Co-funded by
the European Union

3_Repairing DNA to cure diseases

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

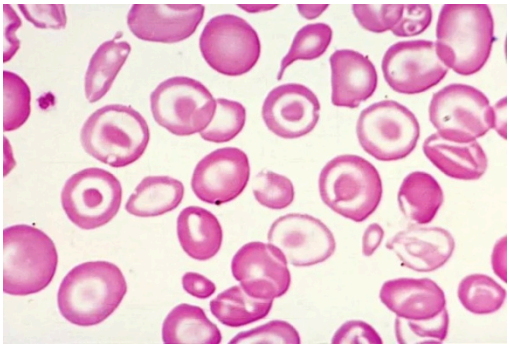
KIT Karlsruher Institut für Technologie · ktu kaunas university of technology · Università degli Studi di Palermo · CEIPES · Eduact

Co-funded by
the European Union

Contents

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

Co-funded by
the European Union



General topic of the learning path	Repairing DNA to cure diseases
Specific name of the learning unit	*Correcting the Code*
Age of the target users	14-18 years
Requirements for the learner	Basic knowledge of cell biology (DNA, genes, proteins, blood). Introductory understanding of genetic inheritance. Familiarity with the idea of mutations and their effects. Openness to discussing ethical and social implications of genetic medicine.
Description of the learning unit	This unit introduces learners to thalassaemia, a blood disorder caused by mutations in the HBB gene, which prevent the production of normal hemoglobin. Students will first discover what thalassaemia is and how it affects the body. They will then explore how gene therapy — using tools such as CRISPR-Cas9 — can repair or replace faulty DNA, offering the possibility of a cure. The unit follows the Explore – Execute – Enhance methodology: Explore: Building a foundation of knowledge about thalassaemia and gene therapy. Execute: Using Augmented Reality simulations and hands-on exercises to practice “correcting” faulty genes. Enhance: Reflecting on advanced applications, ethical debates, and the future of genetic therapies.

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

Co-funded by
the European Union

Subject: Parties involved	Biology, Health Science, Genetics, Ethics, ICT/Digital Literacy. Parties involved: Students (learners and researchers), teachers (facilitators), potential guest experts (geneticists, medical professionals).
Keywords	Thalassaemia, Hemoglobin, Blood Disorders, Gene Therapy, CRISPR, Biotechnology, DNA Editing, Ethics.
Key qualifications, skills and knowledge that can be acquired	Knowledge: Students gain an understanding of thalassaemia and its genetic cause (HBB mutation), learn about current treatments (transfusions, bone marrow transplants), grasp the principles of gene therapy and CRISPR-Cas9, and explore ethical and social debates around genetic editing. Skills: They develop the ability to analyze case studies, use AR tools to visualize DNA editing, work collaboratively in scientific teams, and critically reflect on the risks and opportunities of biotechnology. Competences: Students learn to apply genetic knowledge to real medical challenges, evaluate the societal impact of emerging technologies, and adopt responsible, reflective attitudes toward genetic innovation.
Resources and didactic aids used	Interactive tools: AR simulations of CRISPR-Cas9 editing faulty genes. Hands-on DNA models with beads or paper strips. Digital lab journals for student reflections.
Assessment criteria and evaluation	Knowledge: Understanding of thalassaemia, hemoglobin, and gene therapy concepts. Skills: Ability to use AR to simulate gene correction; participation in modeling and case study activities. Collaboration: Active contribution to group projects and peer discussions. Creativity: Innovative approaches to AR challenges or designing therapy strategies.

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

Co-funded by
the European Union

	Reflection: Engagement in ethical debates and thoughtful entries in lab journals.

Introduction

Thalassaemia is a disease that prevents the blood from carrying enough oxygen. In fact, people affected by it feel constantly tired, have pale skin and have to go to hospital every month for a blood transfusion just to survive.

This is the reality for many people with thalassaemia, a genetic blood disorder that affects haemoglobin, the protein in red blood cells that carries oxygen throughout the body (Thalassaemia International Federation, 2021).

For decades, treatment has involved regular transfusions and, sometimes, bone marrow transplants (Weatherall & Clegg, 2001). These approaches help, but they do not cure the disease and carry risks. Today, however, science is opening a new door: gene therapy. Instead of treating the symptoms, gene therapy offers the possibility of correcting the defective gene itself. For thalassaemia, this means repairing the instructions for producing haemoglobin so that the body can finally produce healthy red blood cells (Cavazza et al., 2016; NIH, 2022).

This unit invites students to embark on a journey into this medical revolution. Step by step, we will explore what thalassaemia is, carry out interactive experiments through augmented reality (AR) that show how gene therapy works, and finally, we will enhance our understanding by imagining the possibilities, challenges, and ethical issues of genetic medicine.

Gene therapy: rewriting the body's instructions

Every cell in our body contains a set of instructions: our DNA. These instructions tell cells how to build proteins, which in turn enable our body to function. But what happens when there is an error in the DNA, like a missing step in a recipe? The result can be serious illness.

Gene therapy is a medical technique that attempts to solve the problem at its source. Instead of treating only the symptoms with drugs or surgery,

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

Co-funded by
the European Union

gene therapy acts directly on the DNA to correct the error. It is like fixing the recipe so that the dish can finally be prepared correctly.

There are several ways to do this:

- Sometimes doctors **replace a defective gene** with a healthy copy.
- Other times, they use special tools such as **CRISPR-Cas9**, often called “genetic scissors”, to **repair or modify the gene**.
- In some cases, scientists **add a completely new gene** that helps the body fight a disease.

In practice, the process often works like this: doctors take cells from the patient, send them to the laboratory, and use gene therapy techniques to correct or replace the defective gene. Once corrected, the cells are returned to the patient's body, where they begin to function normally and produce the healthy proteins that were previously missing (NIH, 2022; Mayo Clinic, 2023).

One of the most obvious examples of this promise is **blood disorders such as thalassaemia**. This disease is caused by a mutation in the **HBB gene**, which prevents the body from producing enough haemoglobin, the protein that carries oxygen in the blood. With gene therapy, scientists can correct the defective HBB gene in the patient's stem cells. When these repaired cells are reintroduced into the body, they can begin to produce healthy red blood cells. For many patients, this could mean reducing or even eliminating the need for lifelong blood transfusions (Cavazza et al., 2016).

Explore:

Thalassaemia is a hereditary disease that occurs when a child receives defective genes from both parents. The defect lies in the HBB gene, which is responsible for producing part of the haemoglobin. Without fully functioning haemoglobin, red blood cells break down too quickly, leaving the body oxygen-deprived (TIF, 2021).

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

Co-funded by
the European Union

Students learn about the daily challenges faced by patients: fatigue, stunted growth, and the constant need for transfusions. Bone marrow transplants can help, but they require a compatible donor, which is rare (Mayo Clinic, 2023).At this point, we move on to the new science of gene therapy. Instead of constantly replacing damaged blood cells, what if we could correct the instructions in the DNA? Scientists are now using tools such as CRISPR-Cas9, often called “genetic scissors”, to cut out the defective genetic sequence and replace it with a healthy version (NIH, 2022). Imagine modifying a recipe that is missing a word so that the dish can finally be prepared correctly. This is exactly what gene therapy does at the molecular level.

Execute:

Once students understand the basics, they step into the shoes of scientists through interactive practice.

In an AR laboratory simulation, learners shrink down to the scale of a cell. They can see the double helix of DNA, locate the faulty HBB gene, and then use a virtual CRISPR system to cut and repair it. As they complete the mission, they watch corrected cells begin to produce healthy hemoglobin.

This exercise transforms abstract science into something visible and hands-on. AR turns invisible molecules into dynamic 3D experiences.

Alongside the simulation, students analyze real case studies of thalassaemia patients who have already benefited from experimental gene therapies (Cavazza et al., 2016). For a tangible classroom activity, they can also build DNA models with beads or colored strips to simulate the difference between faulty and corrected sequences.

Through these activities, students don’t just learn about gene therapy — they experience how it works, and why it offers so much hope.

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

Co-funded by
the European Union

Enhance:

Now that learners have seen how gene therapy can repair faulty DNA, they are invited to think bigger.

Using AR again, they test more complex scenarios: What if only half of the patient's cells are corrected? Could the technique also help with sickle cell disease, another genetic blood disorder? How might gene therapy be delivered to organs beyond the blood?

This stage also uses gamification to deepen engagement. Students earn points and badges for successful missions, rise on leaderboards for creativity, and unlock new levels where they must treat more complex "virtual patients." Collaborative challenges push groups to design strategies together, fostering teamwork and scientific communication.

But it's not just about science it's also about ethics. In guided debates, students consider difficult questions: Should gene therapy be available to everyone, or only those who can afford it? What risks do we face if we edit the human genome? These conversations connect classroom learning to real-world challenges, showing that science is always linked with responsibility.

Conclusion:

By the end of this journey, students will have:

Explored the genetic roots of thalassaemia and the science behind hemoglobin production.

Executed hands-on activities, from AR missions to DNA modeling, to experience how gene therapy works.

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

Enhanced their knowledge by reflecting on real-world cases, ethical questions, and the future of genetic medicine.

Augmented Reality made molecular biology visible, gamification made it engaging, and debates made it socially relevant. Students come away not only with knowledge of how gene therapy might cure thalassaemia, but also with a deeper understanding of what it means to change the very code of life.

Gene therapy is more than a treatment it represents a new chapter in medicine, one where inherited diseases may one day be corrected at their source.

Phase	Description
Explore	- Research and Discovery: In this first stage, students dive into the scientific foundations of thalassaemia. They discover that it is a genetic blood disorder caused by mutations in the HBB gene, which disrupts the production of hemoglobin. Without enough hemoglobin, red blood cells cannot carry oxygen effectively, leading to chronic anemia and other health complications (Thalassaemia International Federation, 2021). Learners are also introduced to current treatments such as regular blood transfusions and bone marrow transplants. These solutions prolong life but do not cure the disease. This sets the stage for the promise of gene therapy, which targets the faulty DNA itself to restore normal hemoglobin production (Cavazza et al., 2016).
	- Content Development: The content is carefully structured so that students first understand the problem (a mutation that causes a defect in haemoglobin) before being introduced to the solution (gene therapy). Teachers use clear diagrams, videos and analogies, for example comparing the defective gene to a recipe with missing instructions and gene therapy to modifying the recipe so that it works again.
	- Needs Analysis: High school students often struggle to visualise microscopic and abstract processes such as DNA mutations or gene editing. They need visual aids, detailed explanations and interactive activities to understand their complexity. Students also need to understand why gene therapy is important: connecting science to real patient stories creates empathy and motivation to learn.
Execute	- Curriculum Implementation: At this stage, theory becomes practice. Students enter a **virtual AR laboratory**, where they can see and manipulate DNA as if they were inside a cell. The curriculum guides them through the process of locating the faulty HBB gene and repairing it with CRISPR-Cas9.
	- Interactive Exercises: AR Mission: Students identify the faulty HBB gene in a virtual patient's DNA, cut it with CRISPR, and insert a corrected sequence. They then observe red blood cells beginning to function properly. Case Study Activity: Learners review real-world gene therapy trials for thalassaemia, comparing traditional treatment outcomes with new genetic approaches.

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

	- Feedback Collection: Immediate AR feedback: The application shows whether the gene was corrected and if the patient's cells now produce hemoglobin. Teacher observation, Student reflection.
Enhance	- AR Integration: AR is expanded to test advanced scenarios. Students can explore what happens if gene therapy only corrects part of the patient's cells, or how the same technique might be applied to other genetic blood disorders like sickle cell anemia. AR provides a safe environment to experiment with possibilities that cannot be replicated in a real classroom.
	- Interactive Learning: Students are encouraged to think critically: How might gene therapy reduce the need for transfusions?
	Gamified Content: Points and Badges: Earned for each successful AR gene correction mission. Leaderboards: Teams compete on accuracy and creativity. Quests and Levels: New challenges are unlocked, such as correcting multiple faulty genes or designing therapies for other disorders. Rewards for Exploration: Bonus recognition for students who bring in examples of recent genetic breakthroughs from news or research. Collaborative Gamified Tasks: Groups must work together to cure a virtual patient, dividing tasks like designing, editing, and presenting results.
	AR-Based Assessments: Students demonstrate mastery by completing gene editing missions. They explain their strategies in presentations or lab journals. Teachers assess accuracy, teamwork, creativity, and the ability to connect science to ethics.

References

Mayo Clinic. (2023). Thalassemia – Diagnosis and Treatment. Retrieved from https://www.mayoclinic.org

National Institutes of Health (NIH). (2022). What is Gene Therapy? Retrieved from https://medlineplus.gov/genetherapy.html

Thalassaemia International Federation (TIF). (2021). What is Thalassaemia? Retrieved from https://thalassaemia.org.cy

Weatherall, D. J., & Clegg, J. B. (2001). The Thalassaemia Syndromes (4th ed.). Blackwell Science.

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

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