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Bio-Based Building Materials: Innovations and Applications

BIOS4YOU AR 2.0

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

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Image 1. Bio-Based Building Materials: Innovations and Applications

General topic of the learning path	Eco-Friendly Materials in Construction
Specific name of the learning unit	Bio-Based Building Materials: Innovations and Applications
Age of the target users	14-18 years
Requirements for the learner	1. Basic understanding of environmental science concepts (e.g.,eco-material,). Basic literacy and numeracy skills. Basic ICT skills. 2. Access to a computer or tablet with internet connectivity. 3. Willingness to engage with digital tools (AR apps, Delightex). 4. No prior coding or AR development experience required, as CoBlocks is beginner-friendly.
Description of the learning unit	This unit introduces students to the concept of eco-friendly materials in construction, focusing on cutting-edge innovations transforming sustainable architecture. It is divided into three sections: "Explore" introduces foundational concepts of eco-materials and sustainable construction. "Execute" delves into bio-inspiration, showcasing how natural processes inspire solutions and how Augmented Reality (AR) can visualize these processes and impacts, supported by real-world examples and practical activities. "Enhance" justifies the

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	pedagogical benefits of AR, offering examples of useful AR applications and practical integration strategies. The unit culminates in a hands-on exercise where students use a gamified AR experience in Delightex to strengthen their understanding and engagement with the topic.
Subject: Parties involved	Environmental Science, Biology, Geography, Digital Literacy/Computer Science, Art & Design, Social Studies, Mathematics, Language Arts (research, communication)
Keywords	Bio-based materials, Nature-Based Solutions, Bio-inspiration, Biomimicry, Environmental Education, Sustainability, Sustainable Construction, Digital Literacy, Augmented Reality (AR), Gamification.
Key qualifications, skills and knowledge that can be acquired	Qualifications (Mindset/Attitude): ● Environmental awareness. ● Proactive and innovative thinking towards environmental challenges. ● Appreciation for nature's role in sustainable solutions. ● Motivation to participate in climate action. Skills: ● **Critical Thinking:** Analyzing environmental problems and proposing solutions. ● **Problem-Solving:** Applying bio-inspired concepts to environmental challenges. ● **Communication:** Explaining complex environmental concepts and presenting ideas. ● **Digital Literacy:** Navigating and utilizing AR applications. ● **Scientific Inquiry:** Interpreting data and observing natural processes (virtual or real). Knowledge: ● Understanding different types of eco-materials and their unique characteristics. ● Understanding the causes and impacts of traditional vs. bio-based materials

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	(e.g., carbon footprint, embodied energy) ● Recognising bio-inspired solutions derived from nature. ● Understanding the potential and applications of Augmented Reality in environmental education.
Resources and didactic aids used	Resources: ● Textbooks/Scientific articles ● Case studies ● Internet resources ● Free AR platforms (Delightex) ● AR-compatible devices (smartphones/tablets)
Assessment criteria and evaluation	● **Participation:** Engagement in discussions and activities throughout the unit. ● **Activity Completion:** Execution of practical AR exercise ● **Concept Map/Mind Map:** Creation of a visual representation linking climate change, ecosystems, restoration methods, and bio-inspired solutions.

Introduction

As our planet faces increasing environmental challenges, the construction industry plays a pivotal role in shaping a sustainable future. This unit will introduce you to innovative materials derived from renewable biological resources, exploring their properties, applications, and the exciting potential they hold for creating greener, healthier buildings. We will also discover how cutting-edge Augmented Reality (AR) technology can enhance our understanding and interaction with these fascinating materials, making complex concepts more accessible and engaging. Get ready to explore the intersection of nature, technology, and sustainable design!

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1. Explore – Foundations of Bio-Based Building Materials

The construction industry is a significant consumer of resources and energy. As we face global environmental challenges, the demand for sustainable building practices is growing. Bio-based building materials offer a promising path towards more eco-friendly construction. These materials are derived from living organisms, primarily plants, and are an alternative to conventional, energy-intensive materials like concrete and steel.

1.1 What are Bio-Based Building Materials?

Bio-based materials are renewable resources that originate from biological sources. Unlike fossil-fuel-derived materials, they are part of a natural carbon cycle, meaning they absorb carbon dioxide during their growth. When responsibly sourced and processed, they have a significantly lower environmental impact. Key characteristics include:

- **Renewability:** They can be grown and replenished within a human lifespan.
- **Low Embodied Energy:** Less energy is consumed during their production, transportation, and construction compared to traditional materials.
- **Carbon Sequestration:** As plants grow, they absorb carbon dioxide from the atmosphere. When used in buildings, this carbon is stored, helping to mitigate climate change.
- **Improved Indoor Air Quality:** Many bio-based materials are non-toxic and breathable, contributing to healthier indoor environments.

1.2 Where are they applied?

- **Timber (Wood):** One of the oldest building materials, wood is versatile, strong, and a natural insulator. Engineered wood products like Cross-Laminated Timber (CLT) and Glued Laminated Timber (Glulam) allow for the construction of tall, large-span buildings previously only possible with steel or concrete.
    - *Applications:* Structural frames, walls, flooring, cladding, insulation.
- **Bamboo:** A rapidly renewable grass with exceptional strength-to-weight ratio, comparable to steel in tension. It grows quickly and requires minimal resources.
    - *Applications:* Scaffolding, structural elements, flooring, wall panels, roofing.
- **Straw Bales:** Compressed bales of agricultural waste (e.g., wheat, rice straw) used as infill for walls, providing excellent insulation and thermal mass.
    - *Applications:* Non-load-bearing walls, insulation.

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- **Hempcrete:** A biocomposite material made from hemp hurds (the woody core of the hemp plant), lime, and water. It's lightweight, breathable, and has excellent thermal and acoustic insulation properties.
    - *Applications:* Non-load-bearing walls, insulation, floor/roof infill.
- **Mycelium:** The root structure of fungi. Mycelium can be grown around agricultural waste to form lightweight, fire-resistant, and insulating blocks or panels.
    - *Applications:* Insulation panels, acoustic tiles, non-structural elements.

1.3 Why Are They Important for the Future of Construction?

The shift towards bio-based materials is crucial for:

- **Reducing carbon emissions:** By storing carbon and requiring less energy for production.
- **Conserving natural resources:** By utilizing renewable and often waste products.
- **Creating healthier buildings:** Through natural breathability and reduced use of harmful chemicals.
- **Fostering a circular economy:** Where materials are reused, recycled, or returned to nature.

While challenges like fire resistance, moisture management, and public perception exist, ongoing research and technological advancements are making these materials increasingly viable and competitive.

2. Execute – The Role of Augmented Reality in Exploring Biobased Building Materials

Augmented Reality (AR) applications can greatly enhance learning about biobased building materials by making complex material properties and ecological benefits tangible for students. By overlaying digital information onto real or model structures, AR allows learners to explore how materials like bamboo, mycelium, hempcrete, or recycled timber perform in real-world construction scenarios. Students can see visualizations of structural strength, insulation, carbon capture, and lifecycle impacts, transforming the built environment into an interactive classroom. This bridges the gap between abstract sustainability principles and practical applications in eco-friendly architecture, fostering understanding, creativity, and a sense of environmental responsibility

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2.1 Specific features and types of AR Tools

An AR application for this purpose would be more than just a visualization tool; it would be a dynamic platform for discovery, design, and problem-solving. Key features and tools could include:

- **3D Model Visualization**: Project 3D models of buildings or construction elements onto real-world spaces (e.g., school grounds or local sites) and overlay simulations showing how different bio-based materials—like bamboo, hempcrete, mycelium, or recycled timber—perform in terms of insulation, durability, and environmental impact.
- **Data Visualization Overlays**: Overlay virtual representations of material properties and sustainability metrics onto existing structures, allowing students to see how each material could reduce carbon footprint, improve energy efficiency, or manage moisture and temperature in real time.
- **Identification and Information**: Use AR to “discover” virtual building materials and access information about their ecological benefits, sourcing, lifecycle impacts, and practical applications in construction projects.

2.2 Real studies and practical exercises

Meaningful integration of AR in hands-on learning is already happening globally, particularly in fields like environmental and urban education. These examples demonstrate how AR can move students beyond passive observation and into active, creative problem-solving inspired by nature.

The study investigated the effectiveness of an augmented reality (AR) simulation game called "ecoCampus" in teaching sustainable design principles to students in building design and construction disciplines. The core of the research involved a building redesign activity where students were tasked with designing, visualizing, and assessing different exterior wall designs to improve the sustainable performance of an existing facility. The "ecoCampus" AR application allowed students to overlay virtual design changes onto real-world images or models of a building. Crucially, it provided immediate feedback on the sustainable performance metrics of their chosen materials and designs.

The study aimed to understand if using an AR simulation game could enhance student engagement and learning outcomes compared to traditional methods. The findings indicated that students who utilized the "ecoCampus" AR game demonstrated higher levels of enjoyment and an increased interest in both building design and, significantly, sustainability. Furthermore, the AR tool facilitated a more robust design process, as students using the application performed more design iterations and considered a wider range of materials, leading to more optimized sustainable solutions. In essence,

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the study highlighted that AR technology, particularly within a gamified context, can effectively bridge the gap between abstract sustainable design concepts and their concrete application, making the learning process more engaging, interactive, and impactful for students (O'Nascimento, 2025).

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3. Enhance – AR for Deeper Learning and Engagement

3.1 Examples of Useful AR Apps and Tools

Various AR tools can significantly enhance the learning experience for ecosystem restoration by providing immersive and interactive ways to explore complex environmental concepts. Here is an example:

Delightex (CoSpaces Edu):

Delightex allows users to create interactive 3D virtual worlds and then experience them in augmented reality or virtual reality. It features a drag-and-drop interface and a visual block-based coding language (CoBlocks), making it highly accessible for students and teachers with no prior coding experience. It offers a free version with core functionalities. Students can design and build their own virtual ecosystems, simulate environmental changes, and visualize restoration efforts. Its creative freedom empowers students to become content creators, not just consumers.

3.2 Practical Suggestions for Integration into the Learning Experience

Gamified learning environments or interactive 3D virtual worlds can challenge students to explore bio based materials. This makes learning about urban design both fun and informative.

Exercise: "EcoBuilder" AR App

"EcoBuilder" AR App helps students explore five different bio-based building materials using an augmented reality (AR) app. Each material reveals a clue about its ecological benefits, such as carbon capture, insulation properties, or sustainability in construction. Students will learn to identify and understand the unique properties of each material and how it contributes to building a greener, more sustainable future. Using AR, students interact with virtual representations of the materials, discover the clues they hold, and answer embedded quiz questions about each material. Correct answers earn points, helping students track their progress and reinforcing learning. This exercise combines hands-on exploration, AR visualization, and problem-solving.

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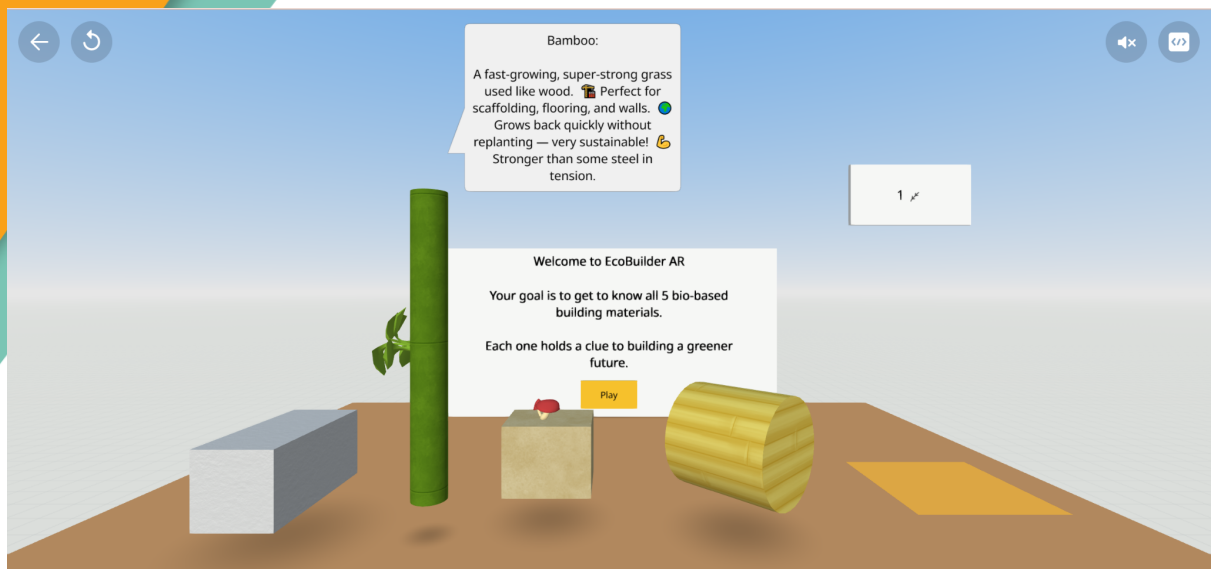

Image 2. “EcoBuilder” AR App

The quiz and scoring system increases engagement, encourages careful observation, and provides measurable feedback on students’ understanding of eco-friendly building materials.

By integrating these AR tools, students transition from abstract knowledge to experiential understanding, building effective and lasting knowledge about eco-friendly construction.

Conclusion

This learning unit has provided a foundational understanding of bio-based building materials, highlighting their significance in sustainable construction. We've explored how nature inspires innovative design, and critically, how Augmented Reality technology serves as a powerful tool to bridge theoretical knowledge with practical application. By engaging with interactive AR experiences like the "Eco-Builder Challenge" in CoSpaces Edu, students can visualize complex concepts, enhance their critical thinking skills, and foster a deeper connection to the principles of eco-friendly design. As we move towards a more sustainable future, the integration of bio-based materials and immersive technologies like AR will be crucial in educating the next generation of innovators who will build a greener world.

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Phase	Description
Explore	- Research and Discovery: Introduce bio-based building materials such as bamboo, mycelium, hempcrete, and recycled timber, highlighting their ecological benefits, sustainability, and practical uses in construction.
	- Content Development: Provide concise background material using visuals, short readings, or videos explaining material properties, carbon footprint, insulation, and lifecycle impacts.
	- Needs Analysis: Assess students' prior knowledge of sustainable construction and environmental concepts to tailor activities appropriately.
Execute	- Curriculum Implementation: Connect material properties to sustainability principles and eco-friendly design practices, showing how bio-based materials can replace conventional building materials.
	- Interactive Exercises: Analyze real case studies. Students use AR to explore virtual models of buildings, select bio-based materials, and see real-time simulations of performance (insulation, durability, carbon impact).
	- Feedback Collection: Share AR designs, reflect on outcomes, and get feedback from peers/teachers.
Enhance	- AR Integration: Use the AR app "EcoBuilder" to visualize bio-based building materials.
	- Interactive Learning:
	Gamified Content: - **Points and Badges**: Students earn points for correct quiz answers and effective material choices. Badges reward mastery of specific material types or sustainability concepts. - **Leaderboards**: Track individual or team progress based on quiz performance, eco-friendly design decisions, and creative material use.
	AR-Based Assessments: Replace traditional tests with AR-based evaluations, such as students exploring their AR urban ecosystem models or completing biodiversity "quests" in real environments.

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