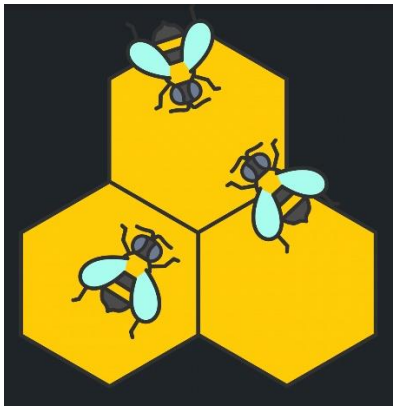
INTELLECTUAL OUTPUT 2

FINAL REPORT

NATURAL ENTREPRENEURS FRAMEWORK

AND LEARNING APPROACHES



Developed in the project
Natural Entrepreneurs

co-funded by the Erasmus+ Programme of the European Union.

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of the European Union

Contents

1. PART ONE – the pedagogical approach

Biomimicry has been defined as 'learning from and then emulating natural forms, processes and ecosystems to create more sustainable designs' (Baumeister, 2014). It might be unfamiliar to many, but has been inspiring designers and engineers for many years.

Natural Entrepreneurs is a European funded project encouraging students aged 15-18 years to use biomimicry as a research and design tool. It offers an opportunity to explore how biomimicry can tackle the sustainability challenges facing Europe today and presents the applications of biomimicry design as desirable and viable solutions. It encourages students to work collaboratively across Europe and instils a greater sense that Europe can successfully transition to a sustainable future.

Biomimicry offers great scope for STEM teaching. The process of biomimicry design integrates science, design and engineering. Biology and physics can be used, for example, to explore how different organisms create colour through structure rather than dyes, design is then used to consider how natural strategies can be translated to a human design solution – perhaps cars with vibrant colours which never fade and are free from chemical pollutants, and engineering to pattern new surfaces onto steel. This approach encourages inter-disciplinary collaboration and teamwork.

The attraction for young people is that they are truly involved in future developments by coming up with realistic designs and lobbying stakeholders like city planners, engineering departments of universities and companies. They learn how to work with their peers at a European level and how to collaborate with different people to develop and promote their designs.
The Natural Entrepreneurs pedagogical framework address the interrelationship between science, entrepreneurship and digital competences using the biomimicry design and is grounded in the UN Sustainable Development Goals.

1.1. The Biomimicry Design Process

Natural Entrepreneurs offers a biomimicry design process which consists from four phases – define, discover, create, communicate – with guiding activities and collaboration tasks in each phase; these are detailed in the NatEnt platform (www.natent.eu).

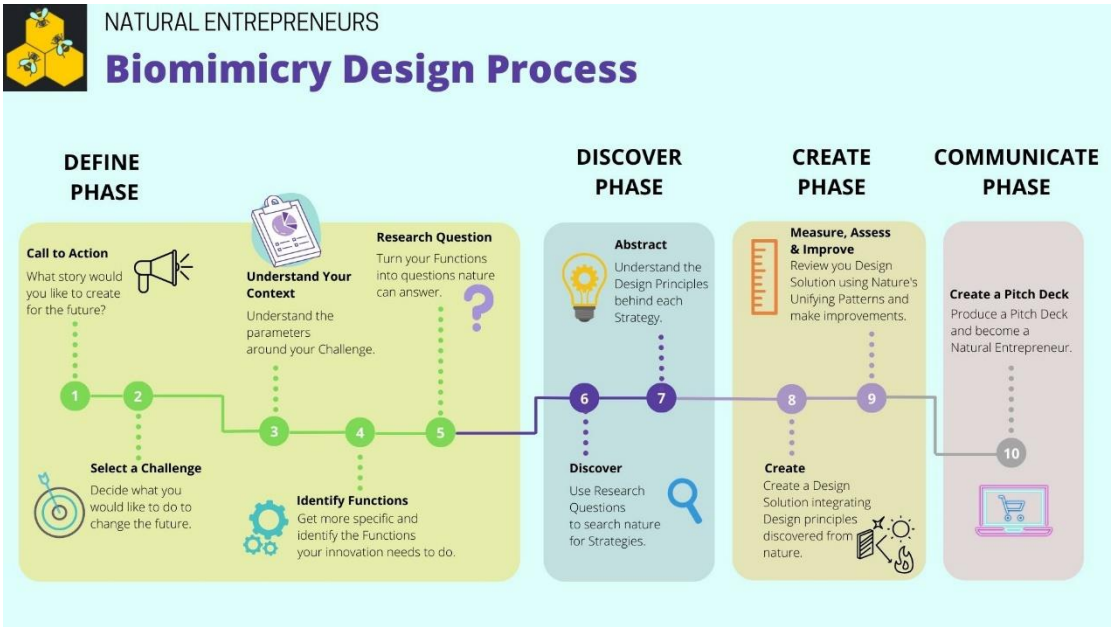


Figure 1: Natural Entrepreneurs Biomimicry Design Process

Natural Entrepreneurs provides an online platform which guides student teams through the Biomimicry Design Process (see figure 1). At each step, notes explain what needs to be done and results are entered online. Teams can see how their work builds progressively towards their design solution. Importantly, they can see the work of other teams and learn from each other collaboratively. A Collaboration Points system 'measures' their level of collaboration, sharing and their progress. In this way, teamwork is encouraged, and sharing of ideas is celebrated in the design process.

1.2. Key Guiding Pedagogy and Approaches

The framework integrates a number of key ideas which support inquiry-based learning, solutions-based design and sustainable development.

1.2.1. **Double Diamond Design model** – the double diamond is a commonly used model within design thinking, and underpins most design processes. The NatEnt model integrated the double diamond. The critical difference likes in how research is centred on inspiration from nature, and translating natural functions into human design principles.

1.2.2. **TPACK (Technological Pedagogical Content Knowledge)** – NatEnt weaves together inquiry-based learning through online and classroom-based tasks. TPACK provides the framework to understand how the online platform can be best used to support content and process knowledge learning, so that the platform enhances the learning experience rather than distracting from it.

1.2.3. **Sustainable Development Goals** – each challenge on the NatEnt platform clearly relates to one of the SDGs, with the SDGs also used to introduce learners to the concept and need for sustainable development.

1.2.4. **Outdoor Learning** – with the Discover Phase of the framework, learners are encouraged to learn directly from the natural world in their locality, to research

organisms which are successful and explore how successful strategies in nature can be adapted into human design. This element strongly reinforces the (re)connect element of biomimicry, so that learners come to a clearer understanding of how they are a part of nature.

1.2.5. **Inquiry-based learning** – the whole NatEnt framework is based on an inquiry approach. At all stages learners are led to carry out their own research and reflect on how this can be used within their challenge. Additionally, learners are encouraged to enquire into the work of other teams on the platform, and ask how they can usefully use the work of others to enhance their own.

1.2.6. **STEM** – NatEnt is best delivered as part of a cross-curricular programme. The sciences (biology, physics, chemistry) play a vital role in understanding how nature works. Design & Technology contributes to the process of turning ideas into viable solutions, supported by appropriate science. And business and entrepreneurship support turning ideas into potential opportunities for implementation.

2. PART TWO – influencing ideas and learning approaches

Part One offered a brief overview of the key influences behind the NatEnt framework. The detailed review in Part Two be of interest to educators and researchers wishing to understand how NatEnt supports learners and replicate this in similar projects.

2.1. UN Sustainable Development Goals

The Sustainable Development Goals (SDGs) were agreed in 2015 by the international community as part of the UN 2030 Agenda for Sustainable Development. Through the goals, countries collectively pledged to eradicate poverty, find sustainable and inclusive development solutions, ensure everyone's human rights, and ensure sure that no one is left behind by 2030.

17 SDGs have been defined, with 169 associated targets, to be reached by 2030. They address the global challenges the world faces and tackle all dimensions of sustainable development in a balanced and integrated manner.

Figure 2: UN Sustainable Development Goals

The Natural Entrepreneurs project focuses on six goals. These provide a focal point for students to locate their challenges within the context of sustainable development, and for schools to locate Natural Entrepreneurs within the UN goals which are now commonly referred to within school learning.

Although the NatEnt platform only currently focuses on six of the UK goals, it can be extended to include challenges relating to all 17 of the goals.

2.2. The European Green Deal

The European Green Deal[1] is an EU strategy to implement the United Nation's 2030 Agenda and the Sustainable Development Goals.

This strategy aims to transform the EU into a fair and prosperous society with a modern, resource-efficient and competitive economy where the EU is carbon neutral by 2050. This transition must be just and inclusive. Since it will bring substantial change, active public participation and confidence in the transition are paramount if policies are to work and be accepted.

Everyone is involved - citizens in all their diversity, national, regional, local authorities, civil society and industry working closely with the EU's institutions and consultative bodies.

To deliver the European Green Deal, there is a need to re-think policies for clean energy supply across the economy, industry, production and consumption, large-scale infrastructure, transport, food and agriculture, construction, taxation and social benefits. To achieve these aims, it is essential to increase the value given to protecting and restoring natural ecosystems, the sustainable use of resources, and improving human health. The EU should also promote and invest in the necessary digital transformation and tools as these are essential enablers of the changes.

EU policies to achieve the goal in the picture below.

Figure 3: The European Green Deal

Biomimicry is a powerful approach to reach these ambiguous EU goals by involving students to redesign their future based on the strategies used by natural organisms. Challenges posed to students on the NatEnt platform by cover all important aspects of European Green Deal.

2.3. Biomimicry

[1] https://ec.europa.eu/clima/policies/eu-climate-action_en

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 abundant diversity of nature offers humanity a wealth of knowledge to address the greatest challenges of our time, if only we choose to look. Janine Benyus first used the term biomimicry in her book 'Biomimicry: Innovation Inspired by Nature' (1997). From the Greek words 'bios' meaning life, and 'mimesis' meaning to imitate, biomimicry is using knowledge from nature as inspiration for sustainable design.

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

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

- 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: seeking sustainable solutions by understanding principles, patterns, strategies and functions from nature.

Biomimicry design provides the context to where, how, what and why biomimicry fits into the process of any discipline or any scale of design. Biomimicry design is a framework that is intended to help people practise biomimicry while designing anything. There are four areas in which a biomimicry 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 design. One can either start from biology or a (technical or social) challenge. The (biology to design starts with an organism, ecosystem or natural phenomenon. For example, 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 challenge to biology route starts 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.

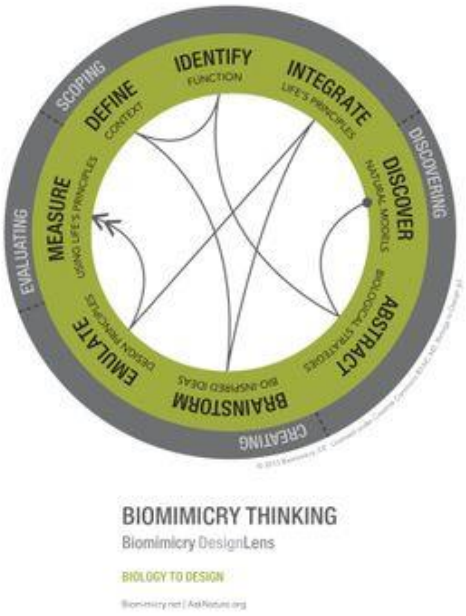
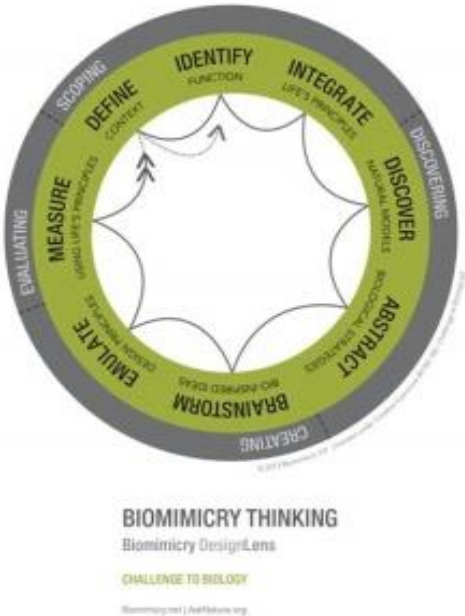
Biology to Design	Challenge to Biology
	
Take a look at a tree. What features can you discover, and what could we learn from this tree or trees in general?	Climate change presents a huge challenge, and it might be interesting to get some inspiration from nature on how to address that.
How come that it feels cooler under the trees than a mile away at the road?	Reducing CO_2 emissions in air traffic/aeroplanes.
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, lightweight).
Create flat water reservoirs on the rooftop of tall buildings that fill up during rain time and start evaporating at a specific temperature.	Creating aeroplane wings from lightweight materials in combination with a structure /shape that uses the principle of uplifting

Figure 4: Two approaches to biomimicry[2]

In the Natural Entrepreneurs project, we start with a challenge students want to solve and all challenges are connected with Sustainable Development Goals.

2.3.1. Nature Unifying patterns (NUP)

Nature's unifying patterns[3] attempt to identify the 10 most essential lessons from the natural world that should be considered part of a design process. They are called nature's

[2] 2013 Biomimicry 3.8 Licensed under Creative Commons BY-SA Biomimicry Thinking g2
[3] https://toolbox.biomimicry.org/core-concepts/natures-unifying-patterns/

unifying patterns because examples of the patterns can be found broadly across the majority of life on Earth.

They are:

1. Nature uses only the energy it needs and relies on freely available energy.
2. Nature recycles all materials.
3. Nature is resilient to disturbances.
4. Nature tends to optimise rather than maximise.
5. Nature provides mutual benefits.
6. Nature runs on information.
7. Nature uses chemistry and materials that are safe for living beings.
8. Nature builds using abundant resources, incorporating rare resources only sparingly.
9. Nature is locally attuned and responsive.
10. Nature uses shape to determine functionality.

Natural Entrepreneurs uses the NUPs as a way to measure the success of a design solution. Students are encouraged to reflect on each of the NUPs and how they are integrated into their design solution: which are present, can they be strengthened, will incorporating other NUPs strengthen their design solution?

2.4. Key Knowledge and Competences

The project is a synergy between nature and economy (not mutually exclusive opponents as some perceive them). In the Natural Entrepreneurs vision, entrepreneurs are working together/collaborating with nature rather than using it. Developing biomimicry ideas give students a possibility to apply acquired knowledge in real-life scenarios.

STEM subjects offer the basic knowledge and competences to be used in biomimicry. For example, biology teaches us about how nutrients cycle in woodland and can help us see how technical nutrients can cycle in product design. Chemistry shows us how nature creates infinite shapes and forms using simple formulas which degrade back into harmless elements. Physics demonstrates how forces can be harnessed to reduce energy use. Finally, technology can use the science of nature to build new products, processes and systems which mirror nature. Biomimicry gives the tools to change the world for the better, and entrepreneurship teaches us how to do it in our socioeconomic reality.

Competence in science [4]refers to the ability and willingness to explain the natural world by using the body of knowledge and methodology employed, including observation and experimentation, to identify questions and draw evidence-based conclusions. Competences in technology and engineering are applications of that knowledge and methodology in response to perceived human wants or needs. Competence in science, technology and engineering involves an understanding of the changes caused by human activity and responsibility as an individual citizen.

For science, technology and engineering, essential knowledge comprises the basic principles of the natural world, fundamental scientific concepts, theories, principles and methods, technology and technological products and processes, as well as an understanding of the

[4] Key competences for lifelong learning — a European reference framework: https://op.europa.eu/en/publication-detail/-/publication/297a33c8-a1f3-11e9-9d01-01aa75ed71a1/language-en

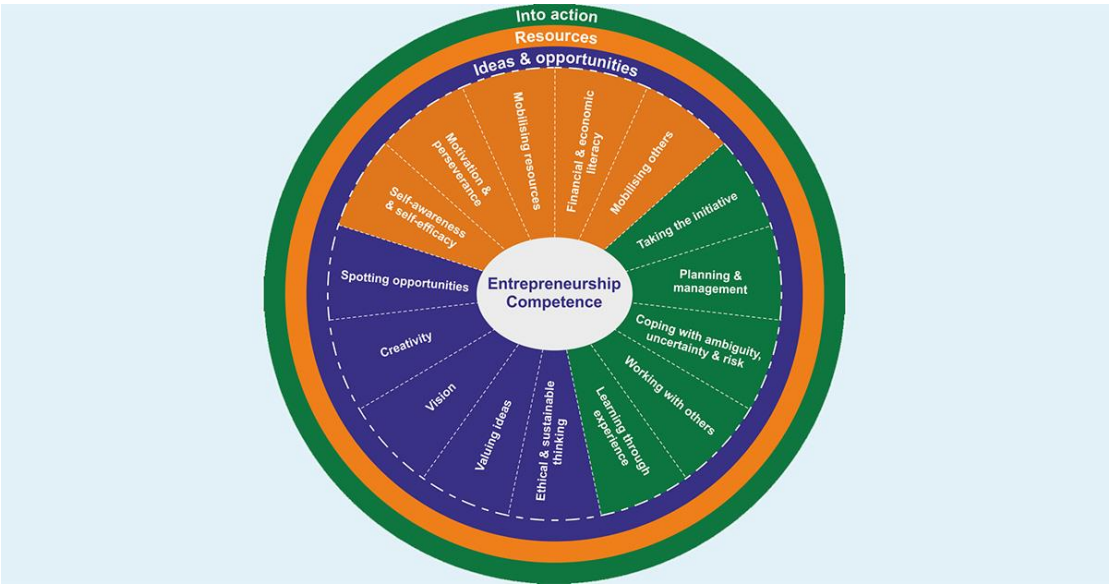
impact of science, technology, engineering and human activity in general on the natural world. These competences should enable individuals to understand better the advances, limitations and risks of scientific theories, applications and technology in societies at large (concerning decision-making, values, moral questions, culture, etc.).

Skills include understanding science as a process for the investigation through specific methodologies, including observations and controlled experiments, the ability to use logical and rational thought to verify a hypothesis and the readiness to discard one's convictions when they contradict new experimental findings. It includes the ability to use and handle technological tools and machines, and scientific data to achieve a goal or reach an evidence-based decision or conclusion. Individuals should also be able to recognise the essential features of scientific inquiry and have the ability to communicate the conclusions and reasoning that led to them.

Entrepreneurship competence [5]refers to the capacity to act upon opportunities and ideas and to transform them into values for others. It is founded upon creativity, critical thinking and problem solving, taking the initiative and perseverance, and working collaboratively to plan and manage projects of cultural, social or financial value.

EU Entrepreneurial Competence Framework defines entrepreneurship as a transversal competence, which applies to all spheres of life: from nurturing personal development to actively participating in society to (re)entering the job market as an employee or as a self-employed person, and also to starting up ventures (cultural, social or commercial). It builds upon a broad definition of entrepreneurship that hinges on creating cultural, social or economic value. It thus embraces different types of entrepreneurship, including intrapreneurship, social entrepreneurship, green entrepreneurship and digital entrepreneurship.

The Entrepreneurial Competence Framework is made up of three competence areas and 15 competences, as illustrated in the figure below. All these competences are relevant to the Natural Entrepreneurs project and address through the biomimicry design process.



[5] https://op.europa.eu/en/publication-detail/-/publication/297a33c8-a1f3-11e9-9d01-01aa75ed71a1/language-en

Figure 5: The European Entrepreneurship Competence Framework[6]

Biomimicry competences are specific competences which are developed through the Natural Entrepreneurs programme. The key competences are:

- Students can identify functional design in nature, develop greater awareness and appreciation for design excellence in nature, and appreciate how nature works as a system that is elegant and deeply interconnected.
- Students can identify essential needs and opportunities that can be addressed through design innovation for products, processes and systems.
- Students can assess the consequences of applying biomimicry solutions.
- Students can abstract principles of sustainability from the way the natural world functions.
- Students can use analogical creativity to innovate, using biological models to inspire solutions to design challenges.

There is wide range of science, entrepreneurial and design competences required in the partner countries national educational curriculums. Those which are connected to the biomimicry design process can be found in the annex.

2.5. The Learning Approach

Biomimicry takes us on a journey to discover the principles which makes nature a model of 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. It empowers students to apply their new competences to create with real solutions that work. Biomimicry is a uniquely valuable pedagogical teaching practice because of its dramatic potential to engage students' interests and generate excitement (Stier, 2021), and for its ability to cut through the dogma attached to sustainability debates towards a practical sustainability in action.

Inquiry based learning is an approach to learning that emphasizes the student's role in the learning process. Students are encouraged to explore the material, ask questions, and share ideas. Inquiry-based learning uses different approaches to learning, including small-group discussion and guided learning. Instead of memorizing facts and material, students learn by doing. This allows them to build knowledge through exploration, experience, and discussion. From a student point-of-view, inquiry-based learning focuses on investigating an open question or problem. They must use evidence-based reasoning and creative problem-solving to reach a conclusion, which they must defend or present.

From a teacher point-of-view, inquiry-based teaching focuses on moving students beyond general curiosity into the realms of critical thinking and understanding. Teachers encourage students to ask questions and support them through the investigation process, understanding when to begin and how to structure an inquiry activity.

Design-based learning (DBL) is an inquiry-based form of learning that is based on integration of design thinking and the design process into the classroom. Design-based learning environments can be found across many disciplines, including those traditionally associated

[6] Bacigalupo, M., Kampylis, P., Punie, Y., Van den Brande, G. (2016). EntreComp: The Entrepreneur-ship Competence Framework. Luxembourg: Publication Office of the European Union; EUR 27939 EN; doi:10.2791/593884

with design (e.g. art, architecture, engineering, interior design, graphic design), as well as others not normally considered to be design-related (science, technology, business, humanities).[3][4] DBL, as well as project-based learning and problem-based learning, is used to teach 21st century skills such as communication and collaboration and foster deeper learning.[5]

Natural Entrepreneurs learning is based on an adapted design-based learning pedagogy.

Outdoor learning is an excellent organisational form for learning from nature and applying it in various biomimicry design cycle stages, but mostly in the discover phase.

Outdoor learning[7] is a broad term that includes discovery, experimentation, learning about and connecting to the natural world, and engaging in environmental and adventure activities. Outdoor learning involves the transformation of knowledge, skills, attitudes and behaviours through direct engagement with the outdoor environment for the personal and social benefit of individuals, families, society and the planet. Purposeful experiences in the outdoors can be a catalyst for powerful and memorable learning.

Research shows that people benefit from outdoor learning in all areas of life. In addition, outdoor learning provides a highly effective way of addressing some of society's key challenges:

- At a global level: fostering a connection that leads to respect and care for the natural world, an appreciation of biodiversity and sustainability, and pro-environmental behaviours (see Re-connect in Biomimicry).
- At the societal level: developing a sense of place leading to greater engagement with the community and an appreciation of the opportunities available to live, learn and work in the local area.
- At the interpersonal level: providing a safe and supportive setting to enhance social skills, appreciate and value difference. Encouraging loving and meaningful relationships across generations that foster tolerance, respect and kindness.
- At the intrapersonal level: engagement with nature and the environment for health, wellbeing and nature connection, leading to lifelong participation and outdoor competence. Developing character, resilience, positive risk-taking.
- All forms of outdoor learning value direct experience, is active learning in the outdoors (out of school building), happens in the natural environments where participants can see, hear, touch and smell the real thing.

2.6. The Teacher's Role

In order to guide students through the biomimicry learning journey teachers need to develop some specific competences.

TPACK (technology-pedagogical-content knowledge)[8] The TPACK framework was introduced by Punya Mishra and Matthew J. Koehler of Michigan State University in 2006. With it, they identified three primary forms of knowledge teachers, educators and

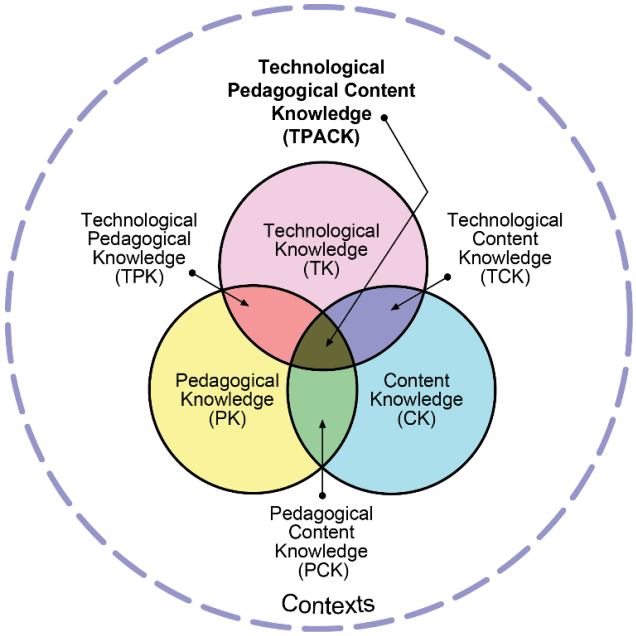
[7] https://www.outdoor-learning.org/Good-Practice/Research-Resources/About-Outdoor-Learning
[8] Acknowledgement: much of this work is adapted from Daniela Conti (CREDA onlus) and the Change the Story project.

curriculum experts need to develop for successful edtech integration: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK).

The key points of the TPACK framework to have in mind:

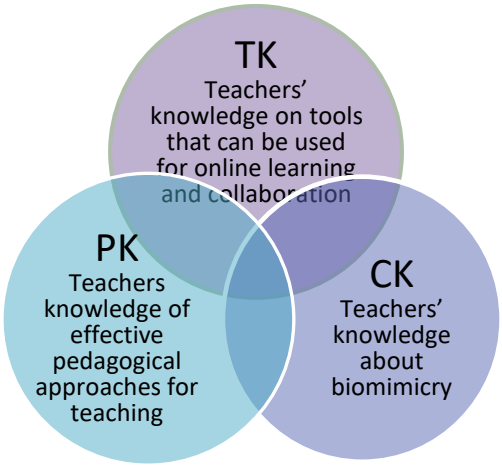
1. The three primary forms of knowledge are not entirely separate. In fact, the intersections of each are critical because they represent deeper levels of understanding of how to teach.

2. The center of the diagram, otherwise known as TPACK, represents a full understanding of how to teach with technology, suggesting that this is not the same as having knowledge of each of the three primary concepts individually. Instead, the point of TPACK is to understand how to use technology to teach concepts in a way that enhances student learning experiences.



3. It implies that the thoughtful pedagogical uses of technology require the development of a complex form of knowledge which cannot be the sum of some knowledge of content, or of pedagogy and of some nice digital tools we may like to use.

Effective technology integration for pedagogy around specific subject matter requires developing sensitivity to the dynamic relationship between these components of knowledge situated in unique contexts.



Individual teachers, grade-level, school-specific factors, demographics, culture, and other factors ensure that every situation is unique, and no single combination of content, technology, and pedagogy will apply for every teacher, every course, or every view of teaching.

Working with TPACK

STEP 1: The 3 Knowledges - My competences and starting contexts

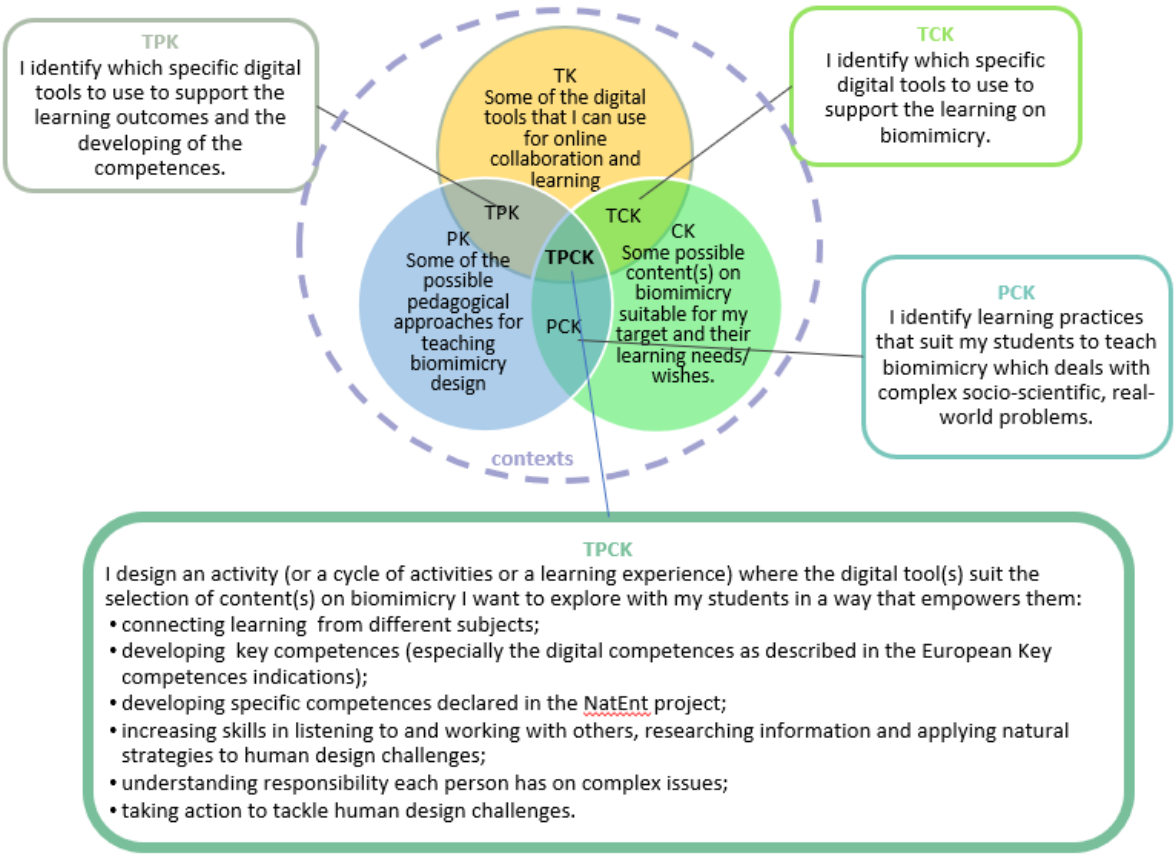
Natural Entrepreneurs encourages collaboration using online tools to develop and share biomimicry design solutions. It also encourages learning to take place both online and through face-to-face teaching.

In doing this, it is important to be aware of both teacher and student competence in relation to the content, the pedagogical approaches teachers already experience in similar contexts, the kind of (digital) tools they are used to work with, what they may need to understand better within the project dimensions and to establish what they wish to develop.

STEP 2: Planning: looking for intersections – I develop new knowledge while planning

After the analysis of what are the resources and needs in terms of knowledge and context, teachers can move to understand how to work with Natural Entrepreneurs learning.
This means to work with this framework at a different level, using it to help to identify specific contents, digital tools and pedagogical approaches (for a learning unit or a single activity) that works in the intersections.

This framework allows to assist the designing from any of the 3 different areas. It encourages to look for and progress with the elements of content, pedagogy, technology and context that suits and makes the difference together. The lens to look through the intersection are the specification and characteristic of the Natural Entrepreneurs project.



Further reading: http://tpack.org/

Annexes – curricula review from partner countries

These are available from the Teachers Section of the Natural Entrepreneurs website.

www.natent.eu/en/for-teachers