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Photobiomodulation: How Low-Level Light Stimulates Healing

BIOS4YOU
AR 2.0
BIO-INSPIRED STEM TOPICS FOR ENGAGING YOUNG GENERATIONS THANKS TO THE USE OF AUGMENTED REALITY

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Table of Contents

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

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Introduction

This document describes the Augmented Reality (AR) exercise titled Photobiomodulation: How Low-Level Light Stimulates Healing, designed for students aged 17–19 within the European project BioS4You 2.0 (Work Package 3: AR Exercises).

The aim of this exercise is to help students understand how low-level red and near-infrared light stimulates cellular repair mechanisms and how it is applied in medical treatments, connecting physics (electromagnetic spectrum, wavelength-dependent tissue penetration), chemistry (photochemistry, mitochondrial bioenergetics), biology (cellular metabolism, chromophore activation), and medicine (wound healing, muscle recovery, scar reduction).

This document follows the standard BioS4You AR Exercise template and is organized into the following sections:

General Information: title, authors, target group, duration, keywords, and topics Pedagogical Specifications: learning objectives, methodology, integration with curriculum Technical Specifications: hardware, software, AR experience design

The exercise has been developed using the 3E approach (Explore – Execute – Enhance), encouraging students to explore photobiomodulation mechanisms step-by-step through interactive AR scenes showing light spectrum and tissue penetration, mitochondrial chromophores (cytochrome c oxidase), ATP production mechanism, and clinical applications.

	General Information
Name of the exercise:	**Photobiomodulation: How Low-Level Light Stimulates Healing** From red light to cellular repair: understanding mitochondrial activation and tissue healing The title reflects both the scientific principles and practical applications of photobiomodulation therapy. "Photobiomodulation: How Low-Level Light Stimulates Healing" emphasizes the dual focus on fundamental biophysics and clinical use, while the subtitle "From red light to cellular repair" highlights the journey from light spectrum properties (red and near-infrared wavelengths) to practical healthcare applications through mitochondrial activation, cytochrome c oxidase stimulation, ATP production, and accelerated tissue repair.

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Description of the exercises:	Photobiomodulation: How Low-Level Light Stimulates Healing is designed for students aged 17–19 to explore the fundamental principles of light-tissue interaction and medical applications through Augmented Reality. The main objective is to help students understand how red and near-infrared light penetrates tissues and stimulates cellular repair mechanisms through mitochondrial activation, and how photobiomodulation therapy is used in clinical treatments. Students will: • Understand light spectrum properties and wavelength-dependent tissue penetration • Visualize mitochondrial chromophores (cytochrome c oxidase) and photon absorption • Explore ATP production mechanism triggered by red/NIR light • Learn about photobiomodulation clinical applications (wound healing, muscle recovery, scar reduction) The AR experience uses Delightex Studio – Spaces (Marker) with 6 sequential scenes and 6 integrated quizzes.
Participants:	The exercise is suitable for both individual students and small groups of 3–5 members. Working in groups is recommended to stimulate discussion about light-tissue interactions, compare observations of mitochondrial activation processes and ATP production mechanisms, and develop collaborative problem-solving skills when analyzing photobiomodulation clinical applications.
Participants' age range:	Students should have basic understanding of physics, chemistry, and biology, in particular the concepts of electromagnetic spectrum, wavelengths, light properties, cellular structure, mitochondria, and energy metabolism. Prior knowledge of cell biology basics (organelles, cellular respiration, ATP) and basic anatomy (tissue layers) is recommended but not mandatory.
STEM subject and specific topic:	STEM Subject: Physics, Chemistry, Biology, Medicine, Engineering Specific Topic: Photobiomodulation therapy, light spectrum, wavelength-dependent tissue penetration, mitochondrial

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

	chromophores (cytochrome c oxidase), ATP production mechanism, cellular bioenergetics, clinical applications (wound healing, muscle recovery, scar reduction) Main challenge of the topic: Students often struggle to understand how invisible light can have biological effects, why specific wavelengths (red and near-infrared) penetrate deeper than others, how cytochrome c oxidase absorbs photons and triggers ATP production, and how increased cellular energy accelerates tissue repair. AR visualization helps bridge these abstract nanoscale and cellular processes with tangible clinical applications.
Gamification process:	The gamification strategy follows BioS4YOU WP2 guidelines, focusing on challenge-based learning and immediate feedback with Delightex Studio. Challenge-based learning: Students follow the journey from light spectrum properties to cellular repair mechanisms and medical applications. Each scene presents a quiz that must be answered correctly to proceed to the next stage, creating a progressive learning pathway. Immediate feedback: Delightex provides instant visual feedback when students answer quiz questions. Correct answers unlock the NEXT button and advance the storyline, while incorrect answers prompt students to reconsider the biophysical and cellular principles involved. Achievement unlocking: Scene 6 requires completing all three medical application quizzes to receive the final congratulations message, providing a sense of accomplishment and mastery.
Written or graphic description of Augmented info:	The AR experience is developed in Delightex Studio – Spaces (Marker) and includes: Scene 1: Title and introduction Title "Photobiomodulation: How Low-Level Light Stimulates Healing" with START button Scene 2: Light Spectrum & Tissue Penetration Two diagrams showing electromagnetic spectrum (highlighting Red 600-700nm and NIR 700-1100nm wavelengths) and tissue cross-section demonstrating wavelength-dependent penetration depth through skin, fat, and muscle layers Scene 3: Cells, Mitochondria & Chromophores Cell cross-section with mitochondria and zoomed view showing cytochrome c oxidase absorbing red/NIR photons Quiz: What

	molecule in mitochondria absorbs red and near-infrared light? Scene 4: ATP Production Mechanism Step-by-step diagram showing photon absorption by cytochrome c oxidase, electron transport chain activation, and ATP production increase Quiz: How does photobiomodulation stimulate healing? Scene 5: Clinical Applications Three panels showing wound healing, muscle recovery, and scar reduction with before/after comparisons Quiz: Photobiomodulation differs from surgical lasers because it... Scene 6: Medical Applications Three quizzes on: • Wavelengths used in photobiomodulation therapy • Why red/NIR wavelengths penetrate deeper than blue light • Clinical applications (wound healing, muscle recovery, inflammation reduction) Final congratulations message after completing all quizzes.
External (or extra) tools required	• Devices: Smartphones or tablets with Delightex app installed (iOS or Android) • AR markers: Required; Delightex Studio – Spaces (Marker) uses marker-based AR. Students scan the provided marker to launch the AR experience • Printed worksheets: Optional for note-taking during AR exploration • Internet connection: Required for initial app download and AR content loading
Links (video, images, text online and so on).	**QUIZ** The quizzes are integrated natively in Delightex Studio (scenes 3-6) and do not require external links. Students answer directly within the AR experience with automatic feedback.

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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?

The AR exercise transforms abstract biophysical concepts into visual, interactive experiences that students can explore in real time. By visualizing light spectrum properties and wavelength-dependent tissue penetration, witnessing photon absorption by mitochondrial chromophores (cytochrome c oxidase), observing ATP production mechanisms inside cellular powerhouses, and making direct connections to real clinical applications, students bridge the gap between theoretical biophysics and medical practice. The immersive nature of AR allows learners to manipulate and observe invisible cellular processes, making photobiomodulation therapy tangible and engaging while demonstrating the interdisciplinary connections between physics, chemistry, biology, and medicine.

Which pedagogical objectives are addressed through this scenario?

The exercise addresses multiple pedagogical objectives across different learning domains. Students develop understanding of light spectrum properties, wavelength-dependent tissue penetration, and the fundamental role of mitochondrial chromophores in cellular energy production. They learn to describe cytochrome c oxidase function, ATP production mechanisms, and identify photobiomodulation clinical applications with their specific therapeutic uses. Through AR visualization, students connect nanoscale photon-molecule interactions to macroscopic tissue healing outcomes, analyze cause-effect relationships in cellular bioenergetics (photon absorption → ATP production → tissue repair), and evaluate appropriate photobiomodulation applications for different medical conditions. At the competence level, the exercise develops scientific reasoning about light-tissue and light-cell interactions and critical thinking about photobiomodulation therapy safety and efficacy in healthcare settings.

Which results are expected to be reached with its use?

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

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Students are expected to explain why red and near-infrared wavelengths penetrate deeper into tissues than shorter wavelengths, describe the role of cytochrome c oxidase as the key mitochondrial chromophore that absorbs red/NIR photons, understand how photon absorption triggers ATP production and cellular repair mechanisms, and match different photobiomodulation applications (wound healing, muscle recovery, scar reduction) to appropriate clinical scenarios based on wavelength properties and tissue penetration depth. Assessment of these learning outcomes includes successful completion of all six quizzes during the AR experience, demonstrated ability to explain tissue layer penetration differences across the light spectrum, correct explanation of the photon absorption and ATP production process, and appropriate selection of photobiomodulation therapy for specific clinical conditions.

Which benefits are expected to be reached with its use?

The exercise provides enhanced visualization of cellular and biophysical phenomena that cannot be directly observed, increasing student engagement through interactive AR technology while delivering immediate feedback that supports self-paced learning. Gamification elements maintain motivation throughout the experience. From an interdisciplinary perspective, the exercise integrates physics (electromagnetic spectrum, wavelength-dependent tissue penetration), chemistry (photochemistry, mitochondrial bioenergetics), biology (cellular metabolism, chromophores), and medicine (applications), providing real-world context that demonstrates STEM relevance in healthcare and bridges theoretical science with clinical practice. Long-term benefits include establishing a foundation for advanced studies in photomedicine, regenerative medicine, sports medicine, or biomedical engineering, developing understanding of safe photobiomodulation therapy use and dosimetry in various professional contexts, and fostering critical thinking about wavelength selection and treatment parameters based on tissue penetration properties and cellular mechanisms.

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Technical specifications

In this part it is necessary to specify whether the exercise was designed to be implemented with AR technology. This part is fundamental for the translation process. Please include text, audio text and all the necessary materials.

AR INFORMATION	
Technology	https://edu.delightex.com/ACG-EUM Delightex Studio – Spaces (Marker) The exercise is designed to be implemented entirely with Augmented Reality. It uses marker-based AR, since Delightex Studio – Spaces (Marker) requires students to scan a printed marker to launch the AR experience and view the photobiomodulation cellular mechanisms and clinical applications on their device screen.
If it's needed a marker, description of the marker	A specific marker is required for Delightex Studio – Spaces (Marker). The marker is a printed image or pattern that students scan with their smartphone or tablet camera to launch the AR experience. The marker can be a custom-designed image related to photobiomodulation therapy (such as a red/NIR light wavelength symbol, mitochondrion diagram, or ATP molecule) or a standard QR-style pattern provided by Delightex.

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Hardware and software needed:	• Hardware: Smartphones or tablets with camera and internet connection. Gyroscope and accelerometer are required (standard in most modern devices) • Software: Delightex app (free, available on Android and iOS). Teachers need a Delightex educational account to access and share the AR project • Other: Printed marker for each student or group
Type of Augmented data	The AR experience integrates different types of content: • 3D text (title "Photobiomodulation: How Low-Level Light Stimulates Healing", scene labels, quiz questions) • Images (light spectrum diagram, tissue penetration cross-section, cell and mitochondria with cytochrome c oxidase, ATP production mechanism, clinical applications before/after comparisons) • Interactive buttons (START, NEXT, QUIZ buttons) • Text overlays (explanatory messages about wavelength penetration, chromophore activation, ATP production, tissue healing) • Quiz interface (multiple-choice questions with automatic feedback)
Written description of the AR data	When students open the exercise with Delightex app and scan the marker, they begin with Scene 1 displaying the title "Photobiomodulation: How Low-Level Light Stimulates Healing" as 3D text. Tapping START leads to Scene 2 showing two diagrams: the electromagnetic spectrum highlighting Red (600-700nm) and Near-Infrared (700-1100nm) wavelengths, and a tissue cross-section demonstrating how different wavelengths penetrate skin, fat, and muscle layers. Students observe UV/blue light stopping at the surface while red/NIR light penetrates deeply to reach muscle tissue. NEXT button advances without quiz. Scene 3 displays a cell cross-section with mitochondria and a zoomed view of a mitochondrion showing cytochrome c oxidase (the chromophore molecule) on the inner membrane. Students see red/NIR photons entering the cell and being absorbed by cytochrome c oxidase in the mitochondrial cristae. A quiz asks which molecule absorbs red and near-infrared light before

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	enabling NEXT. Scene 4 shows the ATP production mechanism in four steps: photons entering the mitochondrion, cytochrome c oxidase activation, electron transport chain reactions with oxygen and protons, and ATP synthase producing ATP molecules. Students visualize the complete pathway from photon absorption to cellular energy production. Quiz covers how photobiomodulation stimulates healing. Scene 5 presents clinical applications in three panels: wound healing (damaged tissue → healed tissue with reorganized collagen), muscle recovery (inflamed muscle → recovered muscle with reduced inflammation), and scar reduction (disorganized collagen → organized collagen matrix). Quiz addresses the difference between photobiomodulation and surgical lasers. Scene 6 presents three consecutive quizzes about photobiomodulation applications: wavelengths used in therapy (red 600-700nm and NIR 700-1100nm), why red/NIR penetrate deeper than blue light (tissue penetration depth), and clinical applications (wound healing, muscle recovery, inflammation reduction). Completing all three reveals congratulations message.
If Image	If the AR data are Images, the formats needed are .jpg and .png (better size < 2Mb). The exercise uses multiple images: • Scene 2: Light spectrum diagram showing electromagnetic spectrum with Red (600-700nm) and NIR (700-1100nm) wavelengths highlighted • Scene 2: Tissue penetration cross-section showing skin, dermis, subcutaneous fat, and muscle layers with colored arrows demonstrating wavelength-dependent penetration (UV/blue stop at surface, red/NIR reach deep muscle) • Scene 3: Cell cross-section with mitochondria and zoomed mitochondrion showing cytochrome c oxidase on inner membrane cristae absorbing red/NIR photons • Scene 4: Mitochondrial ATP production mechanism diagram showing photon absorption, cytochrome c oxidase activation, electron transport chain, and ATP synthase producing ATP molecules • Scene 5: Clinical applications showing three panels with

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	before/after comparisons: wound healing (damaged → healed tissue), muscle recovery (inflamed → recovered muscle), scar reduction (disorganized → organized collagen)
If Text	Short explanatory messages are displayed as text overlays inside Delightex Studio. Scene 1: Title and subtitle Scene 2: "Red light (600-700nm) and near-infrared light (700-1100nm) penetrate deep into tissues, reaching muscles and activating cells. Shorter wavelengths like blue and UV are absorbed at the surface" Scene 3: "Mitochondria are cellular powerhouses. Red and NIR photons are absorbed by cytochrome c oxidase, a key molecule inside mitochondria that triggers energy production" Scene 4: "When cytochrome c oxidase absorbs photons, it triggers chemical reactions that produce more ATP (adenosine triphosphate) - the energy currency of cells. More ATP means faster tissue repair and reduced inflammation" Scene 5: "Photobiomodulation has proven clinical applications: accelerating wound healing, reducing muscle soreness and inflammation after sports injuries, and improving scar appearance. Unlike high-power surgical lasers, PBM uses low-level light to stimulate, not ablate tissues" Quiz questions: • What molecule in mitochondria absorbs red and near-infrared light? • How does photobiomodulation stimulate healing? • Photobiomodulation differs from surgical lasers because it: • Which wavelengths are used in photobiomodulation therapy? • Why do red and NIR wavelengths work better than blue light for deep tissue healing? • Photobiomodulation clinical applications include: Final message: "Congratulations! You've successfully completed the Photobiomodulation exploration! You now understand how

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	low-level red and near-infrared light stimulates mitochondria to accelerate healing and reduce inflammation."
If video	-
If audio	-
If 3D model	3D models in Delightex Studio can be used in formats compatible with the platform (.glb, .obj). The exercise primarily uses 3D text elements for titles and labels. Optional enhancement could include importing 3D models of mitochondria, cell structures, ATP molecules, or photobiomodulation therapy devices from libraries compatible with Delightex.

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