:** Learners complete reflection sheets and participate in group discussions and peer feedback. Teachers provide formative feedback throughout the process.
Enhance	- **AR integration:** AR tools allow students to virtually explore vulnerable ecosystems, observe species in their habitats, and interact with simplified climate simulations.
	- **Interactive learning:** Students conduct outdoor or local investigations supported by AR and engage in collaborative digital storytelling, linking climate science to ecosystem responses.
	Gamified Content: The AR quiz incorporates **gamified elements** that transform assessment into a narrative-driven learning experience rather than a traditional test. The design combines progression, roles, and symbolic recognition to sustain motivation. A **narrative storyline** introduces students to a mission guided by ecosystem guardians, such as a whale representing marine ecosystems, a coral representing reefs, or a tree representing forests. Each guardian introduces its ecosystem and presents challenges related to real climate change threats, creating a sense of purpose and continuity. The quiz follows a **staged progression**. Each correct response unlocks the next ecosystem, simulating movement through environments affected by climate change. This structure helps students understand ecosystem interconnections while maintaining engagement. Instead of focusing only on points, students receive **achievement titles** that reflect their level of understanding and engagement. Titles such as *Ecosystem Explorer*, *Resilience Builder*, and *Climate Guardian* provide symbolic recognition and support learner identity and motivation. A **collaborative reflection** session follows the individual mission. Students compare results, discuss challenging questions, and reflect on what each ecosystem guardian represented. This discussion transforms the gamified activity into a foundation for deeper learning and shared meaning-making.
	Assessment within this unit is based on students' ability to use AR tools to document environmental observations, complete biodiversity logs, and develop evidence-based proposals for enhancing ecosystem resilience. These digital outputs are combined with reflective writing and oral presentations to provide a balanced and comprehensive evaluation of learning outcomes.

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