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Controlled Adhesion: Learning from Geckos and Beetles

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

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Introduction

The purpose of this document is to create guidelines to help the project staff that are dealing with school children, 14-19 aged, to create and re-adapt exercises using Augmented Reality technology.

To this end, a series of templates have been created that define exercises from a methodological, pedagogical and technological point of view.

A good written description, along with images, videos or sketches of the exercise is very important for experts to understand the idea. This will be part of the “General Information” template.

On the other hand, it will be important to define what STEM topic/subject each exercise is intended for and how AR technology can help students or staff or people interested in it when they use these exercises. In addition, people interested in the exercise can understand the usefulness of augmented information, and it will be necessary to explain the benefits.

During the process of defining the augmented information that each exercise will offer, staff working with teachers will be able to develop innovative ideas that make it easier to learn teaching concepts in an easier way.

All students will be able to view the contents explained by professionals projected in the real world in the form of text, 3D model, image, video, sound... This will help them focus their attention on exercise and more easily assimilate the associated concepts.

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

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General information

Name of the exercise:	Controlled Adhesion: Learning from Geckos and Beetles *This exercise introduces students to biomimicry by exploring how organisms like geckos and beetles achieve adhesion and how this knowledge can inspire technological innovations*
Description of the exercises:	This exercise aims to teach students how organisms achieve adhesion using biological mechanisms such as van der Waals forces (geckos) and capillary interactions (beetles). Using Augmented Reality (AR), students will interact with 3D models of microscopic structures in nature and compare them to artificial adhesive technologies. The exercise will be structured into: • **Exploration:** Using AR to observe microscopic details of adhesion mechanisms. • **Analysis:** Comparing biological adhesion strategies with existing engineered solutions. • **Design Task:** Brainstorming how bio-inspired adhesion can be used in real-world applications (e.g., climbing robots, medical adhesives, or space exploration).
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*

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Participants' age range:	Minimum 15 years old Basic knowledge of **physics, chemistry, and biology** is required to understand adhesion mechanisms.
STEM subject and specific topic:	STEM Subject: Physics & Biology Specific Topic: Surface adhesion in nature and its biomimetic applications *Main challenge (stressful aspect) of the topic:* Understanding adhesion at the microscopic level is challenging because: • Forces like van der Waals forces and capillary adhesion operate at the nano/microscale, which is invisible to the naked eye. • Many students struggle to connect abstract molecular forces to real-world applications. • The complexity of adhesion mechanisms (e.g., why geckos can stick to walls but not humans) is difficult to visualize without advanced tools. *How AR helps simplify the concept:* • Interactive 3D models allow students to explore the fine structure of gecko toe pads and beetle adhesive systems in augmented reality. • Zooming & rotating models help students visualize the nano/microstructures responsible for adhesion. • AR animations demonstrate adhesion in action, showing molecular forces at work. • Comparing biological vs. artificial adhesives helps students understand biomimicry applications. *Pedagogical Aim (Learning Outcomes):* By the end of this exercise, students should be able to: 1. Explain the difference between **wet adhesion** (capillary forces in beetles) and **dry adhesion** (van der Waals forces in geckos). 2. Understand how adhesion works at the **nano/microscale** and why it differs from macroscopic adhesion. 3. Apply biomimetic principles to propose real-world innovations (e.g., medical adhesives, climbing robots).

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	Use **AR tools** to explore, analyze, and compare adhesion strategies in nature and technology.
Gamification process:	**Challenge-based learning**: Students will be given real-world challenges (e.g., design a climbing robot foot using bio-inspired adhesion). **Points and Badges**: Completing sections (exploration, analysis, design) earns them points. **Role-playing**: Students act as bioengineers solving adhesion-related problems.
Written or graphic description of Augmented info:	**3D AR models** of gecko and beetle adhesion structures, allowing students to **zoom in, rotate, and interact** with microscopic details. **Interactive animations** showing adhesion in action at a microscopic scale, with **step-by-step breakdowns** of how different forces work. **Overlay information** appearing as **pop-up explanations** when students tap on key areas (e.g., gecko's setae, beetle's capillary pads). **Hands-on AR experiment**, where students **test different adhesion techniques in a virtual environment** by applying biomimetic principles to engineered surfaces. **Highlighting key regions**, such as **nano/microscale structures** responsible for adhesion, helping students focus on critical details. **Visual progress tracking**, guiding students through different stages (understanding natural adhesion, comparing biomimetic designs, brainstorming applications).
External (or extra) tools required	**AR-compatible devices** (smartphones, tablets, or AR glasses). **Printable worksheets** for students to document their findings and sketch biomimetic ideas. **Adhesive materials** (sticky tapes, suction cups, etc.) for real-world comparison.

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	QR codes or printed AR markers, if required for activating AR models. **Different textured surfaces (glass, plastic, paper, fabric)** for students to test adhesion before exploring in AR.
Links (video, images, text online and so on).	Video: *How Do Geckos Stick to Walls?* (Veritasium) Link: https://www.youtube.com/watch?v=YeSuQm7KfaE

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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 gecko adhesion structures and beetle capillary adhesion** at the microscopic level.
- **Use:** Students can **zoom in, rotate, and interact** with models of gecko toe pads and beetle adhesive structures.Tapping on specific components (e.g., gecko's setae, beetle's capillary pads) will **trigger animations**showing adhesion in action. Interactive overlays will **explain key concepts**, such as **van der Waals forces** and **capillary adhesion**, in a simple and engaging way.

Interactive Buttons

- **Goal:** Enable students to actively engage with AR models to better understand the **mechanics of adhesion** at a nanoscale level.
- **Use:** Students can **tap on specific areas** of the AR models to trigger **pop-up explanations** or **animations** that showcase how adhesion works in nature. Buttons allow students to **compare natural adhesion** (gecko/beetle) with **biomimetic applications**(synthetic adhesives, climbing robots, etc.). Progress tracking ensures students **move through different learning stages** in a structured manner.

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Possible Classroom Session Plan

Introduction (5-7 mins)

- ***Goal:*** *Introduce students to the concept of adhesion in nature and biomimicry.*

Start with a **real-world question:** *"Why can geckos climb walls but humans can't?"*

Show a short **introductory video** (e.g., Veritasium's gecko adhesion video).

Discuss **everyday adhesion** (e.g., tape, glue) and contrast it with natural adhesion mechanisms.

Main Activity – AR Exercise (30-35 mins)

Exploring Gecko & Beetle Adhesion with AR

1. **AR Model Interaction (10-15 mins):**
   - Students **scan a QR code** or open an AR app to access **interactive 3D models** of gecko footpads and beetle adhesion mechanisms.

   Hands-on Exploration:
   - Rotate and zoom in on microscopic adhesion structures.
   - Tap to reveal **pop-up explanations** (e.g., van der Waals forces in geckos).
   - Compare wet and dry adhesion mechanisms.
2. **Guided Learning Tasks (10-15 mins):**
   - Step-by-step animation explaining how geckos detach and reattach their feet while climbing.
   - Virtual experiment: Students test how different surfaces impact adhesion in AR.
   - Gamified challenge: Design a biomimetic application using bio-inspired adhesion (e.g., creating a sticky surface for climbing robots).

Conclusion & Recap (10-15 mins)

- ***Goal****: Reinforce learning through discussion and reflection.*

Project the AR experience onto a screen for a class-wide discussion.

Ask students:

- What was the most surprising thing they learned?
- How does adhesion at the nanoscale differ from macroscopic adhesion?

Reflection Task: Have students write a short answer to: "How could bio-inspired adhesion be applied in real life?"

Address any remaining questions and discuss further applications in biomimetic design.

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Which pedagogical objectives are addressed through this scenario?

Active Engagement

Students actively engage with the **3D AR models** of gecko and beetle adhesion structures, allowing them to **zoom in, rotate, and tap on microscopic adhesion mechanisms**. This hands-on approach fosters **curiosity and exploration**, helping students understand how biological adhesion works at the nano/microscale. By **interacting with animations and pop-up explanations**, students can directly connect theory with **real-world bio-inspired applications**.

Critical Thinking

The exercise promotes **critical thinking** as students analyze and compare different adhesion mechanisms (**wet adhesion in beetles vs. dry adhesion in geckos**). By **triggering animations and pop-ups**, students must think critically about **why different species evolved unique adhesion strategies** and **how these biological principles can be applied to engineering and technology**. This process deepens comprehension by requiring students to **connect molecular interactions to macroscopic functionality**.

Application of Knowledge

Through **interactive AR simulations**, students **apply their theoretical understanding** of adhesion forces (**van der Waals, capillary, and frictional forces**) in a **practical, visual** context. The ability to **test different surfaces in AR, analyze adhesion effectiveness, and brainstorm biomimetic designs** allows students to **bridge the gap between STEM principles and innovative real-world applications**, reinforcing knowledge retention.

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

The scenario leverages **visual animations, hands-on AR exploration, and inquiry-based tasks** to address different learning styles. This **multisensory approach** helps students **overcome abstract STEM challenges** by making complex adhesion mechanisms **tangible and interactive**.

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Which results are expected to be reached with its use?

Enhanced Understanding of Bio-Inspired Adhesion Mechanisms

Students will develop a **deeper understanding of natural adhesion mechanisms** found in organisms such as **geckos and beetles**. By engaging with **interactive 3D AR models**, they will grasp how **van der Waals forces and capillary adhesion** work at the microscopic level and how these biological strategies differ from artificial adhesives used in engineering. This immersive learning experience reinforces **theoretical knowledge through visualization and hands-on interaction**.

Increased Engagement and Interest in Biomimicry and STEM Fields

The **interactive and exploratory nature** of the exercise is expected to **increase student interest and motivation** in biomimicry, physics, and biology. By **turning a complex STEM concept into an engaging learning experience**, students are more likely to develop **a positive attitude toward biomimetic innovations** and recognize the real-world applications of **bio-inspired engineering**.

Improved Retention and Recall of Key Concepts

The combination of **animated pathways, interactive models, and gamification elements** is expected to improve students' **ability to retain and recall key concepts** related to adhesion. The **multisensory learning approach** (visual, interactive, hands-on) will help students **connect theoretical knowledge with practical applications**, making it easier for them to explain how adhesion works and why it matters in technological advancements.

Increased Confidence in Explaining Bio-Inspired Design Applications

As students **explore adhesion through AR** and **complete guided learning tasks**, they are expected to **gain confidence in explaining how biomimicry can inspire material science and engineering solutions**. The interactive approach will empower students to **articulate their knowledge effectively**, bridging the gap between **natural adhesion strategies and future technological innovations** such as **climbing robots, medical adhesives, and space exploration materials**.

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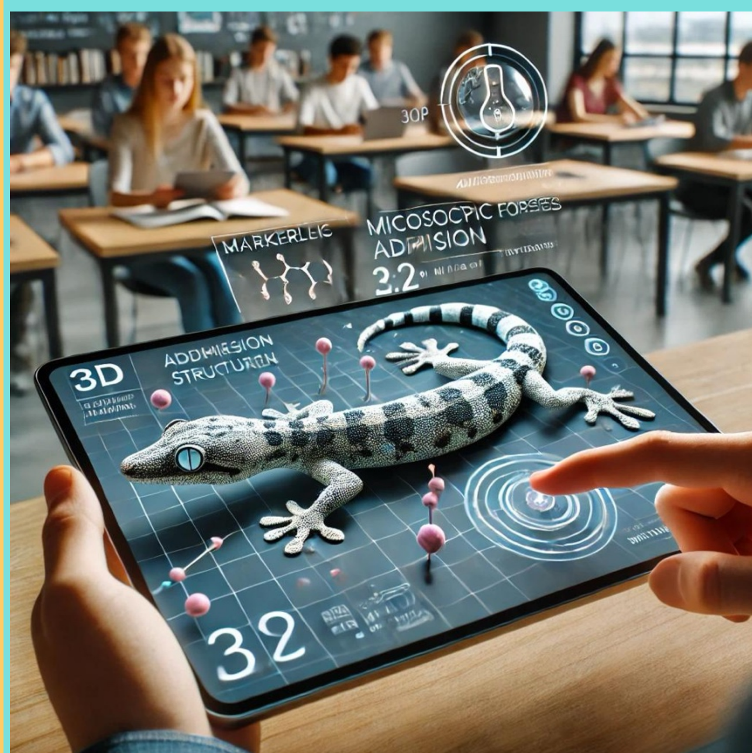
Technical specifications

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:** A web-based AR viewer (such as WebXR) or a mobile AR: Delightex

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Type of Augmented data	3D models of gecko's footpad and beetle's adhesive pads. Text overlays explaining adhesion mechanisms. Animations showing adhesion in action. Interactive elements for zooming, rotating, and placing the models in real-world settings.
Written description of the AR data	After launching the AR experience on their device, students will see a 3D model of a gecko's footpad with microscopic adhesion structures placed on a real-world surface. The title "Biomimicry: Controlled Adhesion" will appear, guiding students through the interactive learning experience. Students can interact with the 3D model by: • Zooming in and rotating to examine microscopic adhesion details. • Tapping on specific areas, which will trigger annotations and explanations, such as: "What are van der Waals forces?" "How does a gecko detach its foot while climbing?" "How does beetle adhesion differ from gecko adhesion?" By clicking on the navigation arrow, the AR scene will change, displaying a beetle's adhesive footpad structure, with additional annotations about capillary adhesion mechanisms. Students can switch between the two models (gecko and beetle) using the navigation arrows, allowing them to compare biological adhesion strategies. **Additional features:** • An animated sequence showing how gecko feet grip and release surfaces. • A biomimetic application section, where students can explore real-world innovations inspired by these natural adhesion techniques. • A "Return to Start" button, allowing students to reset the AR experience and revisit previous models.
Scene	Three scenes: Scene 1: Gecko Adhesion: Students interact with a 3D gecko foot model, exploring van der Waals adhesion and setae structures. Pop-ups explain adhesion mechanics, and animations show how

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If Image	geckos grip and detach from surfaces. Navigation arrow moves to Scene 2. Scene 2: Beetle Adhesion: A 3D beetle foot model is displayed, showcasing capillary adhesion. Interactive elements include tapping to reveal liquid adhesion effects, animations of foot detachment, and surface comparisons. Navigation arrow moves to Scene 3. Scene 3: Biomimetic Applications: The final scene introduces biomimetic innovations, allowing students to explore bio-inspired adhesive technologies. Features include animations, case studies, and an interactive biomimicry challenge. A “Return to Start” button lets students restart or revisit previous scenes. -
If Text	Here are the **pop-up text overlays** that will appear in the AR experience: **How Geckos Achieve Adhesion** • Geckos use **van der Waals forces** to stick to surfaces. • Their feet have **millions of tiny hair-like structures (setae)** that split into even smaller tips (spatulae). • These structures allow geckos to **stick to smooth surfaces like glass** without using glue. **How Beetles Use Capillary Adhesion** • Beetles use **liquid secretion** to create a temporary adhesive bond. • Their **footpads secrete a thin film of liquid**, which helps them **grip surfaces using capillary forces**. • This mechanism allows beetles to **cling to leaves and climb vertical surfaces**. **Biomimetic Applications of Adhesion** • Scientists have created **gecko-inspired dry adhesives** used in **climbing robots and medical devices**. • Beetle-inspired adhesion research has led to **self-cleaning adhesives** for electronics and healthcare. These texts can be integrated into the **AR pop-ups** or used in an accompanying worksheet.

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If video	
If audio	-
If 3D model	Delightex https://edu.delightex.com/TWK-ZGS

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