Co-funded by the European Union

Understanding Leaf Structure and Function Under Light

BIOS4YOU AR 2.0

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

Project Number: KA220-BW-23-30-126516

"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them."

KIT Karlsruher Institut für Technologie · ktu kaunas university of technology 1922 · Università degli Studi di Palermo · CEIPES · Eduact

Co-funded by
the European Union

TABLE OF CONTENTS

Project Number: KA220-BW-23-30-126516

"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them."

Co-funded by
the European Union

Introduction

This exercise introduces students to the fascinating world of plant biology by exploring the structure and function of leaves, with particular focus on how they interact with light. Leaves are vital to plant survival and play a crucial role in photosynthesis, the process that converts light energy into chemical energy, fueling plant growth and development. Understanding how leaves are structured to maximize light absorption can inspire innovations in renewable energy technologies, such as bio-inspired solar panels and energy-efficient materials.

Through this exercise, students will engage with Augmented Reality (AR) technology to visualize the microscopic structures of a leaf, stomata, chloroplasts, and vascular tissue, and observe how these structures facilitate photosynthesis. They will analyze how different leaf shapes and features affect light absorption and efficiency, and consider how these natural processes can be mimicked in human-made technologies.

By the end of the exercise, students will have a deeper understanding of leaf anatomy and its crucial role in energy production, as well as an appreciation for how biomimicry can lead to more sustainable design solutions. This activity is designed to foster curiosity, critical thinking, and creativity, allowing students to explore real-world applications of natural processes in renewable energy.

This document consists of the following points:

- Information about AR technology
- How to define AR exercise thanks to the template:
    - General information
    - Pedagogical specifications
    - Technical specifications

Project Number: KA220-BW-23-30-126516

"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them."

Co-funded by
the European Union

General information

Name of the exercise:	Understanding Leaf Structure and Function Under Light *This exercise allows students to explore the intricate relationship between leaf structure and light absorption, using Augmented Reality to visualize and analyze how plants optimize energy capture for photosynthesis.*
Description of the exercises:	This exercise aims to teach students how plant leaves interact with light, focusing on their structure and the functions that support photosynthesis. Using Augmented Reality (AR), students will interact with 3D models of leaf anatomy, observe how light impacts their structure, and compare the effects on photosynthetic efficiency.The exercise will be structured into: • **Exploration:** Using AR to explore the structure of leaves, focusing on key components like stomata, chloroplasts, and veins. • **Analysis:** Comparing how different leaf structures affect light absorption and photosynthesis. • **Design Task:** Brainstorming how leaf-inspired designs could improve energy efficiency or solar technologies.
Participants:	The exercise is designed for individual students or small groups (3-5 members) to encourage collaborative learning and discussion. Group work is preferred for brainstorming innovative applications.
Participants' age range:	Minimum 15 years old Basic knowledge of **physics, chemistry, and biology** is required to understand adhesion mechanisms.

Project Number: KA220-BW-23-30-126516

"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them."

STEM subject and specific topic:	STEM Subject: Biology & Environmental Science *Specific Topic:* Leaf structure, photosynthesis, and bio-inspired design *Main challenge (stressful aspect) of the topic:* Understanding the intricate structure of leaves and their functions under light can be difficult because the mechanisms of photosynthesis and light absorption occur on a microscopic level, invisible to the naked eye. *How AR helps simplify the concept:* • Interactive 3D Models allow students to explore leaf anatomy, including the stomata, chloroplasts, and veins, to understand how light is absorbed and utilized. • AR Animations will demonstrate how light interacts with different parts of the leaf and the role each structure plays in photosynthesis. *Pedagogical Aim (Learning Outcomes):* By the end of this exercise, students should be able to: 1. Explain how different leaf structures affect light absorption and photosynthesis. 2. Understand the relationship between leaf anatomy and photosynthetic efficiency. 3. Apply biomimetic principles to propose designs inspired by leaves (e.g., solar cells, energy-efficient materials).
Gamification process:	• **Challenge-based learning:** Students will solve real-world challenges like designing a leaf-inspired solar panel using principles of light absorption. • **Points and Badges:** Completing sections (exploration, analysis, design) earns students points. • **Role-playing:** Students act as bioengineers solving problems related to energy efficiency and solar technologies.

"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them."

Written or graphic description of Augmented info:	In this exercise, Augmented Reality (AR) will be used to explore and visualize the complex structures of leaves and their function in light absorption. The AR experience includes: 1. **Interactive 3D Models:** Students will be able to zoom in, rotate, and interact with detailed 3D models of leaf structures, including stomata, chloroplasts, and veins. This allows for an in-depth understanding of the anatomy of leaves and how these structures facilitate photosynthesis. 2. **Text Overlays and Pop-up Explanations:** As students explore the models, pop-up text overlays will provide explanations of the key functions of each structure. For example, the AR will explain how **chloroplasts** absorb light for photosynthesis, how **stomata**regulate gas exchange, and how the **veins** transport water and nutrients. 3. **Animations of Photosynthesis:** Step-by-step animations will show the process of photosynthesis in action, helping students visualize how light energy is captured by chloroplasts and converted into chemical energy. 4. **Comparative AR Models:** Students can compare different leaf structures, such as broad leaves versus needle-like leaves, to understand how each type adapts to various light conditions. They can rotate the models to see how light interacts with different surfaces and how the shape of the leaf influences light absorption. 5. **Progress Tracking:** Visual progress tracking will guide students through the stages of the exercise, from understanding leaf anatomy to analyzing how structure affects photosynthetic efficiency. As students complete sections, they will earn points and badges, which will keep them engaged and provide feedback on their learning progress. 6. **Real-world Applications:** The AR experience will also feature a section on **biomimetic design**, where students can explore how leaf structures inspire innovations in solar technologies, like solar panels designed to mimic the efficiency of leaves in capturing sunlight.

Project Number: KA220-BW-23-30-126516

"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them."

Co-funded by the European Union

External (or extra) tools required	To successfully engage with this exercise and its Augmented Reality (AR) features, the following tools and materials are required: 1. **AR-Compatible Devices:** o **Smartphones** or **tablets** (with camera and gyroscope for AR functionality). o Alternatively, **AR glasses** can be used for a more immersive experience. o Devices should be running **iOS** or **Android** operating systems, with the **Delightex app** installed for accessing the AR content. 2. **QR Codes or Printed AR Markers:** o **QR codes** or **printed AR markers** may be needed to activate the AR models. These will be provided within the exercise to guide students to the correct content. 3. **Internet Access:** o A stable **internet connection** is necessary to load and interact with the AR content through Delightex's platform. 4. **Printable Worksheets (Optional):** o Students will need **worksheets** to document their observations, sketch bio-inspired designs, and reflect on the concepts learned during the exercise. 5. **Real-World Testing Materials (Optional):** o For the comparative study on light absorption and leaf structure, students may use materials like **different textured surfaces** (e.g., glass, plastic, paper, fabric) to simulate real-world environments and test light absorption before interacting with the AR models. 6. **External Videos/Resources (Optional):** o Access to supplementary **educational videos** or images on photosynthesis, leaf structure, and biomimicry (e.g., YouTube videos on photosynthesis or bio-inspired technologies) can enhance understanding.
Links (video, images, text online and so on).	Video: Travel Deep Inside a Leaf Link: https://youtu.be/pwymX2LxnQs?si=BpNlesv4bJ5D4luK

Project Number: KA220-BW-23-30-126516

"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them."

Co-funded by
the European Union

Pedagogical specifications

Here we will collect information on how to use the exercise in the learning session and the results and benefits of using it, from a pedagogical perspective.

How can this augmented information be used to address a STEAM topic in a more interesting way for students?

Interactive 3D Models

Goal:
Help students visualize and interact with detailed 3D models of leaf structures and understand how these structures support light absorption and photosynthesis.

Use:
Students can zoom in, rotate, and explore 3D models of a leaf's surface and internal anatomy, including structures such as stomata, chloroplasts, and veins. By tapping on specific components (e.g., chloroplasts, mesophyll cells, or vascular tissues), students trigger animations showing how light penetrates the leaf and how these structures collaborate to convert light energy into chemical energy. Interactive overlays explain key concepts such as light absorption, gas exchange, and the role of chlorophyll, making the learning process clear and engaging.

Interactive Buttons

Goal:
Enable students to actively engage with AR models to better understand the mechanisms of light absorption and photosynthesis at the cellular level.

Use:
Students can tap on highlighted areas within the AR models to reveal pop-up explanations and animations that illustrate key biological functions, such as how chloroplasts absorb photons or how stomata regulate gas exchange. Buttons also allow students to compare leaves from different environments (e.g., shade-tolerant vs. sun-exposed leaves) to see how structure influences light use efficiency. Progress tracking ensures students move through the learning stages systematically, from anatomy observation to process understanding and finally, to bio-inspired design thinking.

Project Number: KA220-BW-23-30-126516

"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them."

Co-funded by the European Union

Possible Classroom Session Plan

Introduction (5–7 mins)
Goal: Introduce students to the relationship between leaf structure and light.

- Begin with a real-world question: *"Why are some leaves thin and broad while others are small or needle-like?"*
- Show a short introductory video (e.g., *Travel Deep Inside a Leaf – Annotated Version*).
- Discuss how plants use light for energy and how their leaf structures are adapted to their environments.

Main Activity – AR Exercise (30-35 mins)

Exploring Leaf Structure and Light Interaction with AR

1. AR Model Interaction (10–15 mins):
   - **Students scan a QR code or open the** Delightex **AR app to access interactive 3D models of leaf anatomy.**
   - Hands-on Exploration:
     - **Rotate and zoom in on microscopic leaf structures.**
     - **Tap to reveal pop-up explanations (e.g., "How chloroplasts capture light energy").**
     - **Observe how different parts of the leaf contribute to photosynthesis and gas exchange.**
2. Guided Learning Tasks (10–15 mins):
   - **Watch a step-by-step AR animation showing** how light travels through the leaf **and** how chloroplasts convert it into energy**.**
   - **Conduct a virtual experiment comparing how different leaf shapes or structures affect light absorption.**
   - **Gamified challenge: Design a** bio-inspired solar surface **or** energy-efficient structure **based on the leaf's light-capturing efficiency.**

Conclusion & Recap (10-15 mins)

Goal: Reinforce learning through discussion and reflection.

- Project the AR experience on a shared screen and discuss observations as a class.
- Ask students:
  - What was the most surprising thing they learned about leaf structures?
  - How does the microscopic anatomy of a leaf optimize light use?
- Reflection Task: Write a short paragraph answering:
  "How could the structure of a leaf inspire technologies that improve light collection or energy efficiency?"
- End with a discussion about bio-inspired design and how studying natural systems can lead to sustainable technological innovations.

Project Number: KA220-BW-23-30-126516

"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them."

Co-funded by
the European Union

Which pedagogical objectives are addressed through this scenario?

Active Engagement

Students actively engage with the **3D AR models of leaf anatomy**, allowing them to zoom in, rotate, and explore microscopic features such as **stomata, chloroplasts, and leaf veins**. This hands-on approach fosters curiosity and exploration, helping students visualize how each structure contributes to light absorption and photosynthesis. By interacting with animations and pop-up explanations, students directly connect theoretical knowledge about plant biology with visual, real-time simulations of how light influences energy conversion in leaves.

Critical Thinking

The exercise promotes **critical thinking** as students analyze and compare how different leaf structures adapt to varying light conditions. By observing AR animations and interactive elements, they are encouraged to reflect on why leaves from different environments (e.g., shade plants vs. sun plants) exhibit unique structural features. Students must reason through how anatomy affects light use efficiency and photosynthetic performance, deepening their understanding of the relationship between **form, function, and environment**.

Application of Knowledge

Through **interactive AR simulations**, students apply their understanding of **photosynthesis, light absorption, and plant anatomy** in a visual and practical context. The exercise challenges them to connect biological mechanisms with technological innovation, bridging STEM principles with **biomimetic applications** such as solar energy systems or sustainable building materials inspired by leaf structures. This real-world link reinforces comprehension and retention while encouraging students to view nature as a model for solving energy and design challenges.

Multimodal Learning (Visual, Hands-On, Inquiry-Based Learning)

The scenario combines **visual animations**, **hands-on AR exploration**, and **inquiry-based activities** to cater to diverse learning styles. Students engage multiple senses while exploring the interaction between light and leaf structure, transforming abstract biological and physical concepts into concrete, observable phenomena. This multimodal approach supports deeper learning and ensures that complex STEAM topics, such as light absorption, energy conversion, and bio-inspired design, become both accessible and engaging.

Project Number: KA220-BW-23-30-126516

"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them."

Co-funded by
the European Union

Which results are expected to be reached with its use?

Enhanced Understanding of Leaf Structure and Photosynthesis Mechanisms
Students will develop a deeper understanding of how leaf anatomy supports photosynthesis and light absorption. By engaging with **interactive 3D AR models**, they will visualize how structures such as **chloroplasts, stomata, and vascular tissues** together to convert light energy into chemical energy. This immersive experience helps students connect microscopic biological processes with macroscopic plant functions, reinforcing theoretical knowledge through **visualization and hands-on interaction**.Increased Engagement and Interest in Biomimicry and STEM Fields.

Increased Engagement and Interest in Biology and STEAM Fields
The **interactive and exploratory nature** of the AR exercise is expected to increase students' interest and motivation in **biology, environmental science, and sustainable technology**. By transforming a complex topic, such as photosynthesis and energy conversion, into a visually engaging learning experience, students are more likely to develop a positive attitude toward **scientific inquiry and bio-inspired innovation**. They will also recognize the real-world applications of plant-based principles in renewable energy and ecological design.

Improved Retention and Recall of Key Concepts
The combination of **animated pathways**, **interactive models**, and **gamification elements** is expected to enhance students' ability to retain and recall essential concepts about light absorption, photosynthesis, and the structural adaptations of leaves. The **multisensory learning approach**, blending visual, interactive, and inquiry-based exploration, supports long-term comprehension by linking theory to tangible examples of how leaves function under light.

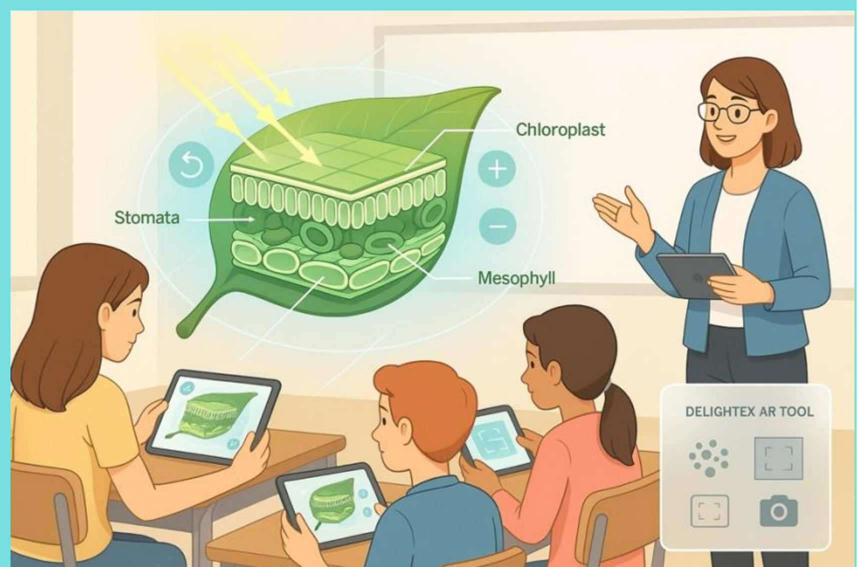
Increased Confidence in Explaining Bio-Inspired and Environmental Applications
As students explore leaf structures and their functions under light through AR and guided learning tasks, they are expected to gain **confidence in articulating biological processes** and their relevance to real-world sustainability challenges. The interactive approach will empower students to explain how the design of leaves can inspire **innovations in solar energy systems, architecture, and materials science**. By connecting biological understanding with technological potential, students will develop a deeper appreciation for **biomimicry and its role in sustainable development**.

Project Number: KA220-BW-23-30-126516

"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them."

Co-funded by
the European Union

Technical specifications

AR INFORMATION	
Technology	**Markerless AR** (no need for a printed marker).
If it's needed a marker, description of the marker	
Hardware and software needed:	**Hardware:** PC, smartphone, tablet (for accessing AR content), Camera (for AR functionality), Gyroscope (for AR tracking on mobile devices). **Software:** The **Delightex** AR web-based viewer or mobile app, compatible with both **iOS** and **Android**.
Type of Augmented data	• **3D models of** leaf anatomy **(including the surface, stomata, veins, and chloroplasts).** • Text overlays **explaining the function of each structure.** • Animations **showing how light interacts with leaf cells during photosynthesis.** • Interactive elements **for zooming, rotating, and observing microscopic features of the leaf.**

Project Number: KA220-BW-23-30-126516

"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them."

Written description of the AR data	After launching the AR experience, students will see a 3D model of a leaf projected into their real environment. The title "Understanding Leaf Structure and Function Under Light" will appear, introducing the learning experience.
	
	Students can interact with the 3D model by:
	
	• Zooming in and rotating to observe structures such as stomata, veins, and chloroplasts.
	• Tapping on key areas to trigger annotations and explanations, including:
	    ○ "How do chloroplasts capture light energy?"
	    ○ "What is the role of stomata in gas exchange?"
	    ○ "How does the structure of the leaf optimize photosynthesis?"
	
	By using navigation arrows, the AR scenes change to show different layers of the leaf, from the external surface to the internal mesophyll cells. Each scene includes animations illustrating how light penetrates the leaf and how energy is transformed during photosynthesis.
	
	Additional features:
	
	• An animated sequence showing the step-by-step process of light absorption and energy conversion.
	• A biomimetic design section, where students can explore how leaf-inspired principles are applied in solar energy or architectural design.
	• A "Return to Start" button allowing users to reset and revisit earlier stages of the exercise.

Scene	Four scenes: Scene 1: Leaf Surface Structure Students interact with a 3D model of the leaf surface, exploring stomata and epidermal cells. Pop-ups explain how stomata regulate gas exchange and water loss. Scene 2: Internal Leaf Anatomy A 3D cross-section reveals veins and chloroplasts. Animations

Project Number: KA220-BW-23-30-126516

"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them."

	show how light travels through the leaf and how chloroplasts capture and convert light energy. Scene 3: Photosynthesis in Action An interactive animation demonstrates how absorbed light drives photosynthesis and energy conversion. Students can view how environmental factors (light intensity, leaf type) affect efficiency. Scene 4: Biomimetic Applications Students discover how leaf structures inspire solar technologies and energy-efficient designs, with case examples displayed as AR pop-ups. A “Return to Start” button allows for replay or review.
If Image	-
If Text	**How Leaves Capture Light** Leaves contain chloroplasts filled with chlorophyll pigments that absorb sunlight, initiating photosynthesis. **Gas Exchange Through Stomata** Tiny pores called stomata open and close to regulate carbon dioxide intake and oxygen release. **Photosynthesis Process** Through light absorption, carbon dioxide and water are transformed into glucose and oxygen—fueling plant growth and releasing oxygen into the environment. **Biomimetic Applications** Scientists study leaf surfaces to design efficient solar panels and light-absorbing materials inspired by nature’s optimization strategies.
If video	-
If audio	-

Project Number: KA220-BW-23-30-126516

"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them."

If 3D model	Delightex https://edu.delightex.com/HCE-UGN

Project Number: KA220-BW-23-30-126516

"Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them."

Co-funded by
the European Union

BIOS4YOU
AR 2.0

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