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The Risks of Gene Editing: What Could Go Wrong?



BIOS4YOU
AR 2.0

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

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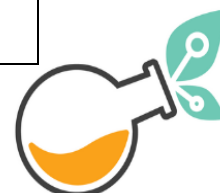
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General topic of the learning path	Genetic Engineering and CRISPR Technology
Specific name of the learning unit	The Risks of Gene Editing: What Could Go Wrong?
Age of the target users	14-18 years
Requirements for the learner	Basic knowledge of genetics and biology, understanding of scientific processes, and interest in ethical questions related to modern technologies.
Description of the learning unit	This learning unit explores the risks and ethical challenges of gene editing, with a focus on CRISPR technology. Students investigate how genetic modifications can affect humans, ecosystems, and future generations. Through reading, discussion, case studies, and Augmented Reality (AR) activities, learners examine unintended consequences of gene editing and reflect on scientific responsibility. The unit encourages critical thinking, ethical awareness, and informed decision-making about emerging biotechnologies.
Subject: Parties involved	Biology teachers, ethics educators, students, AR technology support staff
Keywords	CRISPR, gene editing, biotechnology, bioethics, genome, mutation, genetic engineering, unintended consequences, AR in education
Key qualifications, skills and knowledge that can be acquired	<ul style="list-style-type: none"> Understanding how CRISPR and gene editing work





	<ul style="list-style-type: none">● Awareness of risks and unintended consequences of genetic modification● Ability to identify ethical issues in biotechnology● Critical thinking about science and society● Use of AR tools to explore complex biological processes● Communication, collaboration, and debate skills
Resources and didactic aids used	<ul style="list-style-type: none">● Augmented Reality apps (e.g. Human Genome AR, ARGV – Augmented Reality Gene View)● Educational videos explaining CRISPR technology● Case studies on gene editing in humans and ecosystems● Worksheets, reflection journals, and ethical decision maps● Group discussion and debate activities
Assessment criteria and evaluation	Active participation in discussions and simulations. Completion of AR-based interactive activities. Group presentations on risks and ethical concerns. Quiz on scientific concepts and ethical issues





Introduction:

Gene editing is a powerful scientific technology that allows scientists to change DNA. One of the most well-known gene-editing tools is CRISPR-Cas9, which works like molecular scissors and can cut DNA at a specific place (Doudna & Sternberg, 2017). Scientists can then remove, change, or add genetic material.

Gene editing offers many possible benefits. It can help treat genetic diseases, improve crops, and support scientific research (Lander, 2015). However, this technology also raises serious questions. What if gene editing causes unexpected changes? What if these changes affect future generations or entire ecosystems?

Gene editing has great potential, but it also carries risks. This unit helps students understand both the science behind gene editing and the possible dangers connected to its use.





1: Explore

How Gene Editing Works

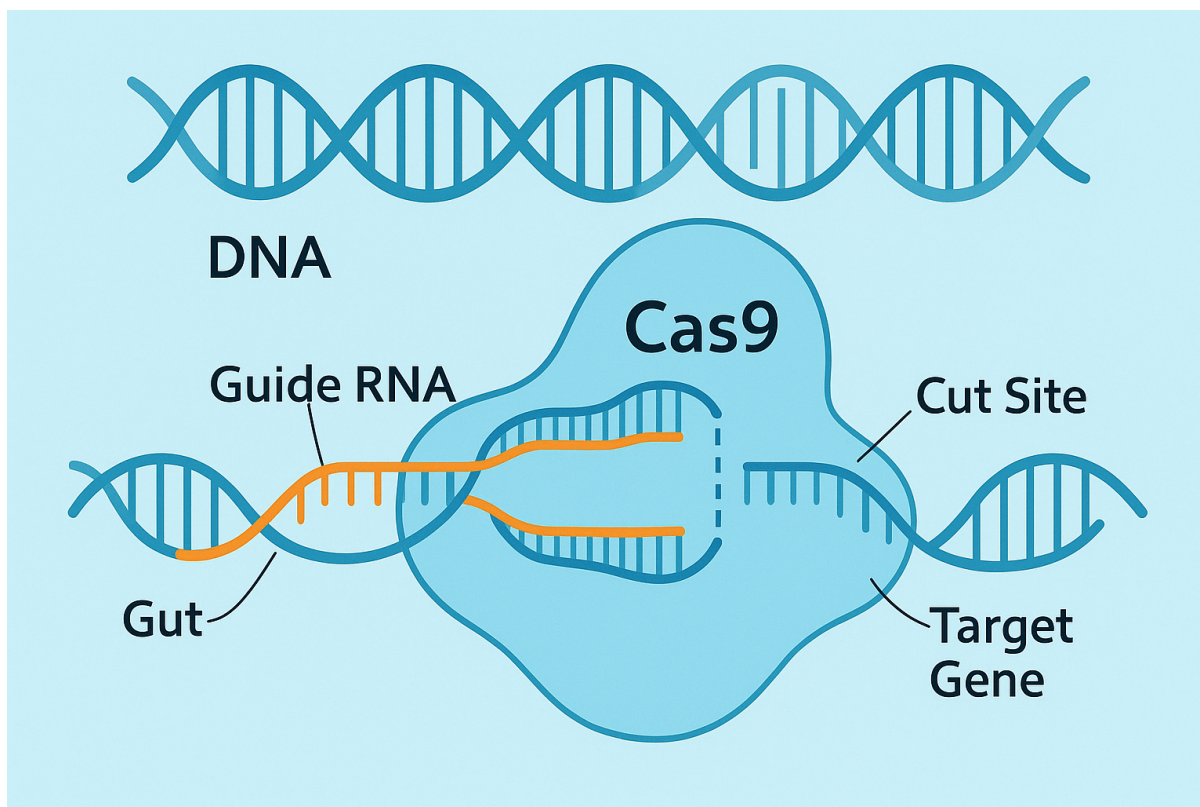


Figure 1. A simplified diagram of CRISPR-Cas9 editing a DNA strand inside a human cell.

Gene editing is a modern biotechnology method that allows scientists to change DNA. One of the most important tools for gene editing is CRISPR-Cas9. This technology was adapted from a natural defence system found in bacteria (Doudna & Sternberg, 2017).

CRISPR-Cas9 works like molecular scissors. It cuts DNA at a specific place. After the cut, scientists can remove, replace, or add genetic material. In this way, they can change genetic traits in plants, animals, or humans.





Gene editing has many possible benefits. Scientists have used CRISPR to study treatments for genetic diseases such as sickle cell anaemia and muscular dystrophy (Lander, 2015). In agriculture, gene editing can help crops become more resistant to pests, drought, or disease. Some researchers have also suggested using gene editing to reduce mosquito populations that spread diseases like malaria.

However, gene editing also involves serious risks. One major problem is off-target effects, when CRISPR cuts the wrong part of the DNA. This can cause unintended genetic changes that may be harmful (UNESCO, 2021). These effects might not appear immediately and could even be passed on to future generations if embryos are edited.

Another risk is linked to how genes interact with each other. A single gene often has several functions. Editing one gene to solve a problem may accidentally affect other important processes in the body, leading to unexpected consequences.

One of the most controversial cases happened in 2018, when a scientist in China announced the birth of gene-edited babies. The embryos were edited to make them resistant to HIV. This caused strong international criticism because the long-term health effects were unknown and the babies could not give informed consent (Cyranski, 2019). The scientific community described the experiment as unethical and irresponsible.

In addition to scientific risks, gene editing raises ethical and social questions. Will everyone have equal access to this technology, or only wealthy people? Could genetic enhancement increase inequality or discrimination? These concerns show why gene editing must be carefully controlled and discussed by society.





Ethical Concerns

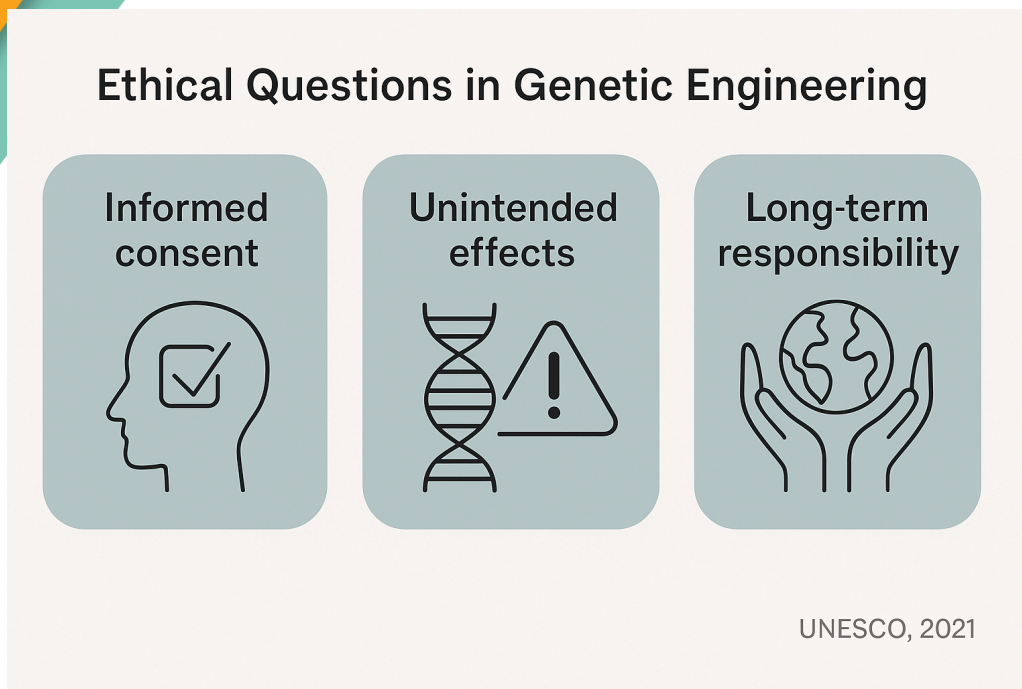


Figure 2. Ethical questions in genetic engineering include informed consent, unintended effects, and long-term responsibility (UNESCO, 2021).

Apart from biological risks, gene editing also raises serious ethical concerns. One important question is fair access. Will gene editing be available to everyone, or only to wealthy people? If only some groups can afford genetic treatments or enhancements, this could create a genetic class divide in society.

Another concern is the idea of designer babies. While gene editing could help prevent serious genetic diseases, some people worry that parents might want to choose traits such as appearance, intelligence, or physical strength. This could increase discrimination and put pressure on society to value certain genetic traits more than others.

There are also important questions about rules and responsibility. Should scientists be allowed to edit human embryos? Who should decide what kinds of gene editing are acceptable? Governments, scientists, and international organisations all play a role, but clear laws and ethical guidelines are still developing.





Because the effects of gene editing can last for generations, scientists must think about long-term responsibility. Decisions made today could affect future children, ecosystems, and societies. For this reason, education and public discussion are essential to help people understand both the benefits and the risks of gene editing (UNESCO, 2021).

The Role of Education and Public Dialogue

For young people today, it is important to understand how gene editing works—not only the science behind it, but also the ethical questions it raises. Gene editing can influence many parts of your future: the food you eat, the medicine you use, and how society thinks about health, fairness, and responsibility.

Schools, museums, and digital tools can help make these complex ideas easier to understand. Augmented Reality (AR) technologies are especially useful because they allow students to see what normally stays invisible. For example, an AR app can show how DNA is edited inside a cell or how changing one gene may affect an entire organism.

When students learn through interactive tools, science becomes more real and meaningful. Education and open discussion help young people become informed citizens who can take part in important decisions about new technologies and their impact on society (UNESCO, 2021).





2: Execute

In this phase, students apply what they have learned about gene editing by taking part in practical, technology-based activities. Augmented Reality (AR) tools such as ARGV (Augmented Reality Gene View) and Human Genome AR are used to help students explore genetic processes in a visual and interactive way.

Students start with scenario-based tasks, where they analyse fictional but realistic situations involving gene editing. For example, they may consider editing the DNA of a human embryo to prevent a genetic disease, changing crops to survive climate change, or modifying animal populations to reduce the spread of disease. With ARGV, students can see gene sequences, simulate the CRISPR-Cas9 process, and explore possible results of genetic changes. This helps them connect scientific methods with ethical decision-making.

One key classroom activity is a bioethics committee role-play. Each student receives a role, such as a scientist, ethicist, policymaker, or patient. Working in groups, students discuss CRISPR case studies and decide whether a gene-editing action should be allowed. AR tools support these discussions by showing which genes are affected and what consequences different decisions might have. This activity develops communication skills, collaboration, and critical thinking.

Another group task is the creation of an “Ethical Impact Passport” for a fictional gene-editing project. Students work in teams to describe the benefits, risks, and social consequences of their proposed genetic intervention. AR visuals help students explain their ideas clearly and make their presentations more engaging for classmates.

Throughout the unit, AR simulations are combined with reflection worksheets. Students write down their observations, predictions, and ethical concerns while interacting with DNA models. This encourages deeper understanding and helps students think critically about the long-term effects of gene editing on humans, ecosystems, and future generations.





3: Enhance

Augmented Reality tools such as ARGV and Human Genome AR further enhance learning by turning abstract genetic concepts into visual and interactive experiences. These technologies help students move from theory to deeper understanding by making invisible biological processes easier to see and explore.

With ARGV, students can zoom in on 3D models of chromosomes, rotate them, and observe the step-by-step process of gene editing. This immersive approach supports visual and spatial learning and helps students understand how CRISPR targets specific DNA regions. It also shows what can happen when gene editing does not work as planned, for example through off-target mutations, where unintended parts of DNA are changed.

Human Genome AR complements this experience by allowing students to explore genes linked to certain traits or diseases. Students are encouraged to ask critical questions, such as:

- Should this gene be edited?
- What could happen if this gene is removed or changed?

These questions lead to meaningful bioethical discussions, where students work together, share opinions, and reflect on the social and biological consequences of gene editing. This strengthens both scientific understanding and collaborative thinking.

To increase motivation, teachers can include gamification elements in the AR activities:

- Students earn points or badges for completing gene-editing tasks without causing unintended effects.
- Leaderboards encourage students to improve both scientific accuracy and ethical reasoning.
- Quests may involve designing safe and ethically acceptable gene-editing solutions and explaining them using AR models.
- Team challenges promote cooperation, debate, and responsible decision-making.





AR-based assessments also play an important role. Instead of only answering written questions, students interact with 3D models to show their understanding. Immediate feedback helps them learn from mistakes, improves memory retention, and builds confidence. Learning becomes an active process of discovery rather than passive memorisation.

By integrating AR tools in this way, educators help students connect biology, ethics, and technology, creating a meaningful and engaging learning experience.





Conclusion:

Throughout this learning unit, students explored both the scientific power and ethical responsibility of gene editing. They learned about the basic principles of CRISPR technology, its applications in medicine and agriculture, and the potential risks linked to genetic modification, such as unintended mutations and long-term consequences (Doudna & Sternberg, 2017; UNESCO, 2021). These topics directly reflect the concerns introduced at the beginning of the unit about safety, responsibility, and unforeseen outcomes.

Augmented Reality tools such as ARGV and Human Genome AR enriched the learning experience by making invisible genetic processes visible and easier to understand. By interacting with DNA models, students were able to connect abstract scientific concepts with real-world examples and ethical questions.

Through simulations, scenario-based discussions, and ethical role-plays, learners developed critical thinking skills and stronger bioethical awareness. They gained a deeper understanding of how gene editing can affect human health, ecosystems, and future generations, reinforcing the idea that scientific progress must be guided by careful reflection and informed decision-making (Cyranoski, 2019; UNESCO, 2021).

Overall, this unit encourages students to think critically about the role of genetic engineering in society. By combining biology, ethics, and AR technology, it prepares learners to engage thoughtfully with real-world challenges and to take part in ongoing discussions about the responsible use of gene-editing technologies in the future.





Phase	Description
Explore	- Students explore basic concepts of DNA, CRISPR-Cas9, and gene editing through short videos, infographics, and adapted scientific readings.
	- Teachers introduce real-world case studies (for example, gene-edited babies or ecological gene-editing experiments) to highlight potential risks, benefits, and ethical dilemmas related to gene editing.
	- Teachers assess students' prior knowledge and misconceptions using short quizzes, brainstorming activities, or guided discussions in order to adapt instruction to students' needs.
Execute	- Curriculum Implementation: Students take part in structured lessons that integrate ARGV and Human Genome AR to simulate DNA editing processes and explore ethical dilemmas in an interactive way.
	- Interactive Exercises: Learners participate in AR-based case analyses, simulate gene-editing scenarios, and engage in bioethics role-play debates. These activities help students apply scientific knowledge to real-life situations.
	- Feedback Collection: Peer feedback during group discussions and teacher-led reflection sessions are used to support deeper ethical thinking and personal reflection.
Enhance	- AR Integration: ARGV and Human Genome AR are used to project editable genome models, zoom into DNA strands, and simulate CRISPR edits in safe and controlled learning environments.
	- Interactive Learning: Students complete self-paced AR tasks that help them visualise the consequences of gene modifications and identify genetic traits that may be at risk.
	Gamification elements are added to increase motivation and engagement: Points and Badges: Awarded for correctly identifying off-target effects or proposing responsible uses of gene editing. Leaderboards: Students progress through scenarios, from basic gene repair to complex bioethical decision-making. Quests and Levels: Learners advance through challenges that require scientific accuracy and ethical reasoning. Rewards for Exploration: Additional AR content is unlocked after completing reflection tasks or group reports. Collaborative Gamified Tasks: Teams work together to develop balanced gene-editing policies, using AR tools as visual support.
	AR-Based Assessments: Assessment includes annotated AR screenshots, short recorded reflections within the app, and digital portfolios that combine scientific explanations with ethical analysis.





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