WATER MANAGEMENT IN A CITY PARK

How does nature manage water?

Erasmus+

AGE RANGE

12–16

DURATION

Preparation:
30 min.

Activity:
200 min. / 4 lessons

KEYWORDS

Water management; city park; design; water purifying

SUMMARY

Our challenges regarding water management are getting bigger and bigger. There are areas that suffer from extreme drought, while in other places there are floods. Access to clean water is a major challenge for many people. In this module, students will discover these challenges and come up with solutions themselves, based on how nature deals with water management. These challenges all come together in one case study, the design of a city park.

BIOMIMICRY PRINCIPLES

3 – Nature fits form to function
4 – Nature recycles everything
6 – Nature banks on diversity
7 – Nature demands local expertise

LEARNING OBJECTIVES

- Students understand a range of different options to manage water sustainably.
- Students are able to apply biomimicry thinking to solve a challenge.
- Students recognise that working in harmony with nature can lead to sustainable design solutions.

LEARNING OUTCOMES

- Students carry out research into the topic of water.
- Students investigate how nature deals with water management.
- Students use biomimicry thinking to create a design to address a water challenge.
- Students present their ideas and critique the ideas of others.

SUBJECT(S)

This learning module can be used flexibly within the curriculum to support key knowledge about Biology, Chemistry and Design Engineering & Technology, 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
Depending on challenges/solutions identified by students, other areas of biology, chemistry and physics will be relevant **Biology:** KS4 Ecosystems • some abiotic and biotic factors which affect communities; the importance of interactions between organisms in a community • organisms are interdependent and are adapted to their environment • the importance of biodiversity • methods of identifying species and measuring distribution, frequency and abundance of species within a habitat. Transport systems • the need for transport systems in multicellular organisms, including plants • the relationship between the structure and functions of the human circulatory system. KS3 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 • differences between species • the variation between species and between individuals of the same species means some organisms compete more successfully, which can drive natural selection • 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.	Students successfully completing this module will have had the opportunity to access these statements: **1b, 1d, 1e, 2a, 2g**. See Annex 1 for full statements.

Programme of Study Reference	

Chemistry:

KS4
Chemical analysis
- distinguishing between pure and impure substances
- separation techniques for mixtures of substances: filtration, crystallisation, chromatography, simple and fractional distillation
- concentrations of solutions in relation to mass of solute and volume of solvent.

KS3
Pure and impure substances
- simple techniques for separating mixtures: filtration, evaporation, distillation and chromatography.

Chemical reactions
- the pH scale for measuring acidity/alkalinity; and indicators.

Design, Technology and Engineering:

KS4
- Design and making principles (links with developing context for design, understanding factors affecting design, critical analysis and applying different design strategies).

KS3
- Design (links with most areas)
- Evaluate (links with most areas).

BIOLEARN COMPETENCES

- Students are able to abstract principles of sustainability from the way the natural world functions.
- Students are able to identify functional design in nature, develop greater awareness and appreciation for design excellence in nature, and appreciate how nature works as a system which is elegant and deeply interconnected.
- 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 use analogical creativity to innovate, using biological models to inspire solutions to design challenges.
- Students are able to work in groups.

SUMMARY OF THE ACTIVITIES

	Activity Name	Description	Method	Duration	Location
1	Finding out	Students discover what they already know about water	• Hands-on activity	20	Indoor
2	Mapping your challenge	Students use a mind map to understand their challenge and key research questions	• Research	30	Indoor
3	Consulting nature	Students identify functions and consult nature for their design	• Research	30	Indoor / Outdoor
4	Natural models	Students create solutions to their problem by translating natural models into a design	• Design activity	45	Indoor
5	Poster pitch	Students present their results	• Presentation	30 (depending on number of students)	Indoor
6	Design the skate park (extension)	Students collaborate to improve their designs	• Design activity	45	Indoor

BACKGROUND FOR TEACHERS

The module assumes some prior knowledge of the students. It is expected that students will already be familiar with the principles of biomimicry. If you have not introduced the principles to students previously, then use the Introduction to Biomimicry from the BioLearn website to introduce them. Other topics you may wish to introduce before the module include understanding the changes in precipitation over time, reduction of green spaces in urban areas due to sealing with hard surfaces and the effect on water retention/runoff, the processes for providing clean drinking water and dealing with sewage, and the role of water in natural systems.

During the lessons, students will become familiar with the terms function and strategy. It is important to be clear about these terms (and we offer the following definitions):

Functions: In biomimicry a function refers to an organism's adaptations which help it survive. For example, the purpose of bear fur is to keep warm, in technical terms its function is to conserve heat (insulation). A leaf can photosynthesise (convert energy from the sun into sugar) and it can distribute water (through its veins). Human products also have functions; a kettle has the functions to both contain water and heat water (modify its physical state). In brief, a function is 'what it does.'

Strategy: Organisms meet functional needs through biological strategies. This is a characteristic, mechanism or process which performs the function for them. In the bear example, fur is the strategy for delivering insulation. In a kettle, electrical energy is transferred into physical heat which modifies the temperature of water. In brief, a strategy is 'how it does it.'

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.

LOCATION
Indoor

TOOLS AND MATERIALS

Access to the internet

1| FINDING OUT

» QUESTION

This activity involves students finding quick answers to questions they may have. It starts with a research task to elicit students current understanding of the topic and engage interest.

The teacher sets students off on a 'race' to find out key bits of information on the topic of water. The teacher may suggest sources, or allow students to choose how to find the information. A suitable time limit can be set.

The activity is a quick way of gathering and sharing information about the topic. It can lead to discussions about the nature of information and data sources, and the teacher can raise questions about the accuracy and sources of the information, and suggest other ways of approaching the topic. This can be a useful mechanism for ascertaining the level of knowledge on a particular topic. It is also a good and efficient mechanism for getting students to find knowledge in a short period of time.

Suggested tasks:

- Provide three possible causes of flooding in your local area.
- List three strategies to mitigate flooding.
- What parameters might be used to test for clean water?
- Name five potential pollutants of water and their sources.
- List five impacts of climate change on water availability.

See T1.1 for suggested answers.

LOCATION
Indoor

2| MAPPING YOUR CHALLENGE

» CREATE

TOOLS AND MATERIALS

- large sheets of paper (e.g. A2)
- markers in different colours
- laptops, tablets or computers for online resources
- student worksheets W2.1 and W2.2

In this activity students start to explore a case study addressing water management issues. Students will work in groups to address a design challenge, using their knowledge of biomimicry gained from previous BioLearn modules.

Students will be working on a fictitious case study addressing water management in a city park. To make this more realistic, you might select a local park as a real example (opportunities to use mapping skills and Google Earth to create realistic maps and plans) or adjust this case study to match a specific water issue in your area.

Worksheet W2.1 provides a full design brief, which is also summarised below. Provide each group with a copy of the design brief.

DESIGNING A NEW CITY PARK

The local council has commissioned you to design a new city park. Your local town faces several challenges around water, including the problems you have previously learned about, and wants a design that solves these problems.

The local council wants a park that consists of three parts. You need to select one aspect that will be the focus for your design proposal:

1. A skatepark which can also deal with excess water flow from the park.
2. Creare an area of lawn and flowers in a part of the park which has a lack of water and is prone to drought.
3. The provision of drinking water stations around the park without access to mains water pipes.

To help students clarify their task and have a clear research question, using a mind map as outlined in worksheet W2.2 can be helpful. The mind map can serve as an overview of their challenge and the questions they will need to investigate.

At this point, students do not need to come up with solutions to their design challenge, only ask questions. Access to additional information online can be useful when completing the mind-map.

LOCATION
Indoor / Outdoor

3| CONSULTING NATURE

» QUESTION

TOOLS AND MATERIALS

- access to the internet
- large sheets of paper (e.g. A2), or whiteboards
- markers or markers
- possible: books on nature, ecology and geography as a source

Once students have created their mind-map and have a clearer understanding of their challenge, they need to start turning their challenge into a form in which 'nature' can help them. This activity helps students understand the function their designs need to perform.

Functions include verbs such as 'purifying' or 'protecting'. Provide students with following definition to help them:

In biomimicry a function refers to an organism's adaptations which help it survive. For example, the purpose of bear fur is to keep warm, in technical terms its function is to conserve heat (insulation). A leaf can photosynthesise (convert energy from the sun into sugar) and it can distribute water (through its veins). Human products also have functions; a kettle has the functions to both contain water and heat water (modify its physical state). In brief, a function is 'what it does.'

Here are some examples of functions in a city park related to water:

- catching water
- transport water
- purify water
- draining water
- directing (channelling) water.

Ask students to review their research from Activity 2. What ideas do they have and what 'functions' will be required to solve their challenge? For example, if they have identified flooding as a challenge, they might need to find a solution with the 'function' to absorb water or even store water.

Help the students become as concrete as possible with these functions. Their design requirements might include multiple functions.

Once students have identified the functions required, it is time to ask 'How would nature do this?'

You could ask students to think about, for example, what in nature moves water, and encourage them to research how. For example, how does water move through xylem and roots of trees? How about in the human body, how does the water you drink in a glass get into each one of your cells? How do archer fish shoot water with their mouths?

ACTIVITY DETAILS

An important source of information is https://asknature.org/, an online database where the functions can be concretely explored by entering the function in the search bar. See the literature list at the end of the module for further sources of information.

Ask students to create a table, similar to the one below, to list the functions they need to deliver and inspirations from nature.

My Challenge: _____

Functions needed to address the challenge	Natural models

It is tempting for students to find only two or three natural models, but this will limit their ability to create a solution. Encourage students to search for as many natural models as they can before moving towards a conclusion.

LOCATION
Indoor

TOOLS AND MATERIALS

- laptops, tablets or computers for online resources
- large sheets of paper (e.g. A2), or a whiteboard
- markers

PREPARATIONS

Inside activity.

Students work in groups of 3–4 persons. You can also go outside for this part of the module; any place with some natural surroundings such as a park will be suitable.

4| NATURAL MODELS

» QUESTION

Having identified key function(s) their challenge needs to deliver, and researched nature for possible ideas, student teams need to come up with solutions by translating natural models to their challenge. The underlying principle of the natural model and how that function is performed can be used in the design.

For example: a lotus leaf has hydrophobic characteristics due to the structure of the leaf (more here: http://www.biomimicrybe.org/portfolio/lotus-leaf-inspired-texiles/). Could the same structure be applied to the surface of the skate park to encourage water to run off in a designated direction? You could encourage students to develop a table similar to the one shown below.

Natural model	Function	Possible application
Lotus leaf	*Expel water*	*The sides of the skateboard park could mimic the lotus leaf making them hydrophobic. This will ensure water drains quickly and the walls dry faster.*
etc...	etc...	etc...

More examples to inspire students...

In natural habitats, water flow is regulated by plants, animals and the absorptive capacity of soil. For example, beavers modify river hydrology by cutting wood and building dams; one reason they are being reintroduced to parts of the UK. https://asknature.org/strategy/stream-remodeling-alters-ecosystems/

Another example, stream surfaces are generally pervious allowing water to pass through into the soil not just continue downstream. In urban areas where streams have been changed by humans using impervious surfaces, the result can be more water being retained within the stream leading to it bursting its banks. https://asknature.org/strategy/hydrological-regimes-maintain-organisms/

This pervious nature of streams is being mimicked in some towns and cities in an approach called Sustainable Drainage Systems (SuDS). SuDS work to capture water and release it more slowly into rivers and streams, thus avoiding the rapid runoff of water which creates flash floods. An outline of how SuDS work can be found here: http://www.bgs.ac.uk/research/engineeringGeology/urbanGeoscience/suds/what.html

The explanations above might be sufficient to provide students with ideas for re-designing their local park to increase areas of vegetation and reduce soil sealing, perhaps incorporating SuDS into their plans.

Ask each student group to produce an initial design sketch of their solution, and to annotate it to demonstrate the functions it will deliver and how these have been inspired by nature. Then, use the evaluation wheel in worksheet W4.1 so that each group can critique their design and create improvements if required.

Finally, each group needs to produce a poster of their final design sketch containing:

- their key research questions (from Activity 2);
- relevant background information (from Activity 1);
- natural models and functions which have inspired them (from Activity 3);
- a design sketch of their solution.

LOCATION Indoor

5| POSTER PITCH

» CREATE

In this final activity, student teams pitch their design ideas, and evaluate the designs of other teams.

Depending on the number of groups, allow teams 1–2 minutes to pitch their poster (the time limit should focus them on communicating the essential points). It is not a standard presentation, but the focus is on their design and what is special about it. Suggest teams 'sell' their design, as if they are presenting directly to a client.

Encourage the audience to provide feedback based on:

- Strengths – what did you like?
- Weaknesses – how could it be improved?
- Enablers – what will support the plan to be implemented?
- Barriers – what might hinder the plans implementation?

LOCATION
Indoor

TOOLS AND MATERIALS

Copies of posters from Activity 5

6| DESIGN THE SKATE PARK (EXTENSION)

» QUESTION

In nature plants and animal collaborate to maintain the optimum conditions. In this activity, students collaborate through sharing information and improving their designs through cooperation.

Invite each team to attach their poster to a wall around the classroom. Mix the student groups so that each new group contains members from different groups/design teams. In their new teams, invite them to:

1. Share their designs from Activity 5.
2. Discuss how their ideas can be improved (refer to student worksheet W4.1 for help).
3. Decide how their designs for the skate park, gardens and water points can be combined into a single design. Are there any synergies between them? Can they work collectively?
4. Produce a new poster showing how all their ideas can work together for the design of the entire park (skate park, gardens and water points).

Students could present their plans as in Activity 5, or create a gallery display around the classroom and invite students to move around to see each poster, using post-it notes to add comments.

LITERATURE, ADDITIONAL INFORMATION

Below are a range of useful website links and book references.

WEBSITES

Ask Nature – https://asknature.org/
The key resource for exploring biomimicry examples; a rich resource to delve in to. Their resources area (https://asknature.org/?s=&p=0&hFR%5Bpost_type_label%5D%5B0%5D=Resources) offers teaching resources, videos and articles to explore.

Biomimicry Toolbox – https://toolbox.biomimicry.org/
Great resources explaining the core concepts of biomimicry and a step-by-step approach to applying a biomimicry approach to design.

Packaging Innovation Toolkit – https://synapse.bio/blog/2017/10/11/biomimicry-packaging-innovation-toolkit
Resources to expand ideas around packaging based on biomimicry thinking.

Genius of Place – https://synapse.bio/blog/ultimate-guide-to-genius-of-place
In the Genius of Place process, biomimics look to native organisms and ecosystems to provide guidance, models, and metrics for how to be generous and resilient as we design for a particular place.

BOOKS & JOURNALS
Biomimicry Resource Handbook
The key resource for biomimicry thinking, processes and applications. A huge amount of information and ideas; expensive but well worth it.
Baumeister, Dayna (2014). *Biomimicry Resource Handbook 2014: A Seed Bank of Best Practices*. Biomimicry 3.8.

Biomimicry: Innovation Inspired by Nature
The book by Janine Benyus which first brought biomimicry to wide attention. Lots of good examples to use and descriptions of the nine principles of biomimicry.
Benyus, Janine (2002). *Biomimicry: Innovation Inspired by Nature*. HarperCollins.

Zygote Quarterly
Showcases examples of science, technology and creativity in the field of biologically inspired design.
https://biomimicry.org/zygote-quarterly/

T1.1 FINDING OUT

Statements	**Responses –** Possible answers might include:
Provide three possible causes of flooding in your local area.	• Deforestation reducing water retention is soil and vegetation • Soil sealing • Straightening/channelling of rivers • Building on a flood plain • Increased rainfall • Steep slopes and high runoff • Very wet, saturated soils • Compacted or dry soil
List three strategies to mitigate flooding.	• Tree planting in the watershed • Flood defences • Constructing houses on stilts • Sustainable Drainage Systems (SuDS) • Constructing levees to contain water • Temporary flood barriers/fences • Rewilding rivers and flood plains • Zoning areas for planning to prevent building in at risk areas • Installing storm sewers
What parameters might be used to test for clean water?	• Dissolved oxygen • pH • Water temperature • Salinity • Nutrients (nitrogen and phosphorus) • Indicator species of macro-invertebrates • Flow rate • Habitat indicators may be helpful (e.g. width, continuity, extent of shading and species composition along banks)
Name five potential pollutants of water and their sources.	• Organic Wastes – domestic sewage, decaying animals and plants, animal waste and excreta, waste discharge from food processing factories • Pesticides – chemical sprays from agriculture • Micro-organisms – domestic sewage • Heat – water discharge from industry and power stations • Toxic heavy metals – industry such as chemical factories • Plant nutrients – excess use of chemical fertilizers • Radioactive substances – mining of uranium containing minerals • Sediments – soil erosion due to strip mining and agriculture
List five impacts of climate change on water availability.	• Changing precipitation patterns • Increased water shortages in some areas • Increased flooding in some areas • Sea level rise • Drying up of lakes due to warmer air and increased evaporation • Increased/decreased river flows • Loss of wetland areas and associated wildlife • Changes in water demand leading to less availability in drier regions • Increased conflict over access to water resources

W2.1 DESIGN BRIEF

Three parts of the city park

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The local council wants a park that consists of three parts. You need to select one aspect that will be the focus for your design proposal:

1. A skatepark which can also deal with excess water flow from the park.
2. An area of lawn and plants which lacks water and is prone to drought.
3. The provision of drinking water stations around the park without access to mains water pipes.

PART 1

The first part is a skate park. A skate park consists largely of concrete and tiles. As a result, it is difficult for water the drain away after heavy rainfall. The local council wants a solution for this. The requirements for the design of the skate park are:

- Minimum surface area of 50 m².
- It should be able to drain water quickly and in a sustainable way.
- Fit the atmosphere and appearance of the whole park.
- Reduce noise so that neighbours are not disturbed.
- Be safe for users.

PART 2

The second part consists of a lawn and gardens. This requires a lot of water to grow grass and plants during spring and summer. During spring and summer there is very little water available, so in this part of the park the challenge is to provide a sustainable source of water and reduce wastage of water. The requirements for the design of this section are:

- Contains a lawn and at least five plant species in the borders.
- Should be able to absorb, store and distribute water in an efficient and sustainable way.
- Minimum surface area of 30 m².
- Fit the atmosphere and appearance of the park.
- Provide footpaths for public access.

PART 3 _____

The third part is a water drinking points. The local council would like to see several drinking water points in this section where visitors can access free drinking water. The local council has a lot of rainwater, a pond and groundwater, and wants to use this water for the water points. To achieve this, any water collected needs to be purified to be suitable for drinking. The requirements for the design of this section are:

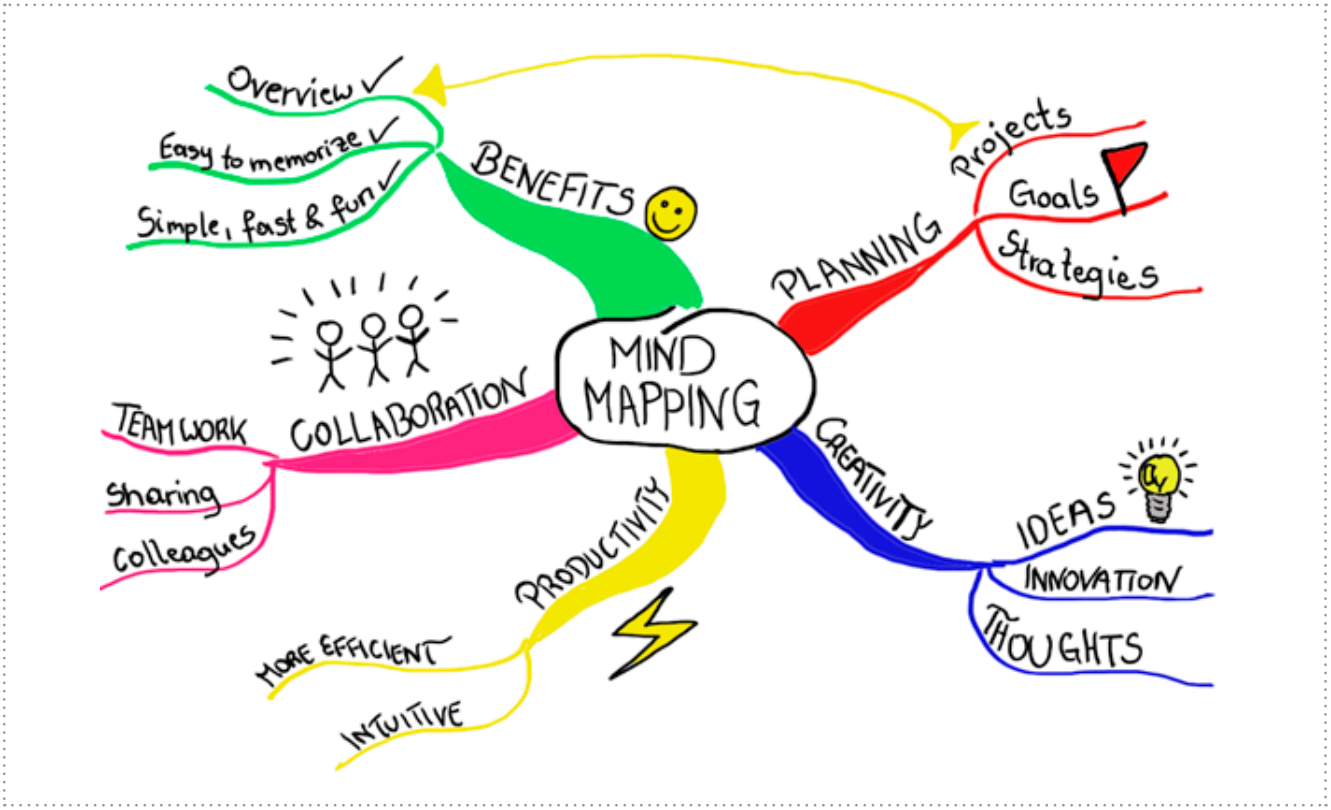
- Contains a pond, a water treatment and drinking water points.
- Should be able to convert wastewater into drinking water.

W2.2 MIND MAPS

How to create your mind map:

1. Write your selected design challenge in the centre (the central idea or theme).
2. List key topics relating to your design challenge and add these as the main branches; remember to label each branch.
3. For each branch, add detail in the form of key words or questions.
4. Add additional branches and details as appropriate.

An example of a mind map:



The main branches of your mind map will become the key research areas for your design challenge, so the more detail you can add the better.

W4.1 IMPROVING YOUR DESIGN

Group Evaluation Wheel and Questions

DESIGN OR PROJECT NAME:. . . . . .

DESIRED FUNCTION / CONCEPT: . . . . . .

Q1: Based on the nine principles of biomimicry, this is close to how nature would design this product/project.

STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE

Q2: Looking at your design and comparing it to the nine principles of biomimicry, which areas are the strongest? **Why is this the case?**

. . . . . .

Q3: Which areas are the weakest? **Why is this the case?**

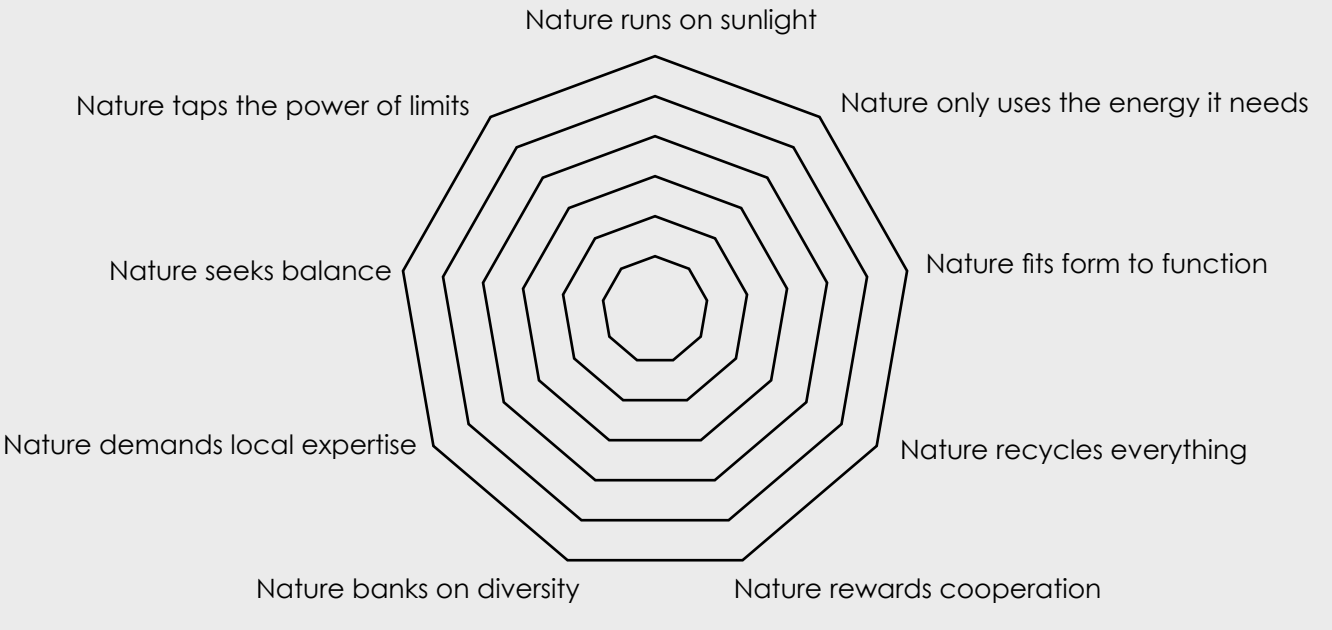
. . . . . .

Q4: Think of one practical way you can improve your design.

. . . . . .

Improving your design
Consider how you might use the nine principles of biomimicry to improve your design. How might nature go about designing the product or function you are trying to produce?

TASK: Use the diagram below to plot how your product achieves in relation to each biomimicry principle of design. Use this to consider the strengths and weaknesses of your design.



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