PRINCIPLE 9: NATURE TAPS THE POWER OF LIMITS

There are limits in nature

AGE RANGE

11–13

DURATION

Preparation:
about 20 min.

Activity:
about 45 min. / 1 lesson

KEYWORDS

Biomimicry principles; cooperation; limits

SUMMARY

People tend to think that all demands can be fulfilled without limits. We should learn from nature how to live within the limits of Earth. In this module students learn what happens if we do not keep within natural limits.

BIOMIMICRY PRINCIPLES

9 – Nature taps the power of limits

LEARNING OBJECTIVES

- Students understand that to live in a finite world everybody has to follow some simple rules.
- Students understand that everything can run out.
- Students understand that 'enough' can be better than 'too much'.

LEARNING OUTCOMES

- Students try to live from an ocean with a limited number of fish.
- Students experience that resources are limited.
- Students learn how to make predictions based on evidence.

SUBJECT(S)

This module is part of a series of modules introducing the nine principles of biomimicry. The table below shows possible KS3 Programme of Study links for all the modules. Many of the activities will also be suitable for upper KS2.

This learning module can be used flexibly within the curriculum to support key knowledge about Biology and develop working scientifically competences. The learning links with the Sustainable Development Goals and provides a broader context for student learning. It is suitable for adapting as a STEM activity or Eco Club.

Programme of Study Reference	Working Scientifically
Biology: Material cycles and energy - Photosynthesis • the reactants in, and products of, photosynthesis, and a word summary for photosynthesis. • the dependence of almost all life on Earth on the ability of photosynthetic organisms, such as plants and algae, to use sunlight in photosynthesis to build organic molecules that are an essential energy store and to maintain levels of oxygen and carbon dioxide in the atmosphere. • the adaptations of leaves for photosynthesis. Interactions and interdependencies – Relationships in an ecosystem • the interdependence of organisms in an ecosystem, including food webs and insect pollinated crops. • how organisms affect, and are affected by, their environment, including the accumulation of toxic materials. Genetics and evolution – Inheritance, chromosomes, DNA and genes • changes in the environment may leave individuals within a species, and some entire species, less well adapted to compete successfully and reproduce, which in turn may lead to extinction. • the importance of maintaining biodiversity and the use of gene banks to preserve hereditary material.	Students successfully completing this module will have had the opportunity to access these statements: **2a, 2b, 3b, 3c, 3d, 3f**. See Annex 1 for full statements.

BIOLEARN COMPETENCES

- Students are able to abstract principles of sustainability from the way the natural world functions.
- Students are able to identify important needs and opportunities that can be addressed through design innovation for products, processes and systems.
- Students are able to work in groups.
- Students are more motivated in learning STEAM and experience that knowledge of STEAM can be widely used.

SUMMARY OF THE ACTIVITIES

	Activity Name	Short description	Method	Duration	Location
1	Introduction	Presenting the principle 9_principles.ppt	• Teacher presentation • Discussion	10	Indoor
2	Harvest game	Groups of students try to live from the same ocean with a limited number of fish	• Game	25	Indoor
3	Review	Discussion after the activity	• Discussion	10	Indoor/ outdoor

BACKGROUND FOR TEACHERS

See at Activity 1: Introduction.

For interconnections see *Nine Principles of Biomimicry* module.

Health and Safety
Appropriate consideration needs to be given to health and safety when working outdoors, but this should not prohibit regular use of the outdoor learning environment.

For guidance on using the outdoor learning environment review the Council for Learning Outside the Classroom suggestions on Plan and Deliver. CLEAPSS also provides guidance for members. We recommend you read and act on L196 – Managing Risk Assessment in Science. Finally, check your school policy on learning outside the classroom.

The Institute for Outdoor Learning provides a good overview into the risks and benefits of outdoor learning here. They also offer specific guidance and advice for schools here.

ACTIVITY DETAILS

LOCATION
Indoor

TOOLS AND MATERIALS

- 9_principles.ppt; 10th slide

PREPARATIONS

Arrange classroom for presentation and discussion.

RESOURCES

Benyus, J. M. (2002): Biomimicry – *Innovation inspired by nature*. HarperCollins Publisher, New York, U.S.A.

1| INTRODUCTION

» QUESTION

Present the slide about Principle 9: 9_principles.ppt, slide 10.

Unlimited growth on a finite earth is not a good idea. All living things are governed by limitations; age, climate, population density and many other factors determine how species and systems develop. Nature has found ingenious ways to work within these limits to be as productive as possible over the long run.

Explanation to 9_principles.ppt, 10th slide:

Succession
Ecological succession is the process of change in the species structure of an ecological community over time. It is a one-way process in which the populations that make up a community are completely or partially exchanged. During succession, pioneer species appear first. The closing of the succession process is the appearance of a climax (closing) community.

- The pioneer community consists of highly adaptable, broad-tolerant, one-year r-strategist species.
- The climax community is the most versatile community with the highest productivity under given climatic conditions. K-strategist species predominate and narrow-tolerant species also appear.

The two types of succession:

- Primary succession occurs where there has not been life in the area before. For example, after volcanic eruption, landslide or glacial moraine.
- Secondary succession occurs when the succession process is re-launched in an association which is stable for a long time. For example, recharging of standing water, mowing stops in a mountain meadow or after a forest fire.

Climax communities are generally resistant but have moderate resilience, whereas primary or intermediate communities have less resistance but greater resilience.

ACTIVITY DETAILS

r and K strategists

Animals can be classified into r and K strategists.

- r-strategist species reproduce very quickly under the right environmental conditions, reaching a maximum value, which quickly reduces due to the depletion of environmental resources. If the environmental conditions are favourable again, rapid reproduction occurs. They live in unpredictable environments (desert, tundra, periodically flooded areas). Examples of r-species include mice, rabbits, weeds and bacteria, which have a lot of offspring, but a short life expectancy.
- K-strategist species have longer lifespans, large body size, with fewer offspring, low mortality rate, stable population size, and frequently have a defined territory. The number of individuals corresponds to the carrying capacity of the environment. Examples of K-strategist species include birds, larger mammals (such as elephants, horses, and primates), and larger plants.

ACTIVITY DETAILS

LOCATION
Indoor

TOOLS AND MATERIALS

- projector or flip chart
- student worksheets: W2.1, W2.2, W2.3 or Harvest_game.ppt
- 250 pieces (coffee beans/ gravel/peanuts/cherry seed) symbolizing fish
- 1 big container symbolizing an ocean
- smaller containers symbolizing fishing boats (2 per group: one is numbered from 1 to the number of groups; the other is for storing fish)
- 10 paper slips per group
- pen/pencil

PREPARATIONS

Indoor activity: prepare a table for each group so they cannot be easily overheard.

Print W2.1, W2.2, W2.3 so there is one set per group or use Harvest_game.ppt

RESOURCES

Sweenex, L. B.; Meadows, D., Mehers, G. M. (2011): *The System Thinking Playbook for Climate Change.* Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH, Eschborn, Germany p. 67–75.

2| HARVEST GAME

» DISCOVER

This game is about using common resources, more about people than nature. It is based on the Harvest Game from The System Thinking Playbook for Climate Change.

Divide the class into 4–6 groups with 2–6 students each. Allocate each group a table and explain that they are fishermen for different fishing companies. Their goal is to maximize their assets by the end of the game, but of course it can be achieved only if there are fish in the ocean. Each team gets a ship and 10 paper slips. They can name their company and ship.

Add 40 fish into the ocean. Put the remainder of the fish in a nearby container that is not accessible to participants.

The rules of the game are on W2.1, you can hand them out to the groups or write onto a board, or use the PowerPoint presentation. W2.2 shows the curve of regeneration:

- If there are no fish left in the ocean after all orders have been filled, then no new fish will be added to the ocean.
- For any number of fish in the ocean between 25 and 50, as many fish will be added to bring the total back up to 50 (carrying capacity) (e.g. if there are 38 fish remaining, 12 will be added).
- Below 25 fish, a number of fish equal to the number remaining in the ocean after processing all the orders will be added (e.g. if there are 12 fish left in the ocean, another 12 will be added).

W2.3 shows the steps of play, which is important for the groups to understand.

Play 6 to 10 rounds. Each round represents one year and lasts approximately five minutes. Give the teams a few minutes to discuss their long-term strategy and to submit their first fish request. Fill requests in random order. Do not reveal the size of the request. If there are enough fish in the ocean to fill the request, remove the requested number of fish from the ocean and put them in the ship. Then fill the orders from the next ship, and so forth. If one order is larger than the number of fish remaining in the ocean, return that paper to the ship with no fish and go to the next ship. When you have processed all the orders, return the ships. The teams should pour their fish into their storage container.

ACTIVITY DETAILS

Ask the teams to decide on their next order. While they are doing that, count the number of fish in the ocean and regenerate following the rules of W2.2.

Collect the ships for year 2, process the orders, and continue. If the teams quickly catch all the fish, let them go through one or two more yearly cycles experiencing the consequences of their mistake i.e. no fish can be caught. Then stop the game. If you can see that the entire group has adopted a strategy that will keep the fish population sustained around the point of maximum regeneration, you can also stop the game. But with most groups you will have to go through at least 6 to 8 cycles before participants experience the consequences of their decisions.

The regeneration curve shows that 25 is the maximum number of fish which can be added to the ocean each year. Therefore 25 fish per year is the maximum number that can be harvested sustainably. Over 10 years, 250 fish could theoretically be harvested without reducing the fertility of the ocean. Divide that number by the number of teams, multiply by the value of each fish, and you have the maximum average wealth possible per team. If any team fails to reach that level of assets, it is the consequence of overharvesting early in the game. Talk about the strategy of the groups and about the winners, and sustainability. Does competition or collaboration provide a better long-term strategy for the benefit of all?

LOCATION
Indoor / Outdoor

3| REVIEW

» QUESTION

PREPARATIONS

Arrange classroom for discussion.

After the activity/ies talk with students about the principle:

- Think about limits; what limits do you experience in your life?
- Are they useful or not?
- What are the aims of these limits?
- Can you see any parallels between your limits and limits in nature?

W2.1 HARVEST GAME

Rules of the game

You are part of a team of people who fish for a living. Your team's goal is to maximize its assets by the end of the game. Each fish you catch is worth one coin.

The ocean can support a maximum of 50 fish. We start the game with between 25 and 50 fish in the ocean.

We will play for 6 to 10 years, making one round of decisions per year.

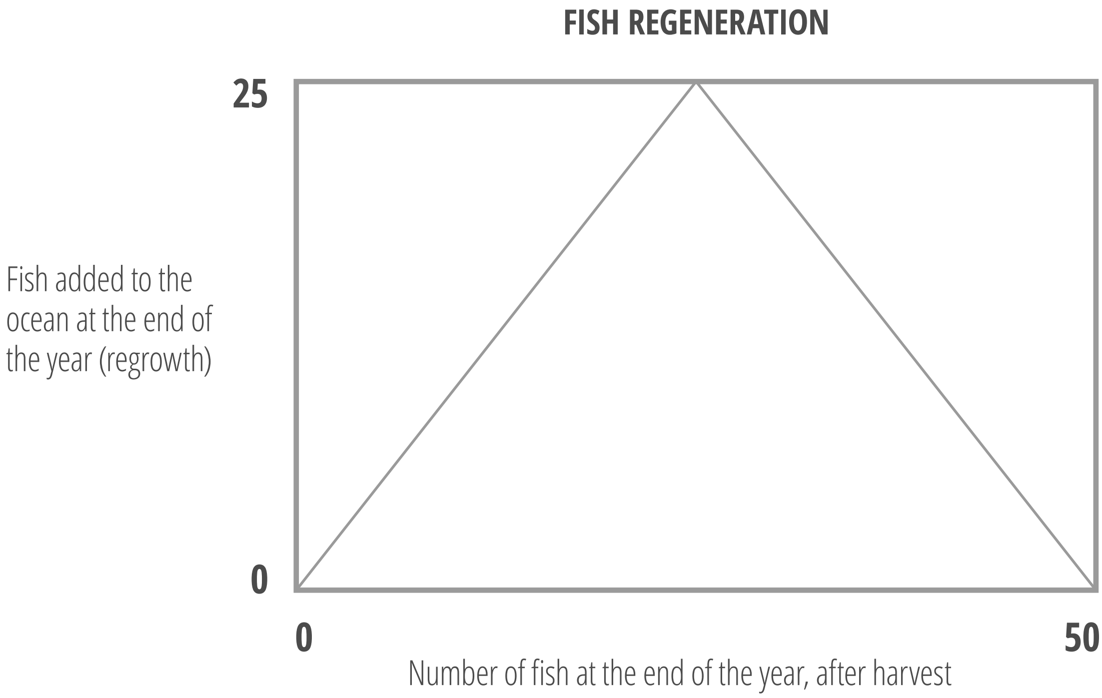
The maximum order is between 0 and 8 fish per boat, per round.

With each decision round, your team decides how many fish it will try to catch that year. You indicate your desired catch by writing the number on a slip of paper, putting the slip in your ship, and taking your ship to the game operator. The operator will fill orders randomly. The fish you catch are returned to you in your ship. If your order exceeds the number of fish remaining in the ocean, you receive no fish that year.

After all orders are processed, and your team's ship is returned, the fish in the ocean will regenerate according to the curve shown on W2.2.

W2.2 HARVEST GAME

Regeneration scheme



W2.3 HARVEST GAME

Steps of play

1. Decide on your team's long-term strategy.
2. With each decision round, select the number of fish you wish to catch this year.
3. Record the number on a slip of paper, insert the paper in your ship, and take the ship to the game operator.
4. Catch requests will be filled in random order, if your order is less than the number of fish in the sea.
5. Receive back your ship, remove the fish, and start again with Step 1.

ANNEX 1

Key Stage 4 Working Scientifically Statements

Through the content across all three disciplines, students should be taught so that they develop understanding and first-hand experience of:

1. THE DEVELOPMENT OF SCIENTIFIC THINKING	a. the ways in which scientific methods and theories develop over time b. using a variety of concepts and models to develop scientific explanations and understanding c. appreciating the power and limitations of science and considering ethical issues which may arise d. explaining everyday and technological applications of science; evaluating associated personal, social, economic and environmental implications; and making decisions based on the evaluation of evidence and arguments e. evaluating risks both in practical science and the wider societal context, including perception of risk f. recognising the importance of peer review of results and of communication of results to a range of audiences
2. EXPERIMENTAL SKILLS AND STRATEGIES	a. using scientific theories and explanations to develop hypotheses b. planning experiments to make observations, test hypotheses or explore phenomena c. applying a knowledge of a range of techniques, apparatus, and materials to select those appropriate both for fieldwork and for experiments d. carrying out experiments appropriately, having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations e. recognising when to apply a knowledge of sampling techniques to ensure any samples collected are representative f. making and recording observations and measurements using a range of apparatus and methods g. evaluating methods and suggesting possible improvements and further investigations
3. ANALYSIS AND EVALUATION	a. applying the cycle of collecting, presenting and analysing data, including: i. presenting observations and other data using appropriate methods ii. translating data from one form to another iii. carrying out and representing mathematical and statistical analysis iv. representing distributions of results and making estimations of uncertainty v. interpreting observations and other data, including identifying patterns and trends, making inferences and drawing conclusions vi. presenting reasoned explanations, including relating data to hypotheses vii. being objective, evaluating data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error b. communicating the scientific rationale for investigations, including the methods used, the findings and reasoned conclusions, using paper-based and electronic reports and presentations

4. VOCABULARY, UNITS, SYMBOLS AND NOMENCLATURE	a. developing their use of scientific vocabulary and nomenclature b. recognising the importance of scientific quantities and understanding how they are determined c. using SI units and IUPAC chemical nomenclature unless inappropriate d. using prefixes and powers of ten for orders of magnitude (e.g. tera, giga, mega, kilo, centi, milli, micro and nano) e. interconverting units f. using an appropriate number of significant figures in calculations