Co-funded by
the European Union

4 - "Grafts" in the CRISPR field

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

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

Contents

Introduction 3

Explore: Building the foundations of knowledge 5

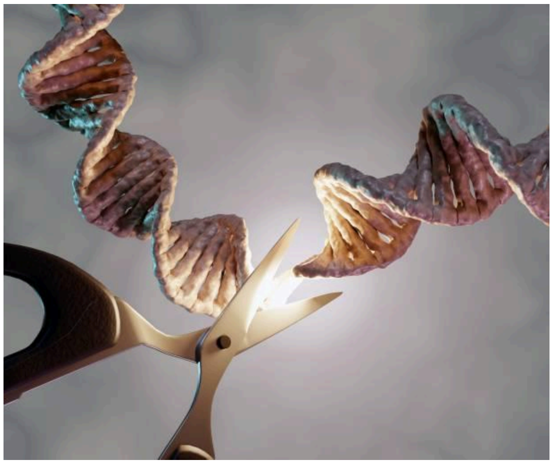
Execute: Experiencing CRISPR in actio 6

Enhance: Deepening understanding and reflection 7

Conclusion: 8

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

Co-funded by
the European Union



General topic of the learning path	Biotechnology and Genetics – Understanding and applying modern tools for gene editing.
Specific name of the learning unit	*Genetic Grafting with CRISPR-Cas9: Correcting DNA through Molecular Scissors*
Age of the target users	14-18 years
Requirements for the learner	• Basic knowledge of biology (DNA, cells, and genes). • Interest in science, technology, and future innovations. • Willingness to use digital tools such as Augmented Reality (AR). • Ability to work individually and in groups.
Description of the learning unit	This unit introduces students to CRISPR-Cas9, a breakthrough gene-editing tool often described as molecular scissors. Students first explore the basics of DNA and genetic mutations (Explore), then experience the editing process through a virtual AR laboratory where they correct a faulty gene (Execute), and finally reflect on applications, ethical implications, and the future of genetic engineering, enhanced by gamified AR assessments (Enhance).
Subject: Parties involved	• Subjects: Biology, Biotechnology, Ethics, and ICT/Digital Literacy.

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."

	• **Parties involved:** Teachers (facilitators), students (active learners and problem-solvers), possible external experts (biotechnologists, ethicists
Keywords	CRISPR-Cas9, Gene Editing, DNA, Mutation, Molecular Scissors, Biotechnology, Augmented Reality, Ethics.
Key qualifications, skills and knowledge that can be acquired	• **Knowledge:** Structure of DNA, gene mutations, principles of CRISPR-Cas9, applications in health and agriculture, ethical debates. • **Skills:** Critical thinking, teamwork, experimental design (virtual), digital literacy, AR tool use, scientific communication. • **Competences:** Understanding biotechnology's impact, applying scientific reasoning to real-world problems, reflecting on ethical consequences of genetic editing.
Resources and didactic aids used	AR application simulating a virtual CRISPR laboratory. Digital lab journals for recording reflections and data. Visual aids (videos, diagrams of DNA and CRISPR mechanisms). Case studies (e.g., CRISPR in sickle-cell anemia research). Gamification tools (points, badges, leaderboards).
• Assessment criteria and evaluation	Knowledge: Understanding of DNA, gene mutations, and CRISPR processes. Practical skills: Ability to complete AR gene-editing missions, accuracy in DNA "repair." Engagement: Participation in group tasks, AR activities, and discussions. Creativity: Original solutions in AR quests, ability to connect science to ethical debates. Reflection: Critical analysis of CRISPR's benefits and risks.

Introduction

Imagine being able to correct an error written in the DNA code of a living cell, like correcting a spelling mistake in a book that contains instructions for life. This is what scientists can now do thanks to CRISPR-Cas9, a revolutionary genetic editing tool.

CRISPR has been described as a “molecular pair of scissors” (Doudna & Charpentier, 2014). It allows scientists to cut DNA at precise locations and modify it, removing defective genes or inserting healthy ones. This technology is already being studied for potential use in correcting genetic diseases, improving crops, and even fighting viruses.

This teaching unit introduces students to the basics of DNA, genes and CRISPR-Cas9, using interactive and accessible explanations. Following the Explore - Execute - Improve methodology, students will first discover the essential concepts, then experiment with the process in a virtual augmented reality laboratory, and finally reflect on the ethical and social impact of this new biotechnology.

What is CRISPR-Cas9 and why it is so important

CRISPR-Cas9 is one of the most powerful scientific discoveries of the 21st century. It is a genetic editing tool that allows scientists to change DNA inside living cells with incredible precision. Some people call it “molecular scissors” because it can cut DNA at exactly the right place.

The word **CRISPR** stands for: **C**lustered, **R**egularly, **I**nterspaced, **S**hort, **P**alindromic, **R**epeats.

CRISPR was originally discovered as a **natural defence system in bacteria**. When viruses attack bacteria, the latter are able to “memorise” fragments of the virus's DNA and store them within their own genome in special CRISPR sequences. If the virus attacks again, the bacteria produce a special RNA-guided protein called **Cas9**, which recognises and cuts the virus's DNA to destroy it.

Scientists realised that they could **reprogram this system** to target **any DNA sequence**, not just viruses. This is how CRISPR-Cas9 became a tool for modifying the DNA of plants, animals and humans.

Co-funded by
the European Union

To better understand what CRISPR-Cas9 is, we need to know that even bacteria, the smallest creatures in the world, wage battles within themselves. Bacteria are constantly attacked by viruses. But unlike us, they have no doctors, vaccines or medicines. Instead, they have developed their own intelligent defence system, which will ultimately change the future of medicine and human science.

When a virus invades, bacteria ‘remember’ it. They take a piece of the virus's DNA and store it within their own genome in special repetitive sequences called CRISPR. Think of it as a ‘wanted poster’ hanging on the sheriff's office wall: it's a reminder of the enemy, so that if it returns, they recognise it immediately.

The Cas9 protein works like a pair of sharp molecular scissors. Guided by a short fragment of RNA (which acts like a GPS), Cas9 is able to track down the invading virus's DNA and cut it to pieces. Once the virus is destroyed, the bacteria survive.

Scientists observed this natural process and had a revolutionary idea: E what if we could use the bacteria's weapon to cut DNA wherever we want? If Cas9 could be guided to viral DNA, perhaps it could also be guided to human or plant DNA. And so, CRISPR-Cas9 was reborn, not only as a bacterial defence system, but as a tool for genetic editing.

The process is surprisingly simple to imagine:

1. First, a scientist designs a **guide RNA**, a short fragment of genetic code that matches the DNA sequence they want to edit. It's like entering the exact address into a GPS.
2. Next, Cas9 is paired with this guide RNA and sent into the cell. Cas9 acts like a pair of scissors, travelling along the DNA until it finds the perfect match.
3. When it reaches its target, Cas9 makes a cut. At this point, the DNA is broken, like a page torn from a book.
4. Finally, the cell's natural repair system kicks in. This repair can be “tricked” into correcting the break in a useful way: either by **deleting** the defective gene or **inserting a correct sequence**.

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

The result? A gene that previously caused problems can now be corrected, just as you would correct a typo in an important instruction manual.

Explore: Building the foundations of knowledge

To understand CRISPR, students must first know what DNA is. DNA is the molecule of life, carrying the genetic instructions that determine how living organisms grow, function and reproduce. Genes are like “sentences” in this code, each providing instructions for a specific protein.

But sometimes mistakes happen. A faulty gene can cause a serious disease, such as cystic fibrosis or sickle cell anaemia. For decades, scientists have dreamed of correcting these mistakes directly at the DNA level.

CRISPR-Cas9 makes this dream possible. It is a tool adapted from a natural defence system in bacteria, in which the CRISPR sequence helps bacteria remember and fight viruses. Scientists discovered that they could use this system to cut DNA exactly where they wanted.

This is how CRISPR works:

A guide RNA is created that matches the DNA sequence to be modified.The Cas9 protein acts like a pair of scissors to cut the DNA at that point.

The cell naturally repairs the DNA: scientists can guide this repair to remove, replace or correct the gene.

Key facts to highlight:

Students need to understand clearly and visually:

- How DNA is made.
- How CRISPR “finds” the right spot in the DNA.
- What happens during the cutting and repair process.
- CRISPR is fast, precise and relatively inexpensive.
- It has already been tested on plants, animals and human cells.

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."

- There are ethical debates about its use, especially on humans.

This prepares them for interactive augmented reality activities.

Execute: Experiencing CRISPR in action

Programme implementation

Students are virtually transported to a 3D augmented reality laboratory. Wearing AR headsets or using AR apps on tablets/phones, they enter a digital environment where DNA strands are magnified and float in front of them.

The AR application guides students through the following steps:

The mission: correct a defective gene within a virtual cell using CRISPR-Cas9.

1. Identify the defective gene: scan a DNA strand to locate the error.
2. Design the guide RNA: select the sequence that matches the defective region.
3. Activate Cas9: observe the enzyme cutting the DNA at exactly the desired location.
4. Repair the DNA: choose the correct replacement sequence, observe the cell “repairing” itself.

During the exercise, the AR system explains each step in simple language, supported by animations and interactive feedback.

Examples from other schools and laboratories around the world can be shown: genetics students use virtual laboratories to practise DNA editing before performing real experiments, reducing risks and costs.

Student performance is measured in the AR lab:

Did they select the correct guide RNA?

Did they successfully correct the gene?

How many attempts did it take?

They receive immediate digital feedback, which reinforces their learning.

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

Co-funded by
the European Union

Enhance: Deepening understanding and reflection

AR integration
AR tools make an invisible process visible and tangible: microscopic DNA editing. Instead of imagining molecules, students can “hold” DNA strands in their hands, zoom in on them and manipulate them in real time. This **connects abstract theory with concrete** experience.

Interactive learning
Students go beyond technical skills to explore:

- **Applications**: correcting human diseases, improving agriculture, developing virus-resistant crops.
- **Limitations**: CRISPR is powerful but not perfect: off-target effects can occur.
- **Ethical issues**: should we edit human embryos? Where is the line between therapy and enhancement?

Classroom discussions and debates allow students to connect science to society.

Gamified content
To make the learning process engaging, the AR lab incorporates gamification:

- **Points and badges** for successful genetic edits.
- **Leaderboards** showing team progress.
- **Missions and levels** where each DNA editing challenge unlocks a new scenario (e.g., correcting a plant gene, correcting a gene responsible for a blood disease).
- **Rewards for exploration**: extra credits for testing innovative solutions.
- **Collaborative tasks**: groups work together to edit multiple genes in a virtual organism.

Augmented reality assessments

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."

Assessments take place directly within the augmented reality:

- students are given a defective gene that they must successfully modify.
- They explain the steps they took and justify their choices.
- The system records their process for assessment by teachers.

This ensures that the assessment is **based on skills** and not just knowledge.

Conclusion:

By following the *Explore–Execute–Enhance* pathway, students gain a strong foundation in **genetics and CRISPR-Cas9**, experience the editing process in a **safe virtual environment**, and reflect critically on the **potential and risks** of gene editing.
The mission correcting a faulty gene becomes a metaphor for their role as future scientists and responsible citizens: learning not only how to use technology, but also how to think about its impact on life and society.

Phase	Description
Explore	- Research and Discovery: Learners begin by exploring the **fundamentals of DNA and genes**. DNA is explained as the "instruction manual for life," with genes as specific sentences that code for proteins. Mistakes in these instructions can cause diseases. CRISPR-Cas9 is introduced as a revolutionary tool discovered in bacteria that allows scientists to "cut and edit" DNA like fixing a typo in a book. Students discover the **natural origin** of CRISPR as a bacterial immune defense, and how scientists adapted it for genetic engineering. Case studies (e.g., CRISPR use in correcting sickle-cell anemia) provide concrete, real-world examples.
	- Content Development: ● What DNA and genes are. ● How CRISPR-Cas9 works step by step (guide RNA, Cas9 enzyme, DNA repair). ● Applications in medicine, agriculture, and conservation. ● Ethical debates: curing vs. enhancing, "designer babies," unintended consequences.
	- Needs Analysis: ● A clear, visual explanation of CRISPR's mechanism. ● An understanding of why gene editing matters for human health and society. ● A safe way to **see and interact with DNA editing**, which prepares them for AR-based practice.
Execute	- Curriculum Implementation:

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

	In this phase, learners move from knowledge to practice. Through an **Augmented Reality laboratory**, students are virtually transported inside a 3D cell. They see a giant DNA strand floating in space, and their mission is to use CRISPR-Cas9 to correct a faulty gene.
	- Interactive Exercises: The AR experience guides students through key steps: 1. Identify the faulty gene – scanning DNA strands to locate the "mutation." 2. Design a guide RNA – selecting the right match for the target sequence. 3. Activate Cas9 – watching the enzyme cut DNA at the exact spot. 4. Repair DNA – inserting a corrected sequence and observing the cell heal itself. Students "work with" digital DNA in real time, making the invisible process visible and interactive.
	- Feedback Collection: ● Team discussions on which diseases could be treated with CRISPR. ● Comparing traditional breeding or genetic engineering to CRISPR precision. Teachers can monitor results through the AR platform, while students log reflections in a **digital lab journal**. Peer review is included: groups exchange feedback on strategies and challenges.
Enhance	- AR Integration: The AR system provides immediate feedback: ● Did the student select the correct guide RNA?, Was the DNA cut at the right point?, Was the repair successful?
	- Interactive Learning: Here, AR becomes a deeper learning tool. Students can manipulate 3D DNA strands, zoom in on molecules, and test what happens if edits are wrong. AR bridges abstract genetic theory with tangible practice.
	Gamified Content: **Points and Badges**: Beyond the technical process, learners reflect on applications and implications **Leaderboards**: track team progress in AR missions. **Quests and Levels**: scenarios increase in difficulty (fixing a single mutation → editing multiple genes).. **Rewards for Exploration**: extra recognition for testing new approaches or finding alternative solutions. **Collaborative Gamified Tasks**: teams must cooperate to edit multiple genes in a shared "virtual organism."
	AR-Based Assessments: ● Students are given faulty DNA and must edit it correctly. ● They explain each step (guide RNA design, cut, repair). ● Performance is measured not only on correct results but also on reasoning, teamwork, and creativity. Teachers use AR data logs and reflective journals to evaluate knowledge, skills, and critical thinking.

References

Britannica. (2023). CRISPR-Cas9 genetic engineering. Retrieved from https://www.britannica.com

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."

Wikipedia. (2023). CRISPR gene editing. Retrieved from
https://en.wikipedia.org/wiki/CRISPR_gene_editing

Ecolife Conservation. (2017). Introduction to Genetic Engineering and Biotechnology (educational manual).

National Agricultural Library (USDA). (2022). CRISPR and Biotechnology Resources.

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

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."