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The Photovoltaic Journey: Capturing the Sun

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

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Introduction

This document describes the Augmented Reality (AR) exercise titled The Photovoltaic Journey: Capturing the Sun, designed for students aged 17–19 within the framework of the BioS4You AR 2.0 project.

The aim of this exercise is to help students understand how solar energy conversion occurs through the intersection of physical phenomena (photon energy), biological structures (semiconductor materials), and technological principles (photovoltaic effect) through a clear, sequential, and interactive learning experience. Using Delightex Studio – Spaces (Marker), students access an AR environment where they navigate through progressive scenes showing how light photons are absorbed by solar cells, converted into electron-hole pairs at the P-N junction, and transformed into useful electric current flowing through a circuit.

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 photovoltaic mechanisms step-by-step, interact with animated visual representations, and reflect throughout the learning process.

Thanks to AR, students are immersed in an enriched environment where text, images, 3D objects, and animations appear overlaid on real-world surfaces. This combination of digital media and physical space helps to visualize invisible processes (photon absorption, charge separation, electron flow), strengthen interdisciplinary connections between physics (optics, energy), chemistry (semiconductors, doping), and engineering (circuit design, renewable energy), and support a deeper understanding of how light energy becomes electrical energy through photovoltaic conversion.

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	General Information
Name of the exercise:	**The Photovoltaic Journey: Capturing the Sun** From photons to electrons: the physics of solar energy conversion The title reflects both the scientific content and the immersive nature of the exercise. The Photovoltaic Journey emphasizes the systematic process through which light becomes electrical energy, while Capturing the Sun conveys the complete pathway from solar photons to usable current through progressive scene navigation. The subtitle From photons to electrons: the physics of solar energy conversion highlights the interdisciplinary perspective of the exercise: the physical side, where photon energy must exceed the semiconductor bandgap to generate electron-hole pairs, the chemical side, where P-N junction doping creates a built-in electric field that separates charge carriers and prevents recombination, and the engineering side, where electrons flow through external circuits to deliver useful electrical power to loads. This structure makes the topic interdisciplinary and accessible for an international audience of 17–19 year old students, integrating physics (photon energy, electromagnetic radiation), chemistry (semiconductor materials, doping mechanisms), and engineering (circuit design, renewable energy technology) in a single interactive scenario implemented through Delightex Studio – Spaces (Marker).
Description of the exercises:	The Photovoltaic Journey: Capturing the Sun is designed for students aged 17–19 to explore the fundamental principles of solar energy conversion through Augmented Reality. The main objective is to help students understand how sunlight is transformed into electricity through a sequence of physical, chemical, and engineering processes: photon absorption by semiconductor materials, electron-hole pair generation at the P-N junction, charge separation by the built-in electric field, and current flow through an external circuit. Using Delightex Studio – Spaces (Marker), students navigate through 5 sequential AR scenes placed on a real-world surface (such as a desk or classroom table). The first scene introduces the topic with a title and START button. The second scene shows how photons arrive at the solar panel and demonstrates the importance of photon energy relative to the semiconductor bandgap. The third scene illustrates how the P-N junction

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creates a built-in electric field that separates electron-hole pairs, with animated spheres representing charge carriers moving in opposite directions. The fourth scene displays the complete circuit with electrons flowing through an external load (lamp), demonstrating energy transfer and current flow, culminating in a visual firework effect when the lamp lights up. The fifth scene presents an integrated assessment with three sequential quizzes testing conceptual understanding of series connections, infrared photon limitations, and recombination prevention mechanisms.

The exercise follows the 3E approach (Explore – Execute – Enhance): students explore the photovoltaic mechanism step-by-step, execute interactions by tapping buttons to progress through scenes and answer quizzes, and enhance their understanding through immediate visual feedback and sequential assessment. The complete experience takes approximately 5-7 minutes, making it suitable for both classroom integration and individual homework assignments. By combining diagrams, text overlays, animations, and interactive elements in AR, the exercise makes invisible processes visible and connects abstract physics concepts (photon energy, bandgap) with concrete engineering applications (solar panels, renewable energy), fostering interdisciplinary STEAM learning.

Participants:

The exercise is suitable for both individual students and small groups of 3–5 members. Working in groups is recommended to stimulate discussion, compare different observations at each stage of the photovoltaic process (photon absorption, charge separation, current flow), and develop collaborative problem-solving skills.

In group settings, students can collectively analyze how photon energy determines electron-hole pair generation, discuss the role of the P-N junction in preventing recombination, and debate practical applications like series vs parallel solar cell connections. This collaborative approach encourages peer learning and enhances engagement with the interdisciplinary content, making abstract concepts like bandgap energy and charge carrier dynamics more accessible through shared exploration of the AR scenes.

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Participants' age range:	• Minimum age: 17 years • Maximum age: 19 years To take part in the activity, students should have a basic understanding of physics and chemistry, in particular the concepts of energy, electricity, light as electromagnetic radiation, and semiconductor materials. Prior knowledge of basic atomic structure (electrons, nuclei) and electric circuits (current, voltage) is recommended. These prerequisites ensure that students can connect the AR visualizations with their existing knowledge and appreciate the interdisciplinary nature of photovoltaic technology.
STEM subject and specific topic:	STEM Subject: Physics, Chemistry, Engineering, Technology Specific Topic: Photovoltaic effect, solar energy conversion, semiconductor physics, P-N junction dynamics, electric circuits, and renewable energy technology Main challenge of the topic: Students often struggle to connect abstract physics concepts (photon energy, bandgap) with chemical structures (semiconductor doping, P-N junction) and engineering applications (circuit design, renewable energy systems). Solar energy is typically taught in separate disciplinary silos: optics in physics class, materials science in chemistry, and circuits in engineering, making it difficult for students to grasp the complete integrated mechanism. Furthermore, the invisible nature of electron-hole pair generation and charge separation makes these processes abstract and hard to visualize. How AR helps simplify the concept: Through Delightex Studio, students can interact with sequential AR scenes that show the complete photovoltaic pathway step-by-step. Each scene focuses on a specific stage (photon arrival → P-N junction → current flow → assessment) with visual representations: diagrams showing solar cell structure, animated particle effects illustrating photon movement, color-coded spheres representing electrons and holes, and visual firework effects demonstrating energy transfer. This sequential AR visualization bridges the gap between abstract concepts and tangible understanding, helping students see how light energy becomes electrical current through semiconductor physics. The integrated quizzes reinforce critical thinking about energy thresholds, series connections, and recombination prevention.

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Gamification process:	The gamification strategy follows the recommendations of the BIOS4YOU WP2 guidelines, focusing on challenge-based learning and immediate feedback that can be realistically implemented with Delightex Studio – Spaces (Marker). Challenge-based learning: Students are given the task of following the complete journey of solar energy from photon arrival to electric current generation. Each AR scene presents a specific stage of this pathway, and students must interact with buttons to progress sequentially, making the learning process active rather than passive. Immediate feedback: The integrated Delightex quizzes provide instant automatic feedback when students answer questions about photon energy requirements, P-N junction function, and current flow mechanisms. Correct answers are confirmed immediately with visual celebrations (lamp fireworks, color preservation), while incorrect answers trigger visual consequences (color desaturation, animation stops) without revealing the solution directly, encouraging reasoning and retry. Visual consequences: Instead of points or badges, feedback is represented through the progression of AR scenes themselves and through visual effects. Successfully answering quizzes advances the narrative from photon arrival to charge separation to current flow, creating a sense of exploration and discovery. Animated elements (particle effects for photons, moving spheres for charge carriers, firework effects for energy transfer) provide visual rewards that reinforce understanding. Wrong answers cause visual desaturation, making the impact of correct knowledge immediately apparent. Role-playing element: Learners act as explorers of the photovoltaic system, navigating through the solar cell to discover how sunlight becomes electricity. In group settings, they discuss and compare their understanding of each stage together, fostering collaborative

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	problem-solving.
Written or graphic description of Augmented info:	The AR experience is developed in Delightex Studio – Spaces (Marker) and includes the following elements: **Title and introductory scene** 3D text displaying "The Photovoltaic Journey: Capturing the Sun" with subtitle and background image, featuring a START button to begin exploration. **Diagrams and images** High-quality images showing solar panel cross-section with n-type and p-type layers, P-N junction detail with electron and hole flows, and complete circuit diagram showing solar cell connected to lamp/load with return path (scenes 2, 3, 4). **Interactive buttons** Rectangular clickable elements labeled START, NEXT, QUIZ, RESTART that students tap to navigate between scenes. **Animated visual effects** Yellow particle systems simulating photons traveling from sun to solar panel (scene 2), blue and red spheres with electron (−) and hole (+) symbols moving in opposite directions to demonstrate charge separation (scene 3), sphere animations showing electrons flowing through circuit and accumulating in lamp (scene 4), and firework particle effects when lamp lights up to celebrate energy transfer. **Integrated quiz modules** Native Delightex quizzes presenting questions with three answer options and automatic branching feedback. Scene 2 asks about photon energy vs bandgap, scene 3 about P-N junction electric field creation, scene 4 about why current stops when panel is covered, and scene 5 presents three sequential conceptual questions about series connections, infrared limitations, and recombination prevention. **Text overlays** Short explanatory captions in each scene describing the process (e.g., "Photons carry energy toward the solar panel", "The P-N junction creates an electric field that separates charge carriers", "Electrons flow through the external circuit, powering the load").

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	All elements are positioned on a marker-detected surface, allowing students to view the complete photovoltaic mechanism pathway in AR overlaid on their physical classroom desk or table. The sequential scene structure guides students through the interdisciplinary content (physics → chemistry → engineering) in a logical, easy-to-follow progression.
External (or extra) tools required	• Devices: smartphones or tablets with the 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 and view the photovoltaic mechanism scenes on their device • Printed worksheets: to allow students or groups to record the sequence of events (photon absorption, charge separation, current flow), reflect on the outcomes of each stage, and prepare a short report connecting physics (energy, optics), chemistry (semiconductors, doping), and engineering (circuits, renewable energy)
Links (video, images, text online and so on).	**QUIZ** The quizzes are integrated natively in Delightex Studio (scenes 2-5) 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 experience transforms the abstract concept of solar energy conversion into a tangible, interactive journey that students can physically explore on their classroom desk. Instead of reading about photovoltaic effect in a physics textbook or memorizing semiconductor band structure from a chemistry diagram, students navigate through 5 sequential scenes that show the complete mechanism step-by-step. The combination of visual diagrams, animated effects (photon particles, moving charge carriers, lamp fireworks), and interactive progression creates an engaging narrative where physics (photon energy), chemistry (semiconductor doping), and engineering (circuit design) are seamlessly integrated. Students see how photons with sufficient energy generate electron-hole pairs, watch these charges separate at the P-N junction, and follow electrons flowing through an external circuit to power a load. This multisensory AR approach makes the invisible visible and the abstract concrete, significantly increasing engagement and understanding compared to traditional lecture-based or static image-based instruction. The challenge-based quizzes at each stage reinforce critical thinking, and the visual feedback system (color desaturation for wrong answers, fireworks for success) creates emotional investment in learning. Optional exploration of renewable energy applications allows curious students to connect classroom learning with real-world sustainability challenges.

Which pedagogical objectives are addressed through this scenario?

The exercise addresses interdisciplinary understanding by connecting physical principles (photon energy, electromagnetic radiation), chemical structures (semiconductor doping, P-N junction formation), and engineering applications (circuit design, renewable energy technology). Students develop the ability to visualize invisible processes such as electron-hole pair generation and charge carrier separation. By navigating through scenes in logical order, students understand cause-and-effect relationships in the complete photovoltaic pathway: photon absorption requires sufficient energy relative to bandgap, P-N junction creates built-in electric field for charge separation, and current flows only when external circuit is complete. Students identify key concepts including photon energy thresholds, bandgap limitations, n-type and p-type semiconductor doping, electron and hole charge carriers, P-N junction electric field, and series vs parallel circuit connections, understanding their specific functions in solar energy conversion. The integrated quizzes require reasoning about energy requirements, charge separation mechanisms, and circuit behavior, moving beyond memorization to applied understanding. Students learn why infrared photons cannot generate current in silicon, how series connections increase voltage, and what prevents electron-hole recombination.

Which results are expected to be reached with its use?

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Students are expected to demonstrate improved comprehension of the complete photovoltaic mechanism compared to traditional instruction, as measured by quiz performance and post-activity assessments. The multisensory AR experience should improve retention of key concepts including bandgap energy, charge separation, and circuit behavior. Students should show higher engagement and motivation during the AR activity compared to passive learning methods, evidenced by active participation, peer discussion, and curiosity about renewable energy applications. Students should articulate connections between physics (photon energy), chemistry (semiconductor properties), and engineering (circuit design) rather than treating them as separate topics. They should explain how these disciplines integrate in photovoltaic technology. Students should correctly identify that photon energy must exceed bandgap energy, understand why the P-N junction prevents recombination, explain how series connections increase voltage, and recognize why infrared light cannot generate current in silicon solar cells. When working in groups, students should demonstrate improved peer discussion and collaborative problem-solving around photovoltaic concepts, sharing insights about charge carrier dynamics, circuit optimization, and real-world solar energy applications.

Which benefits are expected to be reached with its use?

AR makes advanced interdisciplinary content accessible to 17-19 year old students by using visual representations and sequential storytelling to reduce cognitive load. By overlaying digital information on the physical classroom, AR connects theoretical knowledge with everyday experiences of light and electricity. The integrated quizzes provide instant feedback for self-correction during learning rather than on later exams, allowing students to adjust understanding in real-time. The 5-7 minute duration suits various contexts including classroom activities, homework assignments, and flipped learning scenarios, working effectively for individuals or groups. Students develop digital literacy with AR educational tools relevant for future learning environments and careers in STEM fields. The AR experience requires only smartphones/tablets and a marker, making it cost-effective compared to physical solar panel demonstration equipment. The combination of visual diagrams, animations, text, and kinesthetic interactions supports diverse learning styles (visual, auditory, kinesthetic). AR visualization of charge carrier movement and energy transfer develops spatial thinking skills valuable across STEM disciplines. By connecting photovoltaic physics to renewable energy applications, the exercise fosters environmental awareness and sustainability thinking, preparing students to engage with global energy challenges.

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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/NPS-QRW NPS QRW 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 photovoltaic mechanism scenes overlaid on their physical environment.
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 the photovoltaic topic (such as a sun or solar panel illustration) or a standard Delightex marker provided by the platform. Once the marker is detected by the device camera, the AR scenes appear anchored to the marker position, allowing students to view the photovoltaic mechanism pathway overlaid on their physical workspace. Teachers can print the marker on standard paper and distribute it to students or display it on a larger surface for group

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	viewing.
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 launching the AR experience. Internet connection is needed for initial download of the AR project
Type of Augmented data	The AR experience integrates different types of content: - 3D text (title "The Photovoltaic Journey: Capturing the Sun", scene labels, button labels) - Images (solar panel diagrams showing n-type/p-type layers, P-N junction detail, circuit diagram with lamp/load) - Interactive planes (rectangular buttons labeled START, NEXT, QUIZ, RESTART) - Animated particles (yellow photon particles from sun to panel, blue electron spheres with − symbol, red hole spheres with + symbol, firework effect for lamp lighting) - Text overlays (short explanatory captions describing each stage of the photovoltaic mechanism) - Integrated quiz modules (native Delightex quizzes with questions and multiple-choice answers)
Written description of the AR data	When students open the exercise with Delightex app and scan the marker, they begin with the introductory scene displaying the title "The Photovoltaic Journey: Capturing the Sun" as 3D text with subtitle and background image. By tapping the START button, they navigate to the second scene showing photons (yellow particles) traveling from an animated sun toward a solar panel diagram, with explanatory text about photon energy requirements relative to semiconductor bandgap. A quiz button appears asking what determines if a photon can generate electricity. Tapping NEXT after correct quiz answer advances to the third scene illustrating the P-N junction with animated blue spheres (electrons with − symbols) moving upward toward n-type region and red spheres (holes with + symbols) moving downward toward p-type region, demonstrating charge separation by the built-in

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	electric field. A quiz asks what creates this electric field. The fourth scene displays the complete circuit diagram from solar cell through wires to lamp/load and back. The sun repositions to the left and emits photon rays. Blue and red spheres travel through the circuit and accumulate in the lamp, which then explodes in a firework particle effect to celebrate energy transfer. A quiz asks why current stops when the panel is covered. The fifth scene presents three sequential assessment quizzes. Quiz 1 appears first, asking how to increase voltage output (answer: connect cells in series). After correct answer, Quiz 2 appears asking why infrared photons cannot generate current in silicon (answer: energy < bandgap). After correct answer, Quiz 3 appears asking what prevents electron-hole recombination (answer: P-N junction electric field). If Quiz 2 or 3 is answered incorrectly, Quiz 2 and 3 reset to opacity 0 and the student must retry from Quiz 1. After all three quizzes are answered correctly, a motivational message appears: "Congratulations! You've successfully completed the Photovoltaic Journey! You now understand how sunlight becomes electricity." A RESTART button then appears, allowing students to repeat the exercise from Scene 1. The sequential progression through these 5 scenes takes approximately 5-7 minutes and guides students through the complete interdisciplinary pathway from physics (photon energy) to chemistry (semiconductor structure) to engineering (circuit design and renewable energy applications).
If Image	If the AR data are Images, the formats needed are .jpg and .png (better size < 2Mb). The exercise uses multiple images: solar panel diagram with n-type/p-type layers (scene 2-3), electron sphere blue PNG with − symbol (scene 3-4), hole sphere red PNG with + symbol (scene 3-4), and circuit diagram showing solar cell → lamp → return (scene 4). All images should be high-resolution educational diagrams clearly showing structures and flows, optimized for mobile display.
If Text	Short explanatory messages are displayed as text overlays inside Delightex Studio. Scene 1: Title and subtitle. Scene 2: "Photon Arrival - When sunlight hits the solar panel, photons carry energy toward the semiconductor material. Only photons with sufficient energy can generate electricity." Scene 3: "Charge Separation - The

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	P-N junction creates a built-in electric field that separates electron-hole pairs." Scene 4: "Current Flow - Electrons flow from the N-type terminal through the external circuit, powering the load." Scene 5: Assessment quizzes with multiple-choice options. All text uses clear, readable fonts suitable for mobile AR viewing.
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, and a 3D animated sun object from the Delightex library. Optional enhancement could include importing 3D models of solar panels or photovoltaic cells from external sources (such as Sketchfab or engineering model libraries) if Delightex supports direct 3D model import. However, the core implementation relies on 2D images (solar panel diagrams, circuit diagrams), text overlays, interactive planes (buttons), and particle effects (animated photons, electron/hole spheres, firework effects) rather than complex 3D models, ensuring compatibility and smooth performance on standard mobile devices.

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