BIOLEARN

Inspired by Nature

BioLearn Training Guide

Erasmus+

Content

1. Introduction

This manual is intended for trainers who are already familiar with biomimicry and the BioLearn modules.

BioLearn aims to promote the integration of biomimicry in to formal education for students aged 12-16 years. 22 modules in 5 languages have been developed, which you can find on the project website (https://biolearn.eu/). This document is to help those who wish to support others using the modules, a "Train the Trainer" guide. It is specifically developed for trainers who want to implement teacher trainings using the BioLearn modules.

In this booklet we explore what biomimicry is, which methods are used, and how it is applied in education. It also provides practical ideas, the actual BioLearn modules, and it ends with a suggested evaluation form for Teacher trainings.

How can nature inspire?
Life on earth has evolved over 3.8 billion years into a model of sustainability. Nature recycles waste efficiently, uses renewable energy from the sun, is resilient to sudden changes, is adaptable over time to new conditions, and self-regulates through feedback loops. What if we could use the operating principles found in nature to rethink how we live as humans? To flourish without damaging the natural ecosystems we depend upon for our survival? That's what biomimicry – learning from nature – is all about.

Nature-inspired learning takes us on a journey to discover the principles which make nature a model for sustainability. It offers an opportunity to explore how these principles can help tackle some of the greatest challenges facing humanity today, such as climate change and increasing levels of waste and pollution. And finally, empowers students to apply their new competences to create real solutions that work.

Subjects – how can biomimicry fit into the classroom?
Subjects including science, technology, engineering, arts and maths (STE[A]M) offer the ideal vehicle for this inspiring and engaging approach. Biology, for example, teaches us about how nutrients cycle in a woodland and can help us see how technical nutrients can cycle in product design. Physics demonstrates how forces can be harnessed to reduce energy use. Technology and engineering can use the science of nature to build new products, processes and systems which elegantly mirror nature's sustainability.

Bio- what?
Whenever we take a walk in nature, we can observe how it functions. If we look closely, we can observe that the same principles are repeated again and again; these are the basic operating principles which allow nature to be sustainable. We call this nature-inspired learning.

Learners who are connected with nature will discover that nature can be a mentor, offering insights that inspire the building of a brighter future. Inquiry-based learning can be utilised to foster inspiration and to stimulate a desire for understanding.

What's in a name?
There are various terms that refer to, or are related to learning from nature / nature-inspired innovation. See the Glossary on https://biolearn.eu/ for more info

- Bio-inspired
- Bio-based
- Biomimicry
- Learning from nature
- Bionics
- Biomimetics

Background
In the late 1990s, a revolutionary idea arrived on the scene, shepherded by an innovative thinker, and nurtured by scores of curious and passionate individuals. In the book Biomimicry (1997), Janine Benyus introduced the notion that we could be better off by mimicking the ways problems are solved in nature; this idea has proven transformative.

In the book (Biomimicry – Innovation Inspired by nature, 1997) Benyus lists nine principles that govern and define how nature operates.

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

Read more about the 9 principles on p. 8.

The pillars of the project (BioLearn)

The BioLearn project helps young people think about what sort of future they would like to live in and how can they contribute to that future. BioLearn helps empower students to turn their ideas for a better world into reality. BioLearn challenges traditional assumptions about how things are made and how entire economies are managed. BioLearn is about re-thinking the future, a future that is already happening because many companies are already fascinated by nature and are innovative enough to create 'bio-inspired' design.

The pillars of BioLearn project are:

- STE(A)M/science education
- 9 biomimicry principles (Benyus)
- Inquiry-based Learning (IBL)

2. About Biomimicry

Biomimicry is a design method that uses knowledge from nature as inspiration for sustainable design. It is an interdisciplinary approach that brings together nature, biology, design and technology. Biomimicry has the potential to be used for more than design alone – one of its potentials lies in education.

The abundance of nature offers humanity a wealth of knowledge to address the greatest challenges of our time, if only we choose to look. The term biomimicry was first used by Janine Benyus in her book 'Biomimicry: Innovation Inspired by Nature' (1997). Biomimicry, from the Greek words 'bios' meaning life, and 'mimesis' meaning to imitate, is using knowledge from nature as inspiration for sustainable design. It is an interdisciplinary approach that brings together nature, biology, design, business, and technology.

Biomimicry contains three essential elements: Ethos, (Re)connect and Emulate (*Figure 1*).

The **ethos** element inspires the ethical intentions and explains the underlying philosophy of why and for what purpose biomimicry should be practiced. Ethos represents our respect for, responsibility to, and gratitude for our fellow species and planet Earth.

The **(re)connect** element brings up the understanding that we, as humans, are nature. According to Benyus, nature and humanity are now often seen as separate parts. It is the goal of biomimicry to reunite these two. (Re)connecting is a practice and a mindset that explores and deepens this relationship between humans and the rest of nature.

The **emulate** element brings out biomimicry at its most practical: it is about seeking sustainable solutions by understanding principles, patterns, strategies and functions from nature.

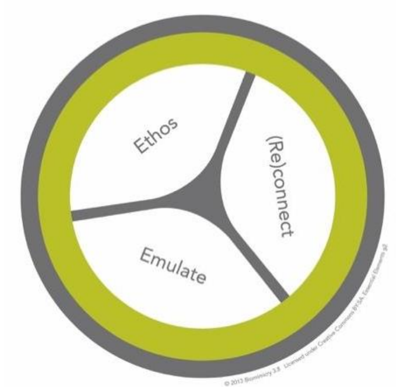


Figure 1: Essential elements of biomimicry (Copyright Biomimicry 3.8 & licensed under Creative Commons)

The Biomimicry Institute has provided several tools that designers can use, called the Biomimicry Design Lens. Biomimicry can be used on three different levels; to design products, processes, or complete systems. For example, learning from maple seeds and kingfisher birds how to channel incoming wind to address root leakage (product). Learning from coral to create colourful textile (process). Or learning from prairies how to grow food in resilient ways (system).

Biomimicry Thinking

Biomimicry Thinking provides context to where, how, what and why biomimicry fits into the process of any discipline or any scale of design. Biomimicry Thinking is a framework that is intended to help people practice biomimicry while designing anything. There are four areas in which a biomimicry lens provides the greatest value to the design process (independent of the discipline in which it is integrated): scoping, discovering, creating and evaluating. Following the specific steps within each phase helps ensure the successful integration of life's strategies into human designs.

There are two possible routes for using Biomimicry Thinking. One can either start from biology, or from a (technical or social) challenge. The first one (Biology to Design) starts with an organism, ecosystem or natural phenomenon. When observing that natural object (e.g. a tree) a designer or engineer may ask the question 'What can we learn from the tree about how the leaves are positioned on the branches?'

The second route (Challenge to Biology) starts off at a given challenge. That could be a challenge like "Cooling the neighbourhood in summer" or "Flying over long distances". The two possible routes are illustrated in the table below. Both routes follow the same steps of Biomimicry Thinking, but the starting point is different, as you can see in *Figures 2* and 3.

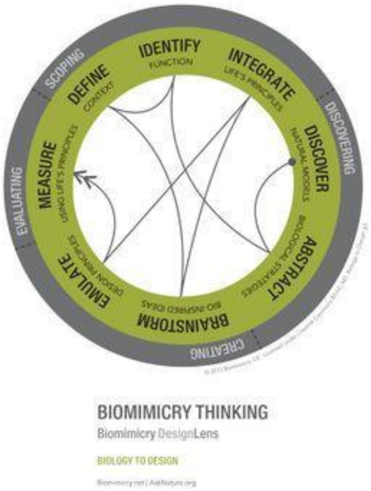
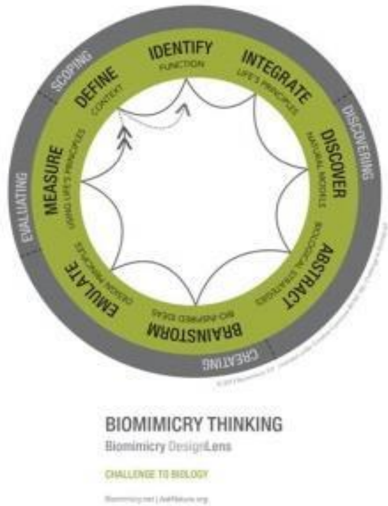
Biology to Design	**Challenge to Biology**
 *Figure 2*: Ecology to design thinking (Copyright Biomimicry 3.8 & licensed under Creative Commons)	 *Figure 3*: Challenge to ecology thinking (Copyright Biomimicry 3.8 & licensed under Creative Commons)
Take a look at a tree, what features can you discover and what actually could we learn from this tree or trees in general?	Climate change presents a huge challenge and it might be interesting to get some inspiration from nature on how to address that.
How come that it feels cooler under the trees that a mile away at the road?	Reducing CO_2 emissions in air traffic/ airplanes.
What can we learn from a tree about 'cooling down the surroundings?'	How does nature fly over long distances without using much energy?
Evaporation of water and creating shade both contribute to cooling down the surroundings.	Have a look at seeds of trees and other plants, at 'long distant' birds like the albatross.
How could we apply this principle to buildings in the city?	The use of a specific form (albatross wing, seed of a maple tree) and specific material (porous, light weight).
Create flat water reservoirs on the rooftop of tall buildings that fill up during rain time and start evaporating at a certain temperature.	Creating airplane wings from lightweight materials in combination with a structure /shape that uses the principle of uplifting

Table 1: Two ways of applying Biomimicry Thinking

See these two routes with activities in the Marvellous models module.

Nature inspired innovation in context

Since humans first started to hunt, we have been learning from nature (think of the shape of a spearhead…it is mimicking the beak of a bird). Leonardo da Vinci spent many hours observing how nature worked and designing miraculous inventions based on his discoveries. He wasn't very successful in building an airplane but the reason we are able to fly around the globe today is because Leonardo da Vinci observed how birds used their wings to create lift and wondered if we could do the same.

A significant number of organisations from different sectors already rely on nature-inspired approaches to innovation for the success and further development of their products and services. Examples range from technology (e.g. Google and Apple's use of neural networks, a nature-inspired artificial intelligence technology), medicine (e.g. immunotherapy, a nature-inspired medical intervention), infrastructure, transportation, manufacturing, and more. Nature-inspired innovation is already a major driver of economic growth worldwide. One study estimates that nature-inspired innovation-related employment opportunities are producing over 1.5 million jobs in the United States alone.

The company Parker Hannifin, for instance, specializes in aerospace, climate control, electromechanical, and filtration engineering solutions, has recently used nature-inspired innovation in the development of industrial hoses now used in the cement industry. Their Vice-President of Technology and Innovation explains why: "You don't want to invest in solutions that have to be abandoned in the future," Peter Buca says. "Nature offers solutions that are practical and sustainable. As an industrial company, understanding that value is important to us."

Looking to the natural world for innovative ideas is a fixture of the research and development efforts at Airbus. Airbus pursues research into shark skin as a model for reducing drag on aircrafts through the application of micro-texture on airplane bodies. And albatrosses served as models for improvements in wing design. Airbus's innovation manager in flight physics, Lee-Ann Ramcherita, explains that "understanding how insects, birds or bats detect and respond to fluctuations in the surrounding airflow may potentially help us identify opportunities to apply on our aircraft." Industries are increasingly looking to nature for innovative ideas, and looking for employees that can help lead the way there.

As Steve Jobs put it, in an interview shortly before his death: "I think the biggest innovations of the twenty-first century will be at the intersection of biology and technology."

The nine biomimicry principles

We can learn from nature by studying adaptations of specific organisms (like the Kingfisher's beak). We can also learn from deep principles that can be found throughout nature, and that almost all organisms adhere too. Janine Benyus discusses nine principles in her book, and in biomimicry, these are being used both as inspiration for our designs, and as evaluation criteria. When evaluating our designs against these nine principles we get an indication of the sustainability of our designs, and how to improve them.

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.

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?

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.

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.

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.

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.

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?

8. **Nature seeks balance**

(Originally in Benyus's book: Nature curbs excesses from within.)
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.

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.

Janine Benyus' list of biomimicry principles shows us that there is an endless amount we can learn if we just pay attention to our surroundings.

3. Biomimicry in education

How can BioLearn fit into the classroom?

Nature-inspired learning leverages the wonder of the natural world and all it has to teach us. It is both fascinating and solution-oriented, an extremely potent combination. As Angela Nahikian, Head of Sustainability at Steelcase has put it: “Biomimicry offers a fresh lens for all the dreamers and doers remaking the man-made world.”

The net result of enriching school subjects using nature-inspired educational approaches can be a dramatic increase in students’ appreciation for the world around them, their interest in creating positive change in themselves and society, and in pursuing further education and careers to help them do so.

Nature-inspired education has the power to generate interest and enthusiasm in teachers just as it does in students, revitalizing their energy and teaching practice. Teachers respond much like students to having subject matter enriched by a nature-inspired approach. Years of working with teachers through workshops and professional development has made this fact abundantly clear.

Three reasons to use nature-inspired learning.

- Nature-inspired education does not require new content be added to the curricula.
- A wide variety of academic ideas and subjects can be approached through nature-inspired learning.
- Academic ideas and subjects are explored in connection with the engaging context of the natural world.

“I feel that this class has offered me a mind-blowing professional development experience! A tsunami inside me is bursting to share all that I learned in our class with my students.”

Lillian Ortiz, IC Community School, Oakland, California

Benefits of biomimicry in education

Biomimicry can provide multiple benefits for education. It can serve as a new way for young people to view and value the natural world. Nature is not only something to learn about in biology class, nature is also a source of wisdom we can learn from.

Biomimicry can serve as a compelling way to present STE(A)M subjects to students. Humans have been attempting to use nature’s wisdom for a long time. Today, we continue in this habit and teachers can take advantage of this by engaging their students in biology through active-learning activities. They can also use examples in biomimicry that address science, technology, engineering and mathematics themes all at once.

Furthermore, biomimicry can be used to create an interdisciplinary platform that connects students to one another and the natural world outside of the traditional classroom.

Biomimicry enhances the creativity and problem-solving skills of students through designing and other project-based activities. Robert Fisher studied how thinking skills can influence learning. He researched ways to help students develop critical, creative and imaginative states of mind. By improving their thinking skills, he believed that students can make more sense of their learning. Using biomimicry in learning touches this topic, because it teaches students to think critically about why certain patterns such as spots or lines occur in nature. The research of Mahgoud & Alawad (2014) shows that teaching biomimicry has long-lasting effects which include the development of skills such as self-reflection and critical and creative thinking. It also shows that biomimicry can positively impact students’ design decisions and thinking skills.

Lastly, biomimicry could be used to create a better learning environment in the classroom itself. One of the essential elements of biomimicry is to (re)connect with nature. Most classrooms do not allow a lot of natural sunlight to enter the room, while it has been shown that natural sunlight can increase the learning productivity of students. Using nature as an example, a classroom can be redesigned allowing more natural sunlight to enter the room.

Preparation for the 21st Century

Students need to be prepared for challenges and opportunities of the future. Society has undergone an immense transformation over the last decades with ever faster changing technology and economy. Students need to be prepared to adapt to these movements in the 21st century, for which a set of skills are needed for success as proposed by educators, business leaders, academics, and governmental agencies. These skills are called the 21st century skills:

Learning and innovation skills:
  - Creativity
  - Innovation
  - Communication & Collaboration
  - Problem Solving
  - Critical Thinking
- Digital literacy skills:
  - Information literacy
  - Media literacy
  - Information and communication technologies (ICT)
- Career and life skills:
  - Flexibility and adaptability
  - Self-regulation
  - Social and cultural interaction
  - Productivity

These skills differ from academic skills as they are not primarily based on acquiring knowledge directly, but more about the process of acquiring this knowledge. They can also be referred to as “soft skills” or “applied skills”.

Two well-known models are the P21 and the Four Cs models, which are explained in the figures below.

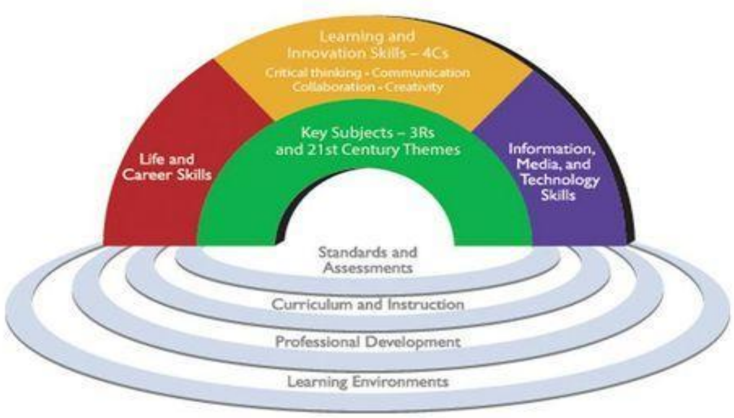


Figure 4: The P21 Model describing how 21st century skills are organized ("C. 21st Century Skills" by actionhero is licensed under CC BY-NC-SA 2.0)

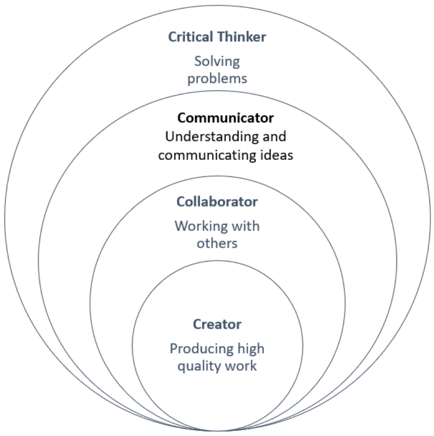


Figure 5: The Four Cs model describing how 21st century skills are organized

Biomimicry offers great potential for students to develop these soft skills.

Interdisciplinarity

Project-based learning is a proven multi-disciplinary approach. Interdisciplinarity is best defined as when distinctive components come from two or more different disciplines. It is argued that the biggest obstacle of the implementation of interdisciplinarity is that most participants in interdisciplinary ventures are educated in traditional single disciplines. They have not learned to think in other ways than their discipline prescribes. Because interdisciplinary thinking is said to increase one's ability of critical thinking, communication, creativity, and pedagogy, it is critical to educate students with interdisciplinary approaches early on. Biomimicry contributes to an interdisciplinary approach, as it provides open questions with multiple views and aspects to be investigated without those being predefined beforehand.

STE(A)M education

Biomimicry is an approach to innovation that seeks sustainable solutions to human challenges by emulating nature's time-tested patterns and strategies. Due to its interdisciplinary character, knowledge from many different disciplines such as nature and biology, (bio-)technology, engineering and mathematics can be combined. This is why biomimicry can be a valuable method to use when teaching STEM (Science, Technology, Engineering and Mathematics) or STEAM (adding Arts) education. This statement fits well with the BioLearn project, as this project focuses on providing teaching materials and training on the topic of biomimicry for STE(A)M educators across the European Union. By viewing biomimicry as a method through which learning in several school subjects can take place, a wide range of possibilities opens up for the implication of biomimicry in education.

In order to connect with the school system, the use of innovative pedagogical approaches is crucial. This is a challenge for teachers and developers of educational materials. By using methodologies that make science learning more meaningful to students, we can gain a large improvement of the learning process in STE(A)M education.

It is important to prepare students to become the innovators, educators, researchers, and leaders of tomorrow, and in order to do this they need (basic) knowledge on all STE(A)M disciplines. The goal of STE(A)M education is to ensure that all students have the possibility to study and be inspired by Science, Technology, Engineering (and Arts) and Mathematics so they will have the possibility to reach their full potential.

Tackling some of the world's greatest challenges necessitates cross-disciplinary thinking; biomimicry offers this.

- An art teacher exploring shading has students find something living or once-living around the schoolyard to sketch, focus in on a detail of it, and sketch it at different times of day.
- A teacher exploring scientific methods has students observe natural phenomena outside the classroom over a period of time, preparing questions about features students notice about nature and what functions these features might serve (e.g. *Why do squirrels have big, bushy tails? Why are tree branches often crooked? What purpose do our toes serve?).* Students then choose one question about which to design an experiment and test a hypothesis about a feature's possible functionality.
- A physics class learning about atomic interactions reads research papers about how geckos can climb smooth surfaces (even upside down!) applying Van der Waals forces.
- Students exploring climate change solutions in an afterschool chemistry club make carbon-negative cement out of car exhaust fumes, based on the chemical process corals use to build their stony reefs.
- Students in a maker lab create prototypes of car tailpipes that remove outgoing pollutants, whose design is based on the students' research into how marine sponges filter food out of seawater, (due to electrostatic attraction), and other biological strategies for filtering.
- A teacher exploring material science and structural engineering concepts of stress and strain has students examine a tree in the schoolyard for clues as to how it withstands the passing breeze, despite its massive canopy.
- A teacher exploring mathematical concepts of volume and mass has students look up from their desks, textbooks, and chalk/white/smart boards, and look out the window or go outside to determine how to weigh a cloud passing over the school.

This optimism about what's possible through nature-inspired learning, and what students aspire to be and do with their lives, is one of the most important benefits. Without hopefulness and ambition, what can humankind really achieve? And yet students too frequently feel disempowered in their education, the very antithesis of why we educate our young in the first place.

To date, STE(A)M education has focused mainly on the physical sciences: physics and chemistry. It is said that these subjects have a more direct link to mathematics and engineering than biology. However, with biomimicry we can easily link biology to these disciplines and see how many technological advances stem from investigations of biological systems. A few examples of how biology has inspired technology can be seen in *Table 2*.

Technological application	**Source in nature**
Swimsuit materials	Dermal denticles of shark skin
Inexpensive solar cells	Light capture and transfer processes in leaf chloroplasts
Velcro fasteners	Hitchhiking seed (bur) design
Bioactive coronary stents	Internal artery wall function
Dry adhesive applications	Gecko foot hairs
Walking robots	Kinematic configurations of a stick insect

*Table 2***:** Different examples of how biology has inspired technology

Biomimicry as a learning methodology

The principles of biomimicry correlate closely to those of inquiry-based science learning and design-based learning (Pedaste et al., 2015). These are teaching methods that stimulate students to actively investigate and discover the world around them. The curiosity that students naturally have plays a key role in these methods.

The biomimicry design spiral (BDS) (see figure 6) developed by Carl Hastrich provides teachers and students with handles to start designing a solution to solve a given challenge. The BDS is often used as a method for problem solving and designing.

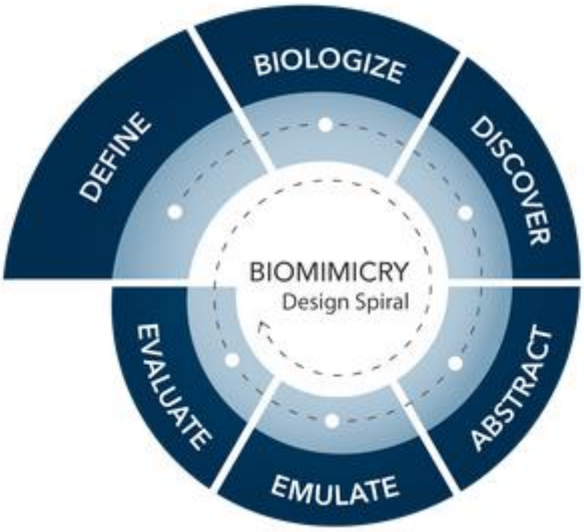


Figure 6: Biomimicry Design Spiral (Biomimicry Institute)

There is a reason this tool is shaped in the form of a spiral. The spiral geometry can be found everywhere in nature. Even though we refer to many processes in nature as cycles, they are in a sense all spirals in time, the endpoint is usually not the same as the starting point. Rossin (2010) notes that the design spiral with its associated 'feedback loops' is more functional as a problem solving tool than its linear contemporaries "because [it] is a reiterative process, after it resolves one challenge and evaluates how it compares to Life's Principles, most likely another problem appears, and the process begins again" (Rossin, 2010: p.562).

Going through the different steps in the BDS ultimately ends up with a design or solution. However, comparing the steps found in the BDS with steps found in inquiry-based science education (IBSE), there are a quite a few similarities based on the 5-E model (see https://bscs.org/bscs-5e-instructional-model/).

Define the challenge and biologize the question

In Figure 7 you see the steps taken in BDS, as well as the steps taken in the IBSE. Both methods start off with defining the context/challenge/problem. In IBSE this is described as engaging, whereby teachers elicit students current understanding of the topic and situate the context in a meaningful real-world problem. In the BDS this is the define step. This is followed by biologizing the problem where a traditional inquiry question is translated into a form nature can answer. Biologizing has a specific meaning within biomimicry, referring to the need to reframe inquiry questions into biological terms (see https://toolbox.biomimicry.org/methods/biologize/). The learner needs to translate a human problem into a form nature can answer. For example, rather than asking 'how would nature design a bicycle helmet?' we ask 'how does nature absorb impact?' With this question in mind, we can explore different strategies found within nature to absorb impact from, for example, buffalo skulls, tortoise shells or the beak of a woodpecker.

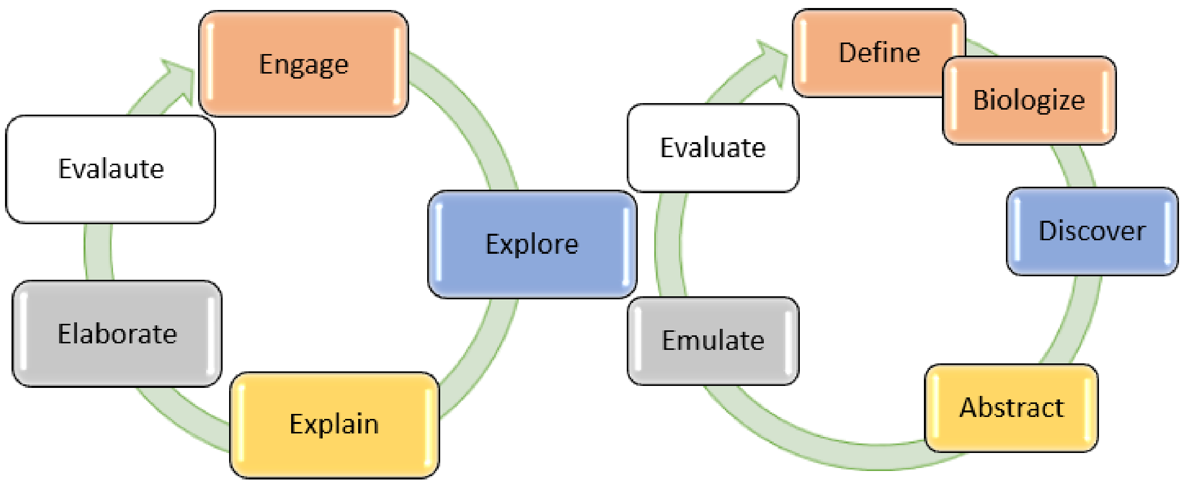


Figure 7: 5-stage IBSE and biomimicry spiral compared (Dawson & Groeneweg, 2020)

Discover / explore
The next phase present in both methods is discovering/exploring. In case of working with the BDS this means finding organisms or ecosystems that have evolved strategies to solve the required functions. In IBSE exploring is a broader term, as students can use a wide range of sources to find the functions they need to solve their challenge. However, the act of discovering and researching itself is an important aspect in the learning process as it teaches the students multiple skills.

Abstract
The BDS diverges at the abstract stage. This phase is important in biomimicry when professionals from different fields work together, as the biologists must be able to describe the natural models so that designers can work with them. In this case, analogical thinking comes to the fore, as students abstract useful examples from the discover phase. In IBSE this is encompassed in the explore stage and continues into the explain phase. In IBSE this step is just as important, as it teaches students to recognize useful solutions and take the information that is most important away from them into their design.

Emulate/elaborate
In the BDS, emulating is the phase where the designing takes place. Biomimicry practitioners hone in on the best ideas abstracted from the discovery and abstract phases and develop a design concept. In IBSE, this is the elaborate phase. In biomimicry, emulating means more than developing your design, as you take nature with you as a model and mentor in every step of design. Biomimicry considers aspects of scale, and whether you can go beyond emulating form to also emulating process and ecosystem (Baumeister, 2014).

Reflect/evaluate
Lastly, in biomimicry the evaluate phase uses the nine biomimicry principles as a reference. This is to ensure nature has been used as a model and mentor in every step of your designing process. Questions are asked such as: could I be more energy efficient? Could I use more biological materials that are already available? Based on answers to these questions, adjustment and redesign (parts of) the design takes place. In IBSE the evaluate phase holds the same activities, taking another look at what the initial design intended and could certain aspects be further improved. However, what lacks in IBSE in this phase, as in most of the other phases, is consciously taking nature as a model and mentor in every step you take whilst designing. This includes the ethos; is the design solution useful, will it improve conditions for life?

While biomimicry is often used primarily as a design method, because of its resemblance in steps with learning methodologies such as IBSE, it can very well be used as a learning method. The most important steps in IBSE are also present in the Biomimicry Design Spiral, and for that reason this method can be used to ultimately achieve the same improvement in the learning process IBSE has. When biomimicry is used as a learning method, it could even add aspects to the learning process that IBSE do not hold. Biomimicry teaches students the value of nature for us as humans, but also the value of nature in itself. As today's students are the leaders of the future, it is important to help them see and experience the beauty of nature, and create gratitude and an ardent desire to protect the genius that surrounds us. On top of improving the learning process itself, biomimicry can teach students to create products, processes and policies that are well-adapted to life on earth over the long term. The eventual aim is, therefore, to create an attitude in students that will motivate them to preserve nature on the planet.

4. Practical approaches

How to apply biomimicry in the School Curriculum?

From a pedagogical point of view, biomimicry offers plenty of rich and engaging approaches to learning. The notion of examining and asking questions to nature in order to address a challenge offers opportunities for problem or project based learning. Furthermore, the invitation to get hands-on with nature, explore concepts in-situ and use the senses to consider where answers might exist creates opportunities to take learning outside, through experiential activity. Much of the activity on offer within the BioLearn materials can be adapted to different settings, to suit a variety of pedagogies and learner needs.

Furthermore, project-based approaches create opportunities for STE(A)M clubs, collaborative challenges. Many of the activities on offer in our materials can be deployed as extension tasks or explored through different subject specialism.

The arts offer multiple inroads for exploration of nature's toolkit in line with global challenges. In particular, design technology presents clear potential for building competencies for thinking like nature, and using biomimicry principles to solve design challenges. Students learn about how design has been inspired by the natural world in the past, and apply the same thinking to their own design challenge. Further opportunities exist in the arts to refine and shape their creation through reflection and review. Pedagogically the arts provide an experiential connection with the materials used, and an opportunity to experience and observe the natural world, not as extra-curricular content, but to better understand materials and their use.

Tools

The biomimicry approach includes several tools that could be used when educating through biomimicry. A few examples are AskNature, the Biomimicry Design Spiral (see above) and the Biomimicry Design Challenge.

AskNature

Finding natural models can be quite a challenge for students and professionals in the field of biomimicry. There are so many examples of functions and solutions in nature, that it might be difficult to know where to start searching. Luckily, the Biomimicry Institute developed AskNature, an online platform that holds information on over 2000 different natural phenomena. Here, professionals and students working with biomimicry can search for natural models based on their function.

This tool could be used by teachers to help students use nature as a source of inspiration for problem solving. When teachers integrate biomimicry in the curriculum as a method for problem solving, students will need to look into nature for solutions to the problem they are trying to solve. AskNature gives them a good starting point in their quest for natural models that could help them design their solution.

https://asknature.org/

Biomimicry Global Design Challenge

The Biomimicry Global Design Challenge (BGDC) is an annual competition that invites students and professionals to address critical sustainability issues with nature-inspired solutions and is open to students and professionals anywhere in the world. The BGDC could be used by teachers to motivate their students by shaping the project as a BGDC assignment. For example, when several groups of students are working on a project using biomimicry as a method, the best design could selected and apply to participate in the BGDC. This could be an extra motivation for the students, as the result of winning this challenge is the possibility to develop your solution further.

https://challenge.biomimicry.org/

Making use of these ideas in your teaching

Finding ways to integrate biomimicry into your teaching can be achieved by considering the needs of the topic. For the BioLearn project we have created resources which we believe teachers are able to use as part of their delivery of the curriculum and specification. Starting with the topic enables the biomimicry approach and its associated thinking to act as a complementary enhancement to student's subject knowledge and learning approaches.

As it lends itself so well to project-based learning, many of the resources produced by BioLearn create further opportunities for enhancing learning and study skills. Offering students independent and team-based learning approaches can be effective ways of bringing biomimicry into the classroom.

While the resources included here are designed to be adapted and developed by educators, we also want teachers to be able to adapt and develop them further. Each resource is intended to be picked up and trialled, but we feel that a few considerations might help prospective biomimicry educators before working with our resources:

Team based or individual work

What are the parameters of the work – will students be working alone or encouraged to work in groups? Further, will there be project based or challenge/problem-based learning involved? If so, how will this be orchestrated and arranged in the learning environment? What resources will you need? Biomimicry enables students to exercise their problem-solving and creative brains, so thinking about how you can facilitate this will be important for some of the modules.

Starting point – introduction or building knowledge?

Think about where you and your students are currently at in terms of knowledge and comfort in biomimicry and its application to teaching and learning. If you are just dipping your toe in, choose one of the introductory modules to work through together, or even a couple of stand-alone activities. If you are feeling more confident, there are plenty of subject linked modules which might be more appropriate or come up with your own mix.

Cross-subject links

Biomimicry education refuses to be put into a neat box, but we have an education system which defines itself by subjects and topics. Teaching with a biomimicry approach will create tensions as the learning will take new directions and offer plenty of occasions for thinking across topics and subjects. This might feel problematic in a school-based setting where topics need to be covered in detail ready for assessment and before the next topic begins. It is worth considering how you will react when learning takes new tangents, perhaps thinking about parking questions and ideas on the board, or speaking with other subject teachers to consider a cross-curricula approach might be appropriate in your school.

Implementation and reflection

Developing and delivering a lesson with biomimicry will likely be a challenge (as it is new) to both educator and students. Reflecting on sessions is a really good way to turn challenges into learning. Nature does not create perfection but perfection is in the process of creating, learning as a natural design process with wrong turns and challenges along the way. Finding ways to reflect and learn from mistakes, whether it is a team-based challenge which did not work due to conflict, or a product design which failed; finding ways to look critically and thoughtfully at what happened will enable improvements, refinements and growth. Building in this time might be something worth considering, perhaps each lesson or at the end of the module.

Adaptation of resources

While our resources are designed to be used directly alongside, or as part of a scheme of work, it is likely teachers will want to adapt the activities to suit their own students. This may be based on prior understanding or other contextual factors.

All activities are designed to fit broadly within a defined age group / study stage, but depending on whether students are at the start or later on their learning journey though the scheme of work, some adaptations may be necessary. We have tried to enable as much flexibility as possible.

Some factors to consider when adapting these resources to suit your group are:

Group size

Will students need to work alone, or as part of a group? Will individual work then feed into group or whole class discussion? Each of these require ways of working and study skills which the students may or may not already feel familiar with. When planning the lessons, ensure the chosen approach will be right for your group. If group work is not the norm for the group, then begin with paired work and build up to working as a team. Dividing up tasks clearly within the group can help. Individuals may need help when working on their own also.

Background knowledge and interests

Paying attention to the backgrounds and interests of the students is essential for biomimicry education to be successful. Can tasks and challenges be adapted to suit individuals' interests and prior knowledge? Can local issues and problems be woven in? Perhaps the school grounds can provide some inspiration and challenges for the students. Creating a 'real world' learning environment is important for biomimicry because it thrives on the direct application of learning.

Skillsets and ability

Biomimicry can be a challenging, yet rewarding, topic to teach and learn. Being responsive to the needs of learners will be essential, ensuring students are not left behind or feeling frustrated by the content. Begin with what feels accessible and build up from there. Not all modules may be appropriate for all situations, and feel free to adapt, and include some aspects while leaving out others to suit a range of skillsets and abilities.

5. Key skills to biomimicry

Each discipline has its own terms and jargon. You will come across these when accessing our material. We created a glossary for your reference. Down below we offer a more detailed explanation. See also in Glossary of https://biolearn.eu/.

Function

In biomimicry a function refers to an organism's adaptation which helps it survive and thrive. For example, the purpose of bear fur is to keep warm, in technical terms its function is to conserve heat (insulation). Often, 'designs' in nature have more than function. 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.'

When using biomimicry thinking, you need to decide what you want your design to do, so you can search nature for an organism which carries out a similar function. For example, if you want to create a more efficient air conditioner, asking a biologist for advice would not help you much. But if you would ask, 'how does nature cool (or manage temperature)' he/she can find many organisms with interesting strategies for cooling/ managing temperature. It is about what you want your design to DO, instead of what you want your design to BE.

With this in mind, you can start searching nature to find organisms or ecosystems that deliver similar functions that you can learn from and translate the mechanisms into your own designs.

A great way to learn more about functions is to go 'hunting' for them in nature. See the Function Hunt activity in BioLearn module Water Water Everywhere.

Examples of functions:

Inspiration from nature	*function*
Tree bark	Protect
Termites	Regulate temperature
Polar bear fur	Insulate
Namib beetle	Harvest water
Ants	Find route
Lotus	Clean surface
Ivy	Generate energy
Humpback whales	Reduce drag
Banana peel	Protect, inform about ripeness

Table 3: Examples of functions

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.'

To use biomimicry thinking, you need to ask yourself how is nature providing the function I am interested in. It might be a simple case of mimicking the same shape, as in the famous example of the bullet train and the kingfisher. But often you will need to mimic a process from nature so you can design something which, for example, decomposes after use back to base elements.

Inspiration from nature	*Function*	*Strategy*
Tree bark	Protect	Bark protects from drying out and from attack by fungal infection, insects and birds. Bark is formed and expands as the tree grows; it also reacts and grows around areas which have been attacked.
Termites	Regulate temperature	Termites build thin tunnels at the edge of their mound. These warmup during the day and as the heat rises to escape it draws cooler air down through the central column of the mound. The process reverses at night.
Polar bear fur	Insulate	
Namib beetle	Harvest water	Hydrophilic and hydrophobic bumps and grooves on the black surface (which radiates at night) of the Namib Beetle allow water to condense from moist air.
Ants	Find route	When ants search food they communicate through pheromones. When they find food they lay down a 'positive' trail which is reinforced by other ants. The ants work randomly at first, but as quicker (less distance) routes emerge they coalesce around the fastest route.
Lotus	Clean	Lotus leaves stay clean without detergents. The plants 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.
Ivy	Generate energy	Ivy grows vertically to avoid competing for sunlight and nutrients with ground plants.
Humpback whales	Reduce drag	The tubercles (bumps) on the flippers of humpback whales allow them to 'grip' water and turn tightly when catching food
Banana peel	Protect, inform about ripeness	When the peel of the banana is green, it is not yet ripe to be eaten. When the skin has become brown, the banana is also not eatable anymore.

Table 4: Function and strategy

Thus, identifying <u>function</u> and <u>strategy</u> are very important biomimicry skills.

Analogical thinking

The final key skill is analogical thinking, in other words seeing where a solution to one problem can be applied to solving a similar problem. This can be difficult as abstract thinking is required. You will, however, find plenty of good examples in the BioLearn resources as well as a few in the table below; cut them up and see if your students can link them together to practice their analogical thinking skills.

Challenge	**Useful strategy/function in nature**	**Nature function/strategy applied to human challenge**	**What is the analogy between them?**
How does nature keep cool?	Bark protects from drying out and from attack by fungal infection, insects and	Use multiple layers in building facades to	This is an example of the form of tree bark being mimicked in

	birds. Bark is formed and expands as the tree grows; it also reacts and grows around areas which have been attacked.	reflect solar heat and aid cooling	creating a building façade.
How does nature regulate temperature?	Termites build thin tunnels at the edge of their mound. These warm up during the day and as the heat rises to escape it draws cooler air down through the central column of the mound. The process reverses at night.	The Eastgate Centre in Harare mimics this process. Warm winds pass through the porous concrete walls of the centre, cooling them before they enter the interior of the centre.	This is an example of the process developed by termites being applied in a building design.
How does nature protect against predators?	Octopus changes its colour and can adapt to colour of its environment	Clothing in the army has a fixed camouflage colour. If that would be adaptable to its environment it would work better	This is an example of the form of octopus pigment cells being mimicked in creating clothes
How does nature keep itself clean?	Lotus leaves stay clean without detergents. The plants 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 being mimicked in self-cleaning panes of glass.	This is an example of the form of lotus leaves being mimicked in self cleaning glass

Table 5: Analogical thinking

6. Introducing BioLearn modules

We encourage trainers to give a short overview of each BioLearn module. According to previous experiences, the best way of learning is trying out some of the activities. We suggest for this reason the activities below. After choosing the modules, open the original descriptions for details. The numbers refer to the number of the activities within the modules.

Overview of BioLearn modules:

<u>Introduction modules</u>
Principle modules

- Nine Principles of Biomimicry
- 9 modules about the 9 principles

Marvellous Models
Introducing Biomimicry
Big Biomimicry Challenge

<u>Other modules</u>
Packaging
Water Water Everywhere... But not a Drop to Drink
The Natural Economy
Buildings
Healthy by Nature
Plant Protection Inspired by Nature
Water Management in a City Park
Cooperative Problem Solving through Natural Design
Adaptation to Climate Change

Introduction modules

Principle modules

- <u>Nine principles of Biomimicry</u>
  This module provides an introduction to the 9 principles of biomimicry. These principles are the basis for biomimicry thinking, which is important in all the modules.
  - *1. Explanation of the 9 principles*
    Presentation (ppt) with 1-1 slides of the principles and explanations to them.

- <u>P1: Nature Runs on Sunlight</u>
  This module is about energy. Most of the energy used in nature comes from the sun through photosynthesis. Students play with the process of photosynthesis in two different ways in activities 2 and 3.

- <u>P2: Nature Uses Only the Energy It Needs</u>
  Nature doesn't waste energy. How can we notice this in nature? In the module students explore how nature uses energy.
  - *Activity 2. Searching for energy forms*
    Searching for examples of energy usage in nature by the help of "energy cards".

- P3: Nature Fits Form to Function
  Nature is a skilful designer. Each form created fits to deliver a specific function, and in addition nature can be beautiful. In this module students investigate how nature fits form to function.
  - *Activity 2. Recognising forms and functions*
    Exploring the function of natural and artificial objects: students work in pairs; blindfolded member of the pair observes the object with all senses but sight and its function.

- P4: Nature recycles everything
  What can we learn from the way nature recycles? In natural systems like a forest, there is no waste. Everything that has come to the end of its life cycle becomes raw materials for something else. In the activities of the module students will observe how nature deals with waste.

- P5: Nature Rewards Cooperation
  We tend to think that nature is based mostly on competition. If we look closer, it is clear that cooperation is more rewarding. In this module students practice cooperation and consider which is better: cooperation or competition?
  - *Activity 2. Playing an oak forest*
    Students become members of an oak forest and search for interconnections by using a string of wool.

- P6: Nature Banks on Diversity
  Diversity is very important in nature, it helps create stable ecosystems. In this module students experience what happens when there is not enough diversity. We suggest Principle 5 and 6 are delivered in order.
  - *Activity 2. Playing a black locust forest*
    Students become members of a black locust forest and search for interconnections – same game as in P5, just the "species" are different: we will have much less interactions and more vulnerable community.

- P7: Nature Demands Local Expertise
  Organisms need to adapt to different circumstances: to local habitat, weather, soil, available food, etc. Nature also uses local materials to build. In this module students explore how the beaks of birds are adapted to local circumstances and available food.
  - *Activity 2. Playing beaks*
    Trying to pick up a range of objects with different kinds of tweezers – mimicking the food and beaks of the birds.

OR

- P8: Nature Seeks Balance
  Nature is a fine-tuned system; everything is carefully regulated. In this module students explore how deer live in-tune with their habitat.
  - *Activity 2. Playing deer and natural resources game*
    Students become deer and mimic how they meet their needs.

OR

- P9: Nature Taps the Power of Limits
  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 natural limits.
  - *Activity 2. Harvest game*

Groups of students try to live from the same lake with a limited number of fish. The goal is to do it sustainably.

Marvellous models

Learning from nature to address a challenge or opportunity starts with asking the question ''how does nature manage a similar challenge?" This introductory module focuses on the basic skills that are needed to be able to learn from nature.

- *Activity 3. Observation in nature*
  Students go outside to observe and investigate nature and writing down characteristics of a species by the help of various questions.

- *Activity 6. Poster presentation*
  Teams present their poster made about their chosen species (marvellous model) to each other.

Introducing Biomimicry

This module introduces students to biomimicry through different activities. It can be alternatively used for introducing biomimicry instead of Marvellous Models or in preparation for the 'Big Biomimicry Challenge' module.

- *Activity 3. Learning from Nature*
  In this activity students make pairs of nature examples and technologies that imitate nature.

- *Activity 6. What can we learn from a seed?*
  Students examine a maple seed and try to figure out its features and functions.

Big Biomimicry Challenge

This module takes students through the process of nature-inspired design, and a structured design task, 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 teamwork and presentation competencies in students.

- *Activity* 1. Choose a project
  Students choose a challenge connected to one of the Sustainable Development Goals and gather ideas from nature how to solve it.

- *Activity* 3. How would nature...?
  Connected to Activity 1 students look for concrete examples from nature for solution.

Other modules

Packaging

Like our food and many other products, every organism is packaged. Our skin, the armour of a crab, the peel of a banana, the shell of an oyster, the bark of a coconut, a pineapple (seed pack) and every cell in our body has its own packaging.

How can nature's different ways of packaging help us design solutions to our own packaging challenges?

- *Activity 2. Biologize your question!*

Students develop biologized questions: they identify one or more functions of packaging and write question to find solutions in nature.

Water Water Everywhere… But Not a Drop to Drink

In this module students explore how nature has a range of different abilities we can learn from. Students use the abilities of nature to inspire ways to address the challenge of plastic bottle pollution. By the end of the module, students will have created their own solutions to the challenge of plastic bottle pollution.

- *Activity 1. So... how does nature work?*
Students understand how nature works as a sustainable system: they search for different functions in nature.

The Natural Economy

In the natural world, all materials are made using resources found locally; organisms do this at room temperature and pressure. Once materials are done with, they biodegrade back to their base elements. Humans do things differently. They dig up minerals, use high temperatures and pressures to turn them into useful materials. These are often thrown away after use and cannot easily be reused. We could say that nature produces materials using a circular economy, whereas humans have a linear economy. This module explores how we can learn from nature to produce the materials we need sustainably.

- *Activity 1. Grown to be Grown Again (if you have time)*
  Students use mycelium to grow a product by the help of Grown bio Grow it yourself kit.

- *Activity 3. If Nature is the Solution, What is the Problem?*
  Students interrogate a short video to understand why change is necessary. They use De Bono Thinking Hats methods to encourage thinking about an issue with a specific focus.

Buildings

Shelter, warmth and protection (and many others) are all functions humans use buildings for. In this module, students search for similar functions in nature and investigate how to use this knowledge during planning a building.

- *Activity 1. Shelters in nature*
  Students search for functions of shelters in nature.

- *Activity 3. Let's build… a nest! (if you have time)*
  Students make some research among nests, then build one

Water Management in a City Park

In this module, students will work with the challenges around water. By doing research themselves, they come up with solutions to different challenges. They do this on the basis of a case: the students make a design for a new city park.

- *Activity 2. Mind maps*
  The goal is to let students identify the problem by coming up with research questions in their case. They create a mindmap that serves as an overview of the questions and what to investigate.

STE(A)M links of BioLearn modules

As we wrote in details about it, biomimicry can be used very well in STE(A)M education. The table below shows some particular topics of STE(A)M subject where BioLearn modules can be successfully implemented.

STE(A)M Topics	Biomimicry Examples	BioLearn Module Links
Adaptation, Variation and Classification **(Bio)**	Finding natural solutions to problems and challenges faced by human society can be as straightforward as looking to how nature has adapted to its environment. Structural and behavioural adaptations can be mimicked in human designs – for example looking at the ingenious ways that desert-living creatures can maintain habitable temperatures by living underground, or building self-cooling structures.	- Nine Principles of Biomimicry - Modules about 9 principles (particularly 3, 6, and 7) - Marvellous Models - Big Biomimicry Challenge - Water Management in a City Park
Biodiversity and Ecosystems **(Bio)**	At an ecosystem level, nature teachers us much about how to organise society and live as part of an interconnected web of life. This offers learning opportunities which go beyond simply looking at one organism – and instead prompts us to consider what it might mean to live in community and to occupy specialist niches without jeopardising the living system we rely on.	- Nine Principles of Biomimicry - Modules about 9 principles (particularly 5-9) - Marvellous Models - Big Biomimicry Challenge - Packaging - The Natural Economy
Cycles and Nutrients (**Bio);** Lifecycle and Recycling **(E/DT)**	The cycles which underpin life on earth; whether carbon, nutrient or water are fundamental to the balancing of giving and taking which is in continuous motion across all ecosystems. This topic once again makes us aware of the large, interconnected whole we are a part of on this planet. Offering much in the way of sustainability thinking, considering the ways in which nutrients are cycled and reused in an ecosystem presents opportunities to learn about circular economies, and new ways of thinking about commerce.	- Nine Principles of Biomimicry - Modules about 9 principles (particularly 2 and 4) - Marvellous Models - Big Biomimicry Challenge - Packaging - Water Water Everywhere - The Natural Economy - Buildings - Water Management in a City Park
Photosynthesis **(Bio);** Energy Sources **(E/DT)**	Energy and its uses is the centrepiece of life – and for much life on earth that energy comes from the sun. Understanding photosynthesis is a key piece of science which has allowed us to consider the function of food chains and population pyramids – but so too it has enabled humans to vision the possibility of producing clean abundant energy.	- Nine Principles of Biomimicry - Modules about 9 principles (particularly 1 and 2) - Big Biomimicry Challenge - Water Water Everywhere - The Natural Economy
Materials, Forces and Properties **(DT/Phys/E)**	Nature is versatile, and it rarely produces waste. The materials deployed and produced by processes and organisms are honed over millennia and are fit for purpose. Looking at how nature produces flexible,	- Nine Principles of Biomimicry

	hard, strong and light materials which enable the most incredible functions and offer inroads to thinking about overcoming the biggest design challenges. Looking at how Geckos stick to smooth surfaces has resulted in engineers creating new adhesives which work on structure rather than solvents; looking at bee's use of hexagons for storing honey in a hive has opened our eyes to strong and efficient use of materials for building.	- Modules about 9 principles (particularly 4) - Marvellous Models - Big Biomimicry Challenge - Packaging - Water Water Everywhere - Buildings - Water Management in a City Park
Biochemistry / Organic chemistry	- Nature makes use of a cocktail of minerals, elements and compounds – - Products from oil - What can we learn from the way nature organises chemicals – can we find better ways of making products and compounds which dont harm people and planet. - Nature stores data (DNA) – cell organisation/ cell processes - Materials used in personal life – chemicals	- Nine Principles of Biomimicry - Modules about 9 principles (particularly 1, 2 and 4) - Big Biomimicry Challenge - Packaging - Water Water Everywhere
Maths	- Look at Sams website – - Nature has found efficient ways of doing things. - Ratios/ use of materials / strength. - Shapes	- Nine Principles of Biomimicry - Modules about 9 principles (particularly 2, 8 and 9) - Marvellous Models - Big Biomimicry Challenge - Water Management in a City Park

Table 6: STE(A)M topics and BioLearn modules

7. Setting up a teacher training workshop

We offer some options for organising a teacher training event. In the tables below you can see a half day, a one-day and a three-day long version. We suggest a mixture of online and face to face training in the case of the half and the one-day long events and face to face training if you have three days with teachers.

The time (in minutes) are written for the face to face parts. For trying out the activities we suggest to use the face to face part, as for most of the activities a group is necessary.

The “online” parts mean that the materials should be sent to participants to read prior to the training. These materials can be a link or a pdf about the topic.

If the situation does not allow for a face to face meeting, you can choose a digital platform (e.g. zoom, skype etc.) for the training. In this case you should pick the activities from modules carefully, because most of the games in small groups/alone will not work!

Lesson plan

	0,5 day (4 hours – net about 210 min.)	**1 day** (8 hours – net about 360 min.)	**3 days** (3x8 hours – net about 1080 min.)
1. Introduction	Short introduction: name and workplace of participants	*"Search for somebody, who ..."* (a game for getting to know each other) [1]	*"Search for somebody, who ..."* (a game for getting to know each other) [1] Tree with bringing and taking away [2]
2. About sustainability	reading online material at home	reading online material at home	ppt + conversation
3. BioLearn introduction	15 min. version of ppt	30 min. version of ppt	30 min. version of ppt + practise
4. Biomimicry	reading online material at home	reading online material at home	ppt + practise
5. STE(A)M Education	reading online material at home	reading online material at home	ppt + practise (e.g. conversation in small groups)
6. Key skills	reading online material at home	reading online material at home	ppt + 90' practise (e.g. NL module – Marvellous models)
7. Modules trying out/explaining	*Introduction modules* – choose 2 of them *Other modules* – choose 4 of them	*Introduction modules* – choose 3 of them *Other modules* – choose 6-7 of them	*Introduction modules* – choose 4 of them *Other modules* – choose 7-8 of them
8. Closing	short verbal feedback	short verbal feedback	longer verbal feedback/discussion review of the tree of introduction
9. Evaluation	filling out evaluation form	filling out evaluation form	filling out evaluation form

Table 7: Lesson plan for different length of teacher trainings

[1]: Introduction game: We write as many attributes as there are participants on a sheet of paper. The participants must find a person for each attribute. The attributes can be related to the training, e.g. heard about biomimicry, knows a business using biomimicry, but can also be very simple/common, like goes to work by bike.

[2]: We make a drawing with a tree (branches and root must be seen) on a big (A2) sheet. The participants get 2 post-it notes each. On one of the post-its they write what kind of experience they bring to the training (e.g. teaching science or taking the kids to excursions); on the other post-it they write what they want to take away from the training (e.g. new ideas, knowledge about biomimicry). The participants read their notes one by one out loud and we stick the experiences to the root of the tree and the taking away purposes to the crown of it. At the end of the training we check if the take away requests were fulfilled or not.

BioLearn – Evaluation of Teacher Training

Thank you for taking part in the BioLearn project and participation at BioLearn teacher training.

To ensure we improve the BioLearn teacher training in the future, please complete the survey below. It is really helpful for us when you provide a comment with each of your answers. Your feedback will be treated as confidential and your name will not be used in public reports. However, we appreciate you providing your name and contact details at the end of the survey so we can follow-up on any comments you have made.

Many thanks in advance.

1. BioLearn teacher training was useful and inspiring.

STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE

Please comment on your answer

2. BioLearn teacher training made me familiar with the toolkit methodology as well as various online resources that could be used when educating using biomimicry.

STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE

Please comment on your answer

3. BioLearn teacher training helped me deepen my understanding of the following biomimicry key skills:

a) Asking questions

Not at all								Very much	
1	2	3	4	5	6	7	8	9	10

b) Identifying functions and patterns in nature

Not at all								Very much	
1	2	3	4	5	6	7	8	9	10

c) Ability to apply natural solutions to human challenges

Not at all								Very much	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

4. BioLearn teacher training included hands-on activities that I can use with the students.

STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE

Please comment on your answer

5. BioLearn teacher training helped me understand how biomimicry can fit into the school curriculum.

STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE

Which subjects have been included? *Please list.*

6. BioLearn teacher training included demonstrations of activities from at least one module.

YES / NO

Name of the tested module:

Name one activity that you found useful for your students:

7. BioLearn teacher training helped me feel confident to implement biomimicry in my teaching

Not at all								Very much	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

Please comment on your answer

8. BioLearn teacher training was well organized.

STRONGLY AGREE	AGREE	NEITHER AGREE NOR DISAGREE	DISAGREE	STRONGLY DISAGREE

Please comment on your answer

Contact Details

We will follow up with some teachers completing the survey. Please provide your contact details if you are happy for us to contact you to talk further about the BioLearn teaching resources. Your contact details will remain confidential.

Name:
School:
Position:
Email:
Phone:

8. References

Benyus, J. (1997): Biomimicry: Innovation Inspired by Nature. Morrow, New York

Alawad, A. A (2014): The Impact of Field Trips on Students' Creative Thinking and Practices In Arts Education. Journal of American Science 10(1):46-50