Challenge Title:	**Duration:**
Cooperate or die	20 minutes

Short description:

--- 1. INTRODUCTION ---

If we look around we see many examples of cooperative behaviours in both animal and human societies, whereby an individual gives up part of his success in order to help someone else be successful. This seems to contradict the idea that evolution is driven by competition, by the 'survival of the fittest'. The evolution of cooperation thus constitutes an important question for biologists.

Indeed, in a village with finite resources, if every individual behaves in a rational, selfish way, only thinking of his own benefit, the common resources will sooner or later be depleted and the system will collapse. At the level of the planet, overfishing, deforestation and climate change are a few current-day examples of the so-called 'tragedy of the commons'.

--- 2. THE PUBLIC GOODS GAME ---

A very simple model that captures this dilemma is the public goods game (which has been studied mathematically within the field of evolutionary game theory). The game is played within a group; the goal of each player is to end up with as many counters as he can. In each round, each individual in the group can decide how many of his counters he wishes to contribute to the common pool. The total is then multiplied by a certain number (larger than one) and divided equally among all the players (irrespective of whether they have contributed or not).

A player who decides to defect (i.e. to contribute nothing while benefitting from others' contributions) will do better than his fellow cooperators. But if this behaviour spreads and no-one contributes anything, the common pool becomes empty and the group collapses. So in fact a group of cooperators will do much better than a group of defectors. In biological terms 'doing well' means having more offspring and subsequently displacing groups with less or no offspring. This way the presence of group structure is one of the mechanisms that helps explain the presence of cooperation in nature and in human societies.

--- 3. THE CHALLENGE ---

After an initial collective discussion where cooperative behaviours in everyday life will be identified, the students will play out the public goods game in small groups. By observing the outcomes of the different strategies as they play along, they will first individually and then in a group discussion gain awareness of the conflict of individual and group-level interests that arises in such a setting, and of how the dilemma seems to resolve itself when the output of a group of cooperators is compared to the (much smaller) output of a group of defectors. They will reflect on the effect of individual decisions on the fate not only of the individual but also of the group, and analyse the feedbacks between the good of the individual and the good of the group.

Finally a link to pressing environmental problems at the planetary level will be made, by helping the students identify examples of the 'tragedy of the commons' which are currently being played out at the international level (overfishing, deforestation, global warming).

Venue:

Classroom fit for group work (tables set out in small groups).

Number of Participants:

Ideally in the range 15-25, only limited by the number of facilitators present in the session. Each group of 4, 5 or 6 students (the same number of students in each group, if possible) will be helped by a facilitator during the main activity (the public goods game).

Year Group: Y7/Y8 though the activity can be adapted to other year groups (younger or older).

Resources:

- Small counters (e.g. dry chickpeas or beans) – a lot of them!
- Some sweets – the counters can be exchanged for sweets at the end of the game.
- Paper plates (or something to keep one's counters in), one per student.
- Paper and pencil for each student.
- One facilitator (e.g. teacher or student ambassador or older student) per group of players – they will be in charge of the common pool.
- One bowl/ jam pot per group (to serve as the common pool – in practice the facilitator may choose to collect the counters directly in his/her hand, for speed).

Health and Safety guidance:

- Remind students NOT to put counters into their mouths, nostrils or ears.

Challenge context:

No background knowledge is needed, apart from curiosity, basic maths and a general environmental awareness.

Instructions:

1- (If there is time) To start with: What is a model?

Physicists and scientists in general use models (simplified representations) to help understand the part of the world they are asking questions about (i.e. the system), in particular to capture and gain insight into the underlying mechanisms that give rise to observable/measurable characteristics of the system. In this session we will explore one model that helps answer the question of why both animal and human societies show cooperative behaviours.

2- Introduction to the subject: What is cooperation?

Ask the students what this word suggests to them, encourage them to put their hands up and make a list on the board of everyday examples of cooperation they can come up with (e.g. team work, helping a fellow student with his/her exercises, donations to charities, assistance to the elderly, blood donations, a football team; firemen risk their lives to save others', doctors cure patients, mothers and fathers look after offspring, etc.). To look at the bigger picture, one can start by asking 'What did you have for breakfast?' 'How did that toast/cocoa drink/etc get to your plate?' and get the students to think about the many unknown people whose efforts come together behind such an apparently simple thing as a breakfast toast/drink. One may also ask 'What happens if I break my leg?' 'Why do you go to school – would you be going to school if you had been born 400 years ago?' etc. to suggest that our modern globalised society and the welfare state are in fact brimming with large-scale cooperation. Ask them to name examples of cooperation in nature (e.g. wolf pack hunting, ant colonies, etc).

3- Time to play! Set up and explanation of the rules of the public goods game.

To set up the game: each student will receive 2 counters, a paper plate (which will be folded so that others can't see its content), and pencil and paper. For each round, each player will write down the number of counters that he/she has contributed to the common pool and the number of counters that he/she is given back at the end of that round (this list must also be kept out of sight of the others):

Round	IN	OUT
1	*e.g. 2*	*5*
2	*0*	*4*
3	*…*	*…*
4	*…*	*…*

To explain the rules of the public goods game – SEE SLIDE. In short: in each round each student can decide to ANONYMOUSLY give 0,1 or 2 counters to the facilitator of that group, who puts them into the common pool. After having received the contributions from all members of the group, the facilitator then multiplies the total T by a certain number N and divides the resulting quantity evenly among all the members of the group. In practice, to keep things easy the number N shall be taken to be equal to the number of members of the group, i.e. if the facilitator will give back T counters to each player. (This is the sole role of the facilitator – a sort of silent treasurer). It must be made clear that the goal is to individually accumulate as many counters as possible; counters may be converted into sweets at the end of the game.

4- Let the students play the game in their groups, for as many rounds as the time will permit, but no less than 5 or 6 per group (each group plays in parallel).

5- Stop the games and get them to count the total number of counters on their plate, and to add up the group totals. For a few minutes, the students should individually and then in their groups think about what conclusions they can draw from the game.

6- Plenary: get feedback from each of the groups – USE SLIDES to guide the questions and the reasoning (What happens if… ? … What happens if no-one contributes at all? … What happens if we compare a group of co-operators to a group of defectors? etc.)

7- Context (SEE SLIDES): explain the 'tragedy of the commons' - firstly the original story (farmers grazing their cows on the village commons; individual benefit and shared costs lead each selfish farmer to put as many cows as he can in the field, which becomes overgrazed and all cows die).

   Then make explicit links to the environment and the planet, by asking the students to think of examples of situations where finite common resources are being depleted. If there is time, mention the on-going international discussions to establish norms that could prevent the tragedies from happening (e.g. Kyoto protocol and other attempts at regulating and limiting CO2 emissions, fishing bans to prevent the extinction of endangered species like the red tuna, treaties to protect the arctic environment etc.). Ultimately, help them realize that on the Earth we only have one round of the game (e.g. extinctions of species, or rise of the sea level, are irreversible processes).

8- Wrap-up: What have we learnt today? (SEE SLIDE).

Plenary

See points 2 and 3 of the Short description above, and points 6 and 7 of the Instructions above, as well as the corresponding SLIDES.

Further Reading

- The real world does not know about academic disciplines – problems are often intrinsically inter-disciplinary. In this case, links can easily be made to other subjects currently studied by the learners. Here are some examples of keywords.
  - Environmental science: real-life ongoing examples of the tragedy of the commons include global warming and climate change, overfishing, deforestation, pollution, …
  - Biology: natural selection, competition versus cooperation, debate on the levels of selection (controversy over whether natural selection acts not only on the individual level but also on the group level - individual versus group selection).
  - Social science / economics: taxes and redistribution as a public goods game, the social contract.
- Background/further reading for teachers (and possibly students, depending on the age group):
  - Original article by Garrett Hardin, *The Tragedy of the Commons* (Science 13 December 1968: Vol. 162 no. 3859 pp. 1243-1248, DOI: 10.1126/science.162.3859.1243) http://www.sciencemag.org/content/162/3859/1243.full.pdf
  - Maths and evolutionary game theory: research articles - e.g. review by Martin Nowak, *Five rules for the evolution of cooperation* (Science 8 December 2006: Vol. 314 no. 5805 pp. 1560–1563, DOI: 10.1126/science.1133755) http://www.sciencemag.org/content/314/5805/1560.full.pdf ;
  - See also research articles by Arne Traulsen and Manfred Milinski (for experiments on public goods games).
  - For some context on public goods games and group selection see chapters 4 and 10 of Martin Nowak's book *SuperCooperators* (2011).

About

My name is Diana Garcia Lopez and I am a postdoctoral research associate in the School of Physics and Astronomy at the University of Manchester. I studied Physics in Madrid and in Paris.

One of the great things about studying Physics is that you can later apply your skills to look into problems from a variety of fields, from biology to social sciences to finance. I work in collaboration with biologists and computer scientists modelling bacterial population dynamics – for example, how the joint evolution with viruses (their parasites) can influence bacterial cooperation. (Yes – just like us humans, bacteria play public goods games! They can produce chemicals that help all bacteria that are nearby).

In my spare time I enjoy hiking and playing and listening to music.