Gene editing: Bioethics

Step 1: What is gene editing?

This first section aims to ensure that students have **scientific knowledge** about what gene editing is and the advances offered by recent development of the CRISPR-Cas9 system.

Introduce the topic of gene editing using the powerpoint. Show one of the videos (links in the notes section). Get students to answer the following questions. [20-30 minutes]

1. What are the 4 steps needed for gene editing?
    - ***target*** *a specific DNA sequence*
    - ***cleave*** *(cut) that DNA sequence*
    - ***recombine*** *(stick back together) DNA sequences*
    - ***express*** *the recombined DNA in cells*
2. What is the name of the system of gene editing, which has made it faster, simpler and cheaper?
    CRISPR-Cas9
3. What does CRISPR stand for?
    C*lustered* ***R****egularly* ***I****nterspaced* ***S****hort* ***P****alindromic* ***R****epeats*
4. What type of enzyme is Cas9?
    A nuclease

Step 2: Why is gene editing controversial?

Listening, taking notes, articulating and sharing answers in this section all contribute to students' **scientific literacy**.

Play the interview carried out by the BBC with Professor Doudna (the leader of a group of scientists in the US who developed the CRISPR-Cas9 system for gene editing). Get students to answer the questions below. You may need to play the interview more than once to extract all of the information, or get students to target particular questions and then share their answers (encouraging co-operative learning). [15-20 minutes]

1. What is Cas9?
   A protein that can be programmed cut different DNA sequences
2. What can Cas9 be used for?
   To induce (cause) precise changes to the DNA in cells like our own
3. Since Professor Doudna published her work back in 2012, what type of organisms has CRISPR been used in?
   Animals, plant, humans, fungi, other bacteria. (Basically any organism that labs are studying.)
4. What could the practical uses of this gene-editing technology be?
   - *Human heath*
   - *Agriculture*
   - *Protecting the environment*
5. What great advantage does this 'tool' for genome editing have over previous technologies?
   Allows DNA to be edited much more accurately / precisely. Sequences of DNA in cells can be rewritten / the genome can be recoded. It can 'fix' mutations that cause genetic disease. Allow scientists to understand the function of genes we don't currently understand.
6. What could this gene-editing system do for human health?
   Treating diseases like sickle cell anaemia (correcting a single mutation in a well-known gene) by removing blood cells from the patient and editing outside the body and replacing. I think that diseases will be cured, but in years and years.
7. What are the 'redlines' that Professor Doudna thinks we shouldn't cross using these gene editing technologies?
   - *Making heritable changes to human beings, for example by changing DNA in early embryo*
   - *'Gene drives', introduction of a change in a cell so rapidly that it can be used to drive a trait through a population very quickly, for example in getting rid of mosquitoes, but the environmental risk requires very careful consideration*

Step 3: What are the ethical implications of gene editing?

Reading and assimilating facts and opinions contribute to students' **scientific literacy**. It also provides examples of how scientific information is structured and presented by Government organisations, scaffolding later work for the students and providing possible links to future careers in Science writing.

Get students to read the Nuffield Council of Bioethics booklet on 'Genome editing' about the ethical implications of this new technology. This is a review considering possible applications and ethical implications (September 2016).

[variable – possible homework]

Step 4: What do you think now?

This section encourages students to begin forming their own opinions, to see how opinions vary, to identify the most contentious issues and to begin considering the reasons behind the opinions expressed. It is a **scaffolded opinion exercise**. For more information on 'lines of agreement' and other strategies that can be used to scaffold discussion in the classroom see the **Citizen**Science project: http://www.nationalstemcentre.org.uk/elibrary/resource/2293/exploring-issues-a-teachers-guide.

Introduce 6 different scenarios from the powerpoint and explain that to get a quick idea of students' opinions you will use a 'line of agreement'. There are 9 possibilities given, as you may wish to select the scenarios used based on your knowledge of your students and their backgrounds.

Show where the 'line of agreement' runs in the classroom. Allocate one end as the 'agree' end (a quick sign can help students to remember which one this is!) and one end as the 'disagree' end. Inform students that they can stand anywhere along the 'line of agreement' and that they are not tied to any opinions they express now.

As students move into the 'line of agreement' get them to identify:

- *Which questions are there consensus about?*
- *Which questions show a wide range of opinions?*
- *Which questions polarise opinion?*

If students are confident and comfortable, you can encourage them to begin articulating why they stood where they did and what it was that lead them to their opinions.

Alternatively, for less confident or cohesive classes, this can be performed as an exercise placing cards along a line of agreement. [10-15 minutes]

There are 9 scenarios to choose from. They are phrased as, "Scientists should be able to…" statements.

… use gene editing to develop new plant strains in agriculture, for example disease-resistant strains of wheat.

- Examines opinions about gene editing in plants, which may otherwise be possible through selective breeding over a longer time scale.

… use gene editing to create chickens that produce only female offspring to improve the yield of eggs.

- Examines opinions about gene editing in animals, which is not of benefit to the animals, but is of benefit to food production.

… use gene editing without the need to label farm produce from these organisms as genetically modified.

- Examines opinions about gene editing and consumer choice.

… use gene editing to control mosquito populations that spread infectious diseases like malaria, using gene drives.

- Examines opinions about gene editing causing rapid genetic change in a population, some of the outcomes of which may be unpredictable.

… use gene editing to alter pig cells to prevent virus transmission, so that organs can be transplanted from pigs to humans (xenotransplantation).

- Examines opinions about gene editing in animals, so that they can be used for the benefit of human health (to their detriment).

… use gene editing to produce bacteria intended to cause a disease outbreak.

- Examines opinions about gene editing for military use.

… use gene editing to correct the genetic mutation that causes muscular dystrophy through gene therapy in children or adults.

- Examines opinions about gene editing to overcome genetic disorders in humans after birth. Genetic changes will not be passed on to offspring.

… use gene editing to correct the genetic mutation for cystic fibrosis in early stage embryos (pre-implantation genetic manipulation).

- Examines opinions about gene editing to prevent genetic disease being passed on within a family. Genetic changes will be passed on to offspring.

… use gene editing to enhance athletic ability in early stage embryos (pre-implantation genetic manipulation).

- Examines opinions about gene editing for human enhancement. Genetic changes will be passed on to offspring.

Step 5: Making scientific arguments

Scientific argumentation is a way to incorporate socio-scientific issues and encourage functional scientific literacy – that is an ability to engage with and consider relevant issues in depth. Abrahams and Millar (2008) refer to this as having 'minds on' the Science. The model of Data, Claim and Warrant used in this exercise (Toulmin, 1958), is not new, but is a simple explanation of the components that makeup a scientific argument.

Briefly introduce the components of a scientific argument and give an example. There are 2 powerpoint slides intended to support this. Allow students to choose their claim. Encourage them to make links with other ideas, use independent research to gather evidence and reference their work.
[30-45 minutes]

Some suggestions for scientific arguments for the students are given in the powerpoint. These are:

- Should gene editing be allowed in humans?
- Should gene editing be allowed in animals?
- How would gene editing affect consumer choice about their food?
- How would gene editing affect the environment?

There are, of course, many possible directions that could be considered. Allowing students to select their own specific question helps to engage them and ensure that their chosen subject is relevant for them.

Step 6: Discussing the implications of gene editing

After expressing initial opinions, then having time to make more considered arguments about the use of gene editing in a variety of contexts, students should be prepared to engage in more **reasoned discussion** about the implications of gene editing. Such informed, reasoned discussion encourages listening skills, shared thinking, and consideration of scientific possibilities within their societal context, a valuable tenet of the **scientific literacy** that is considered highly desirable in education (DfES, 2002).

Scientific discussion can develop a range of student skills (Simonneaux and Simonneaux, 2008). To encourage as much sharing of reasoned, detailed discussion as possible, amongst a wide range of students, use 'The Fisherman's Circle' as a format. Again this method of multiple paired discussions, has been taken from the **Citizen**Science project: http://www.nationalstemcentre.org.uk/elibrary/resource/2293/exploring-issues-a-teachers-guide.

To introduce this section you could highlight how scientists working at the cutting edge of DNA technology have halted work on more than one occasion to allow the social and ethical implications of their advances to be considered. There are 6 powerpoint slides intended to support this, one including a further video from The Wellcome Trust that you may wish to show.

For the discussion, I have suggested the 'Fisherman's Circle' format as it is easily used with classes in a range of sizes, permits exchange of views with a range of other students and sharing ideas can be easier for students who do not frequently participate in discussion to carry out in pairs, rather than larger

group sizes. Form two, equally-sized circles, one inside the other. Pairs share views for 2-3 minutes, then the outer circle students move. The aim is to allow students to experience reasoned ideas other than their own, to manage conflicts of opinion and to review their ideas with their peers.
[dependent on class size, about 30 minutes]

Ensure that ground rules are laid out about respecting other students' opinions and views. Act to facilitate and mediate the short discussions without sharing your opinions.

Following discussion, the line of agreement exercise from before can be repeated to see whether students' opinions have changed.

Step 7: Expressing your opinions on gene editing

The generation of students who participate in this exercise will be the decision-makers for issues about DNA manipulation of ever-increasing complexity. Writing a letter, summarising their positions on gene editing, using scientific argumentation not only provides an opportunity to develop their **literacy and scientific communication skills**, but also for them to start to engage with highly relevant questions facing today's society on the acceptable applications of gene editing technology. The importance of their opinions is made apparent by the submission of their work to the Nuffield Council on Bioethics, contributing to the ongoing bioethical debate.

Outline the task – to write a letter to the Nuffield Council on Bioethics, setting out reasoned opinions. Explain that students' work will be submitted to the Nuffield Council on Bioethics. Recap the structure of scientific argumentation and how you expect their letters to be laid out. [about 30 minutes]

The letters can be assessed using criteria that you set (some suggestions are made in the powerpoint), which should, of course, be made clear to the students.

Letters can be sent to the Nuffield Council on Bioethics, who have a remit to "***make arrangements for examining and reporting on bioethical questions with a view to promoting public understanding and discussion***". Their website is found at http://nuffieldbioethics.org/ . Their address is: Nuffield Council on Bioethics, 28 Bedford Square, London, WC1B 3JS. Their email is: bioethics@nuffieldbioethics.org.