INTRODUCING BIOMIMICRY

What can we learn from nature's principles for solving design-based challenges?

Erasmus+

AGE RANGE

13–15

DURATION

Preparation:
varies (10–20 minutes)

Activity:
90 minutes / 2 lessons

SUBJECT(S)

- Science – *Biology*
- Design, Engineering and Technology

KEYWORDS

Biomimicry introduction; natural design; functions

SUMMARY

This module introduces students to biomimicry through the use of examples, a card sort and an activity where they learn to apply biomimicry principles. This module can sit alone, or in preparation for the 'Big Biomimicry Challenge' module.

BIOMIMICRY PRINCIPLES

1 – Nature runs on sunlight
2 – Nature uses only the energy it needs
3 – Nature fits form to function
4 – Nature recycles everything
5 – Nature rewards cooperation
6 – Nature banks on diversity
7 – Nature demands local expertise
8 – Nature seeks balance
9 – Nature taps the power of limits

LEARNING OBJECTIVES

- Students are able to define biomimicry and cite examples of nature-inspired design.
- Students are able to apply natural functions to design problems.
- Students are able to discuss the benefits of nature-inspired design for solving problems.

LEARNING OUTCOMES

- Students consider and discuss the merits of a biomimicry approach.
- Students understand the application of natural functions to design problems.
- Students consider the natural world in a new way.

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 assess the consequences of applying biomimicry solutions (values).
- Students are able to work in groups.

SUMMARY OF THE ACTIVITIES

	Activity Name	Description	Method	Duration	Location
LESSON 1: What is Biomimicry?					
1	Exciting examples	Students listen to a short presentation and 2 short videos	• Teacher presentation	15	Indoor
2	Thinking about biomimicry	Students give more examples on cards	• Group work	10	Indoor
3	Learning from nature	A game about what we can learn from nature	• Card sort	20	Indoor
LESSON 2: Seed design task					
4	Think-Pair-Share	Refreshing memories about biomimicry	• Discussion	5	Indoor/ outdoor
5	Biomimicry principles	Learning about the 9 principles of biomimicry	• Exploration	10	Indoor/ outdoor
6	What can we learn from a seed?	Students examine maple seed for learning from it	• Exploration	10	Indoor/ outdoor
7	Seed observations	Students make closer observation of the maple seed	• Observation	10	Indoor
8	Mini-design challenge	Students design flood prevention by the help of the maple seed	• Design activity	10	Indoor

BACKGROUND FOR TEACHERS

This module takes students through the process of nature-inspired design, incorporating a basic introduction to Biomimicry, and a structured set of design tasks, involving individual and group work. The module is designed to stand alone, or as part of a large scheme of work. While many of the concepts are relevant to Design Technology and Biology, the module will also appeal to teachers looking to develop study skills including team work and presentation competencies in students. The module can be easily adapted to suit a range of time-allocations, and might be delivered in different arrangements – for example:

1. Lessons 1–2: Introduction to Biomimicry
2. Lessons 1–6: Introduction to Biomimicry + Biomimicry challenge
3. Lessons 1–8: Introduction to Biomimicry + Biomimicry challenge + Presentation of design

The module utilises accompanying presentations which contain detailed teaching notes, in order that different teaching staff can deliver each lesson. More straightforward teaching notes are included in this guide under each lesson/activity overview below.

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).

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.

Expressions see also in Glossary.

ACTIVITY DETAILS

LESSON 1: What is Biomimicry?

This lesson is designed to introduce the concept of Biomimicry to a group ahead of students embarking on a design challenge. It can be delivered together with Lesson 2, which is an introductory nature design-thinking challenge. During this module, students will learn about biomimicry: what it is, how it can be used as inspiration for problem solving, and consider examples of biomimicry. Students will work as a small team through this activity.

LOCATION
Indoor

TOOLS AND MATERIALS

PC, projector

PREPARATIONS

Indoor activity.

Arrange the room for watching ppt/video.

RESOURCES

Bullet Train and Janine Benyus videos (will require internet access)

www.youtube.com/watch?v=YVU6YBPaaB8

https://youtu.be/FBUpnG-1G4yQ

1| EXCITING EXAMPLES

» DISCOVER

Bullet Train Video (duration 1:30)
Students watch BBC video about the development of the Bullet Train inspired by the Kingfisher's Bill. This is an example of Biomimicry. Following the video, the teacher can provide the students with a definition of Biomimicry as stated in the accompanying ppt (adaption/differentiation) might include asking students to come up with their own definition after watching the video, and asking them to share with one another, if time permits).
https://www.youtube.com/watch?v=YVU6YBPaaB8

Janine Benyus Video (duration 2 minutes)
This video gives a short explanation of what biomimicry is by its founding advocate Janine Benyus.
https://youtu.be/FBUpnG1G4yQ

ACTIVITY DETAILS

LOCATION
Indoor

2| THINKING ABOUT BIOMIMICRY

» DISCOVER

TOOLS AND MATERIALS

W2.1 student worksheet

PREPARATIONS

Indoor activity.

Arrange classroom to suit small group work.

Provide students with the examples of how nature has inspired design (W2.1). Ask them to consider in small groups how this might have helped with human design problems.

LOCATION
Indoor

3| LEARNING FROM NATURE

» DISCOVER

TOOLS AND MATERIALS

W3.1 student worksheet

PREPARATIONS

Indoor activity.

Print and cut cards of W3.1 according to the number of pairs.

Now that students have had a chance to think about each aspect of nature, they can have a go at the card sort in pairs.

Instructions:

1. Students are given card sort and lay them out on the table. They then separate out cards into **two** piles:
   a. Green Challenge picture cards (these represent an aspect of nature). **Make sure that they keep the Challenge sides facing upwards and the 'Nature's strategy' side facing down.**
   b. Brown picture cards (these represent a technology that imitates nature)
2. Students pick up a Green Challenge picture card and read through the challenge questions with their partner. **Prompt to discuss thoughts on the challenge question with partner.**
3. Next, they look at the brown picture cards and choose one that they think shows a human invention that imitates that aspect of nature.
4. Once students are confident in their choice and have discussed reasons with their partner, they turn over the challenge card and read the information on the back. This will tell them about how this technology was inspired by nature to overcome a problem.
5. Repeat steps 2–4 with the other three challenge cards in turn until all challenge cards have a matching imitation card.

As an **extension** to this activity (c. 15 minutes), students can watch the accompanying videos for each of these examples, in the ppt. There are detailed teaching notes for each of the examples in the PowerPoint slides. After the activity students complete the success criteria for the lesson.

LESSON 2: Seed design task

This lesson follows on from the introduction activity (Lesson 1) and provides students with a hands-on activity to encourage them to think about how functions in nature can be used as inspiration for solving human design challenges. The activity is very simple, and is not designed so that each student / group comes up with a different approach. Rather, it is to guide them through a particular method of problem solving which can be utilized in the next lesson.

LOCATION
Indoor / Outdoor

4| THINK-PAIR-SHARE

» CREATE

Ask students to recap on the previous activity and discuss in pairs 'what is Biomimicry'? Ask them to describe two examples of biomimicry and how it has led to innovation. Feedback selectively if time.

LOCATION
Indoor / Outdoor

5| BIOMIMICRY PRINCIPLES

» CREATE

TOOLS AND MATERIALS

- W5.1 student worksheet

Show the students the 9 principles of biomimicry. The accompanying worksheet (W5.1) can be given out (or viewed online) also. Let them investigate the principles.

ACTIVITY DETAILS

6| WHAT CAN WE LEARN FROM A SEED?

» CREATE

LOCATION
Indoor / Outdoor

TOOLS AND MATERIALS

- Paper and pens (for group work)
- Maple/Sycamore seed (one per student ideally)
- If maple seeds are not easily available, use a video reference (see link in Introducing Biomimicry ppt).

PREPARATIONS

This activity can take place indoors or outside.

Arrange the room for small group work. Each table should have a pot of maple seeds, pens and paper.

- Give each group one sycamore seed – *Be careful not to damage the seed!*
- Students spend 5 minutes playing around with it and analysing its movement and structure in as much detail as possible.
  - Examine the seed structure in detail.
  - Throw it in the air.
  - Look at how it flies – what allows it to move like this?
- As students are doing this, ask them to think about why the seed has these features.

7| SEED OBSERVATIONS

» CREATE

LOCATION
Indoor

TOOLS AND MATERIALS

W7.1 student worksheet

PREPARATIONS

Indoor activity.

Print W7.1 in number of pairs.

Students work in pairs to fill in the attached worksheet (W7.1) – they are required to observe the seed closely to consider its structure and function. This activity is designed to encourage the students to think about how nature is well suited to a variety of tasks. The key here is getting the students to think about the function of the seed (i.e. it falls slowly, it rotates, it is aerodynamic) to serve a purpose, and then thinking about how we might copy these functions to solve design challenges.

Some examples of how the design and function of the seed has been applied:

- Provide students with a few examples of how the design and the function of the seed can be seen in human designs e.g. pumping, flow regulation and electricity generation (see Introducing Biomimicry ppt slide 25).

ACTIVITY DETAILS

LOCATION
Indoor

TOOLS AND MATERIALS

W5.1 student worksheet

8| MINI-DESIGN CHALLENGE

» CREATE

How can the design and function of the seed be copied to help people who are at risk of flooding?

The purpose of this is to get students to consider how looking to nature's designs can help to prompt us to think and see differently – applying the ingenuity of the seed to a human design problem.

Students draw their design and label it with functions as observed in the previous activity making use of the 9 principles of biomimicry already given out to assess their design (W5.1).

Ask the students to consider how their design performs against the biomimicry principles – are there any which it is particularly strong at; are there any which are weak?

After the activity students complete the success criteria for the lesson.

EXTENSIONS

If time – finish with a class discussion – Volunteers can share their designs and how the sycamore seed inspired them.

Challenge: Explore the 'Ask Nature' website to be inspired by biomimicry.
https://asknature.org/

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/

W2.1 THINKING ABOUT BIOMIMICRY

Examples of nature

Take a look at these species. Each has inspired a human invention. Can you guess which one it is?

W3.1 LEARNING FROM NATURE

Cards

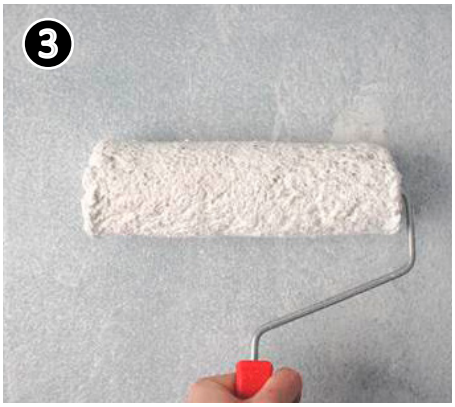
Print and cut up one set of cards per group.

Print and cut up one set of cards per group.

1

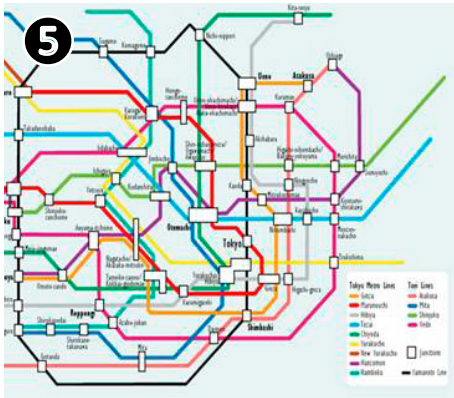
2

3



4

5



Print, cut and fold each challenge/strategy card to make one set of double-sided cards per group.

FOLD & GLUE

CHALLENGE 1

Japanese Bullet trains travel so fast they produce a loud boom when they exit tunnels caused by a cushion of air building up in front of the train. This cushion of air slows them down. How does the Kingfisher transition between different environments and how has it helped to inspire the new design of Bullet train?

NATURE'S STRATEGY TO MEET THE CHALLENGE

The Kingfisher dives from the air (low drag) into rivers to catch fish, creating very little splash as it enters to water (high drag). It achieves this due to its streamlined beak which steadily increases from tip to head. Engineers mimicked this on the train and found it not only removed the boom, but also saved 10–15% more energy by being more aerodynamic.

CHALLENGE 2

We want things to stick together tightly yet come apart easily and readily; seemingly an impossible challenge.

How can we use nature to help us design a material that holds two surfaces strongly together, yet allows them to detach easily?

NATURE'S STRATEGY TO MEET THE CHALLENGE

Geckos adhere (stick) to vertical surfaces using millions of tiny setae (microscopic hairs) on their feet. Unlike glue they leave no residue behind. **Gecko tape** mimics the concept of Gecko feet using millions of synthetic fibers which replicate the function of these setae (hairs). Used appropriately, these can provide enough attractive force to hold the weight of a human!

CHALLENGE 3

Newly painted buildings quickly get dirty, requiring time and effort to clean them. How does nature keep surfaces clean? How could we learn from this?

NATURE'S STRATEGY TO MEET THE CHALLENGE

Lotus leaves stay clean without detergents. The plant's cuticle is extremely water repellent. This is accomplished through **microscopic bumps** on their leaf surface. This reduces the stickiness of water droplets to the surface so they run off easily and take dirt away at the same time.

This is now being mimicked in self cleaning paints and glass. Clever stuff!

FOLD & GLUE

CHALLENGE 4

How could we connect two things quickly and easily, yet in a way that they could also be taken apart just as quickly? How would nature attach things together in this way?

NATURE'S STRATEGY TO MEET THE CHALLENGE

The Burdock seed has tiny hook-tipped burrs. As an animal brushes past, the hooks connect with the animal's fur and the seed detaches from the plant; it is then carried to a new location and will eventually drop off the fur and into a new environment where it can grow.

Observing this inspired the creation of Velcro which is commonly used in clothing, tents and work equipment where two pieces are material need to be regularly sealed and unsealed.

CHALLENGE 5

Working out the most **efficient*** way to connect a large number of different points requires huge computing power. There are lots of examples in nature where this happens naturally. What is nature's elegant solution?

*(*achieving maximum productivity with minimum wasted effort or expense)*

NATURE'S STRATEGY TO MEET THE CHALLENGE

Slime mould grows in patterns which **efficiently** find the quickest route to food sources.

Using oat seeds to represent neighbourhoods in Tokyo, scientists observed how over a number of days the slime mould created a network of connecting "nutrient-tunnels" which closely replicated the Tokyo rail system.

W5.1 BIOMIMICRY PRINCIPLES

What is Biomimicry?

Janine Benyus describes biomimicry as "learning to live gracefully on this planet by consciously emulating life's genius. It's not really technology or biology; it's the technology of biology. It's making a fibre like a spider, or lassoing the sun's energy like a leaf." Designing for sustainability is also important to biomimicry thinking.

It's this kind of thinking that's inspired some remarkable designs in recent decades, including a Japanese bullet train partially modelled after the aerodynamics of the kingfisher bird; a shopping center in Harare, Zimbabwe that mimics the cooling strategies of a termite mound; and a synthetic surface called Sharklet that inhibits bacterial growth through texture alone, inspired by the bacteria-repellent skin of a shark.

Here are the **nine Basic Principles of Biomimicry** that we are working with. They are very simple, but once you unpack them you discover they lead everywhere. It is possible to use these principles as starting points for design, or as a way of checking our design work and then making improvements.

1. Nature runs on sunlight

Nature uses sunlight as the main source of energy. Organisms use heat and UV radiation from this never-ending source. We can say that nature is powered by sunshine. Humans use fossil fuels, these sources are not renewable, and burning them creates CO_2 which is one of the gases causing climate change. Why don't we do the same and prevent the climate crisis? A wise person would mimic nature and rely on renewable power.

Where does the energy come from to power your product? Can it generate its own energy?

2. Nature uses only the energy it needs

Nature takes only what it needs. Why do we not do the same? Our economy is focused on maximizing output and is a big energy consumer. We transport food around the world because that is economically cheaper. Only money seems to count in a lot of decisions, not energy consumption and impact on the natural world. How can we learn to optimize the performance of goods and services to sip energy rather than gulp it?

How does your design minimise energy use?

3. Nature fits form to function

A tree is rooted in the ground to draw water and nutrients from the soil; it spreads its branches and leaves wide to increase surface area and absorb sunlight to produce energy and grow. Seeds are lightweight and some even come equipped with a sort of umbrella so they can float in the air. Nature creates designs for the function they provide, so should our buildings, transportation systems and schools.

How does your design compliment the context/situation in which it will be used?

4. Nature recycles everything

There is no 'away' to throw things. Everything produced in nature is biodegradable, there is no waste. There can still be abundance, look at all the blossom on a cherry tree; but that all serves a purpose and will be food and nutrients for others. Once the natural life of a pinecone has come and gone, it breaks down into essential elements that are repurposed into new life.

Is your product made using life-friendly chemistry? Can it be mended, recycled or reused in a different way?

5. Nature rewards cooperation

We see competition in nature, but only when it is impossible to avoid; in general competition costs too much energy. On the other hand, very little in nature exists in isolation. Plants cooperate with pollinators to disperse seeds, and the pollinators feed on nectar. Ladybirds feed on aphids and help plants to stay healthy. Nature favours cooperation because it maintains the health of the whole system.

How does your product link positively with other services and products?

6. Nature banks on diversity

Diversity is one of nature's best insurance policies. When one food source is unavailable, others can be found. Plants use several different strategies to spread seed or defend against predators. We know that species with limited genetic diversity have more difficulty adapting to environmental change, and that ecosystems rich with diversity are more stable.

Does your product create greater or lesser diversity? Does it impact biodiversity?

7. Nature demands local expertise

Nature's systems are inherently local. Certain species thrive under specific conditions; local and regional weather patterns matter, as do other conditions such as soil, air quality and water temperature. Relationships are created locally and local resources are used. Of course, some birds travel long distances but have you seen them take their food with them?

Does your design make good use of local conditions? It is designed to work within local conditions (e.g. climate)?

8. Nature seeks balance

Ecosystems try to keep in balance. More mice? Then you will see more owls to feed on the mice and keep the population in balance. Forest fires are a great example of a natural phenomenon that renews and refreshes, reducing excessive growth and allowing for regeneration. Every natural system has a tipping point, a carrying capacity or a state of disequilibrium that triggers a change to a different state.

Are feedback loops designed into your product to ensure you can monitor any unintended consequences?

9. Nature taps the power of limits

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.

Is your product really needed?

W7.1 SEED OBSERVATIONS

Structure and function

Can you make some observations about your seed? Use the prompt questions below to help you and answer the questions in your book (10 mins).

1. Describe its **structure** (e.g. shape/size/weight).

2. What do you notice about the fine details of the seed (when you look really closely)?

Observations about our seed!

4. Describe its **movement** when you drop it from above your head

3. What are the **functions** of the seed (e.g. what is the seed's purpose?)

5. How might we be able to use these functions to solve real-life challenges?