Biomimicry Design for Sustainability Skills in VET

KA220-VET-00620D4B

KA220-VET - Cooperation Partnerships in Vocational Education and Training

WP3 Training modules on biomimicry process design

D3.1 Self-regulated learning kit

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Document Info	
Project reference	2023-1-EL01-KA220-VET-000158477
Deliverable	D.3.1 Self-regulated learning kit
Dissemination level	Public
Date	12.05.2025
Document version	4
Status	Final
Sharing	CC-BY-NC-ND
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1. Introduction

Humans have long looked to nature for inspiration and developed functional, environmentally friendly solutions. Biomimicry has emerged as a design philosophy in recent years and has been established as a viable approach that inspires creative minds and drives human innovation. Biomimicry designs are constructed with consideration for both sustainability goals and cost-effective solutions. These designs utilise plants, animals, and nature-inspired forms to tackle challenges we face as individuals and societies, solving complex human problems. Equipping students with the skill sets that would enable them to draw on natural organisms and processes to fuel innovation effectively has become a priority in education.

The LET’S MIMIC Project invests in developing skills that would enable future generations to create sustainable designs that mimic nature’s efficient use of resources, reduce waste, and lower environmental impact.

The LET’S MIMIC Self-Regulated Learning (SRL) Kit aims to promote sustainability Skills through Biomimicry Process Design through educational challenges, solutions and case studies for building sustainability skills. VET learners will work collaboratively on the LET’S MIMIC platform and/or by themselves to apply the steps of the Biomimicry design methodology.

The challenges, solutions, and case studies are based on real-life problems and require the application of 21st-century skills such as problem-solving, critical and analytical thinking, and creative thinking, as well as the use of ICT and multi-disciplinary approaches to STEM subjects. The solutions, by nature, were chosen to reflect the level of VET learners' age and knowledge.

The document includes the following sections:

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- **Chapter 1** provides an overview of this deliverable's role within the project workflow and the approach taken.
- **Chapter 2** describes the project's SRL approach and the benefits and challenges of modelling the self-regulated patterns on the Let’s Mimic platform.
- **Chapter 3** details the examples of challenges and solutions inspired by nature that have been documented within the project and will comprise the SRL and other learning processes during the piloting. It also presents examples of biomimicry case studies identified and validated as a basis for inquiry-based learning.
- **Chapter 4** documents the assessment of the SRL processes modelled on the Let’s Mimic platform.
- **Chapter 5** synthesises the main conclusions of the SRL Kit documentation phase.

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2. The Let's Mimic Self-Regulated Learning Kit

From a biomimicry perspective, the adoption of SRL practices forms the backbone for constructing key habits and skills that support adolescents, the primary target group of the Let's Mimic Project, in adopting and applying the biomimicry methodology. The approach resonates with building and consolidating complex problem-framing and problem-solving skills.

2.1 The Self-Regulated Learning educational approach

The evolution of the teacher-controlled learning environment towards the inclusion of more self-directed online education has highlighted the need for learners of all ages to develop self-regulated learning skills, such as goal setting, self-monitoring, self-assessment, strategic planning, self-motivation, time management, self-reflection, resource management, adaptability and metacognition.

SRL environments aim to model instinctive, unforced learning patterns by encouraging learners to take responsibility for their learning, take initiative, diagnose their learning needs, formulate their learning goals, identify resources to support a suitable learning process, apply appropriate learning strategies, and evaluate the learning outcomes. Learners can plan their learning and progress at their own pace. Such environments capitalise on the learner's curiosity and construct valuable habits that nurture lifelong learning processes. Self-regulation has a more profound significance in adolescence, as it concerns the capacity to select and pursue personally meaningful aims and societally valued goals.

Self-regulated theories have explored different dimensions of impact, and regarding the Let's Mimic target group, have examined, for example, how SRL integrates with

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other key aspects and activities of adolescent life [1], such as homework, leisure time physical activity, and reflecting on purpose in life. Moreover, as highlighted by [2], adolescence presents new challenges for the maturation of self-regulation processes, as a broader range of cognitive, emotional, and social experiences emerges, along with increased social and societal demands and opportunities.

Three main components define the self-regulation process [3]:

- **Goal setting**, where an individual defines objectives and plans how to achieve them.
- **Monitoring** for discrepancies between goals and current states.
- **Implementing** behaviour consistent with goals to reduce the behaviour-goal discrepancy.

Self-regulated learning activities form a cyclical process. Students learn to plan a task or a succession of tasks, monitor their performance, and assess the outcome they have obtained. These steps repeat, and students learn to reflect, adjust, prepare for the following process, and start a new task. The SRL process is not one-size-fits-all; it must be tailored to individual purposes, needs, and specific learning tasks [4, 5].

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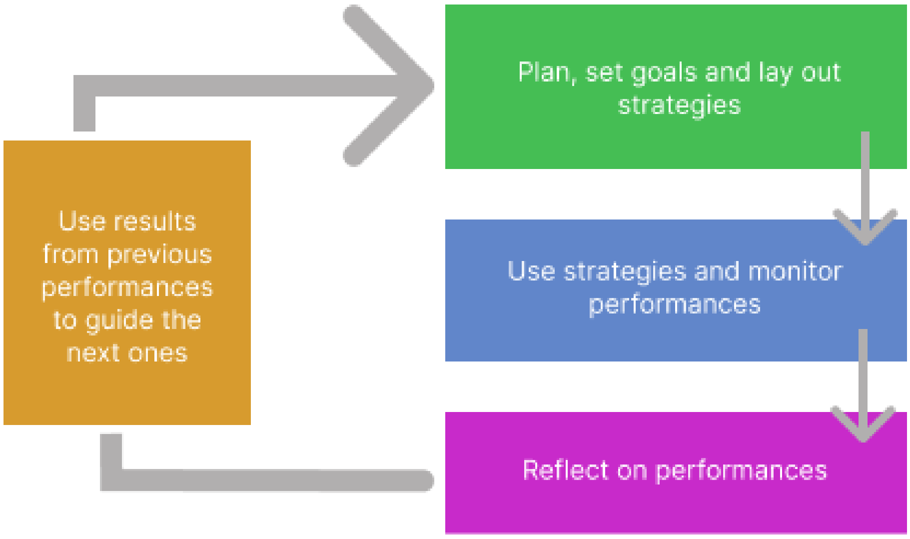

Figure 1. The cycle of Self-Regulated Learning [5]

Technology is increasingly used to guide, assist, and enhance self-regulated learning processes [6]. It can explore diverse facets of self-regulation, such as goal setting, planning, monitoring, metacognitive knowledge, attention, and emotion control [7].

Highly relevant to the Let's Mimic Project, we are considering how digital tools can provide direct access to personal learning analytics and how such tools can enhance learners' capability to understand and take action based on the feedback they have received, thereby supporting student agency and long-term behavioural change better [8] and providing a basis for enhanced personalised support [9].

The successful adoption of digital learning tools largely depends on their ability to contribute to learners' satisfaction and support their motivation. Motivation is the driving force behind maintaining meaningful and active engagement in the learning process and behind self-regulation practices [10].

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2.2 Benefits and challenges of Self-Regulated Learning

Self-regulated learning (SRL) offers numerous benefits but comes with challenges, identified and addressed in the learning content design phase and the Let's Mimic Platform.

2.2.1 Key benefits of Self-Regulated Learning (SRL)

1. Improved academic performance.

- Learners who practice SRL tend to achieve higher academic success due to better planning, monitoring, and reflection on their learning processes. These learners take responsibility for their learning and tend to be more mature towards their goals.
- SRL encourages students to set personal objectives and take ownership of their learning, which can increase intrinsic motivation and engagement.

2. Better time management.

- By being responsible for defining their goals and planning their study schedules, learners can manage their time more effectively, balancing academic and personal responsibilities more efficiently.

3. Increased autonomy.

- SRL fosters independence, allowing learners to become more self-sufficient and less reliant on external guidance.

4. Improved metacognitive skills.

- Learners develop better metacognitive skills, such as self-assessment and self-reflection, crucial for achieving efficiency during lifelong learning activities.

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To be implemented effectively, SRL initiatives and assisting tools need to consider key components that shape and guide the learning process:

- **Goal setting:** Students learn to set specific, achievable goals for their learning tasks.
- **Self-monitoring:** Students can regularly check their progress and adjust their strategies.
- **Self-assessment:** The learning paths incorporate activities requiring students to evaluate their understanding and performance.
- **Strategic planning:** Students develop habits in forming and applying effective learning strategies tailored to their individual needs.
- **Time management:** Students create schedules and prioritise tasks to manage their time efficiently.
- **Reflection:** Students learn to reflect on their learning experiences and outcomes to identify areas for improvement
- **Use of technology:** The learning process integrates tools and applications that support Self-Regulated Learning (SRL), such as planners, reminders, and educational platforms.

Self-regulated learning is crucial because it facilitates effective learning and personal growth. It can empower students to improve their academic performance by promoting self-reflection. Through this self-assessment and resource management, it is hoped that students can develop a more refined understanding of how to tackle learning tasks and improve their study techniques. To be clear, it is not simply about better grades, it is about the fact that this approach can also positively influence a student’s mental well-being, allowing them to feel more in control of their performance and experience less stress, especially during exams.

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2.2.2 Key challenges in SRL adoption and implementation

1. Lack of motivation.

- Some learners may struggle with maintaining motivation, especially if they do not see immediate results or find the subject matter uninteresting. SRL activities must incorporate enough variety and stimuli to pique curiosity, motivate learners and balance their long-term involvement.

2. Difficulty in self-assessment.

- Accurately assessing one's understanding and progress can be challenging, leading to either overconfidence or underestimation of abilities. SRL assessment must be designed to indicate progress and opportunities for improvement.

3. Time management issues.

- Despite the potential for better time management, some learners may find it challenging to commit to their schedules and manage their time effectively, especially for long-term activities.

4. Distractions.

- In blended or online learning environments, learners may face numerous distractions from social media and other online activities, hindering their focus and productivity.

5. Strong self-discipline.

- SRL requires a high level of self-discipline and commitment, which not all learners may possess or be able to develop easily. Collaborative learning forms a good environment that can stimulate consistent habits.

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6. Limited support.

- Without adequate support from teachers or peers, learners may struggle to implement SRL strategies effectively, especially in the early stages. Building the right environment to stimulate efficient SRL is crucial for achieving success.

By understanding these benefits and challenges, educators and learners can collaborate to create supportive environments that enhance the effectiveness of SRL. It is also essential to consider that SRL planning must be long-term for consistent results.

2.2 Let's Mimic SRL Kit

Self-regulated learning (SRL) fosters learner autonomy and lifelong learning skills. The Let's Mimic Project explored and conceptualised self-regulation processes to enable environmental behaviour change. The kit aims to support the understanding, adoption, and application of the steps of the biomimicry framework.

The Let's Mimic Self-Regulated Learning Kit is designed to help learners take control of their educational journey by supporting key activities such as planning, monitoring, and reflection on learning achievements. The SRL Kit is implemented on the Let's Mimic Platform, and it is supported through features such as:

1. Goal-setting options.

- **Planners, calendars, goal-setting components:** The platform provides access to an online calendar to help students set and track their academic and personal goals. Learners can use the platform calendar to define short-term and long-term goals.

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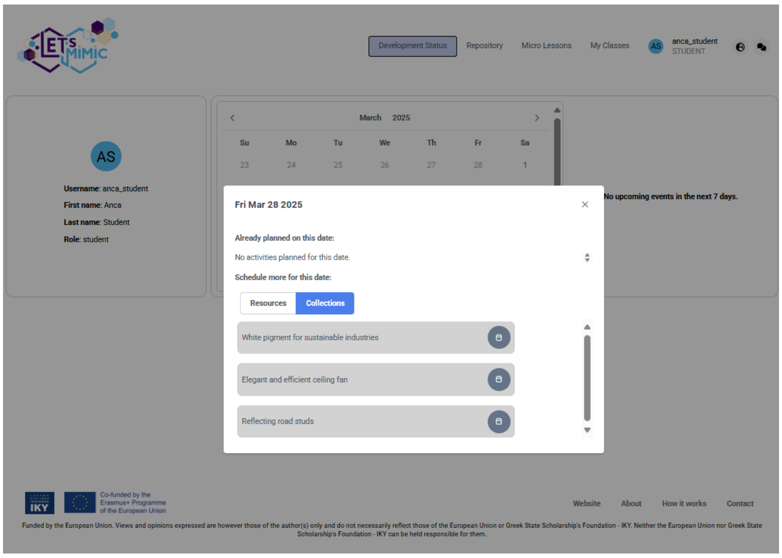

Figure 2. Let's Mimic Platform - planner

2. Monitoring tools.

- **Checklists:** Learners can use checkpoints set in their calendar to track daily tasks and progress.

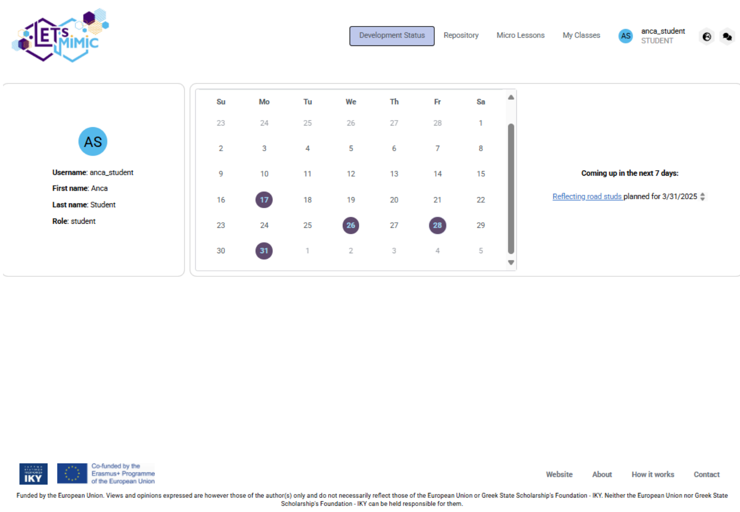

Figure 3. Let's Mimic Platform - calendar

- **Self-assessment forms:** The platform analytics helps learners evaluate understanding and performance regularly.

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3. Reflection tools.

- **User profiles/ Journals:** Learners can track their learning history and reflect on learning experiences and outcomes. The user profile provides an overview of the learner's planning and achievement.

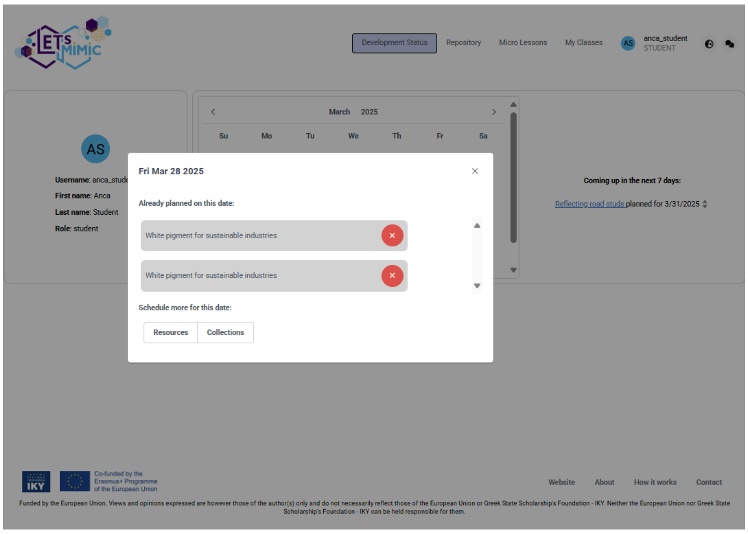

Figure 4. Let's Mimic Platform - scheduling

- **Feedback:** Learners can use the platform chat to gather feedback from peers and instructors.

4. Study aids.

- **Concept maps/ Mind maps design:** The platform is structured based on the Biomimicry Framework. The steps of the framework were used for organising and visualising information. The steps can be expanded or contracted to support quick review and memorization of key concepts.

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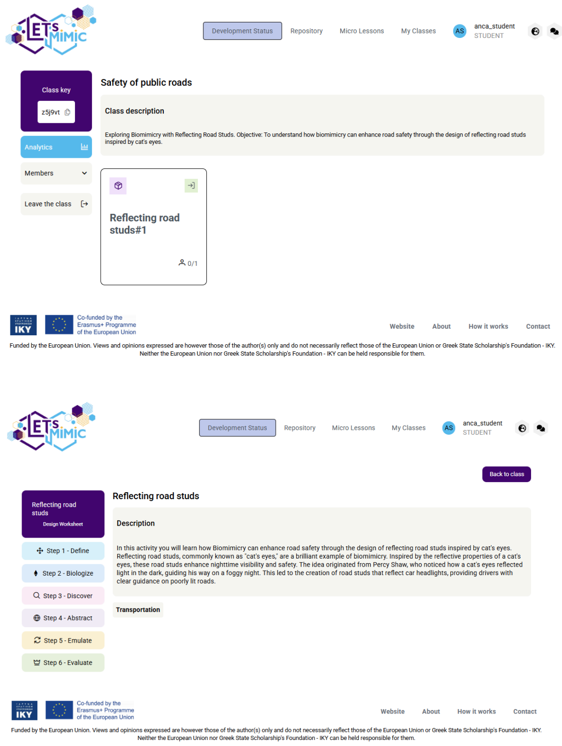

Figure 5. Let's Mimic Platform – biomimicry design

5. Time management.

- The calendar available on the platform helps learners manage study sessions effectively, while the analytics component helps them monitor the time spent on different tasks. This feature builds learner responsibility, improves efficiency in planning and controlling specific tasks, and maximises the effectiveness of an individual's efforts. Coupled with the reward systems, it can increase the learning ability to self-manage activities and increase motivation.

6. Gamification and motivation.

- **Reward system:** The platform integrates gamification mechanics and rewards for achievements to keep learners motivated across SRL paths. The reward system is a valuable SRL mechanism for building motivation and reinforcing learning.

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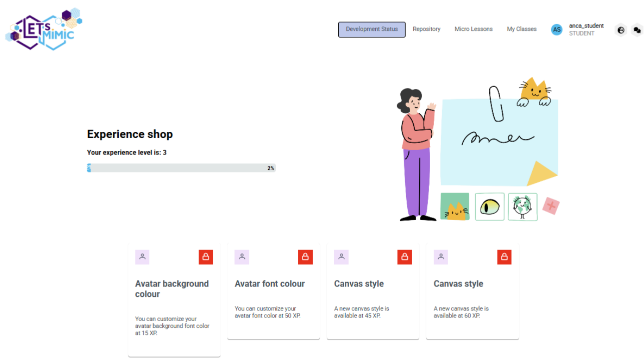

Figure 6. Let's Mimic Platform - gamification mechanics

7. Educational resources.

- **Books, articles:** The platform provides access to relevant reading materials for the subject matter. Links to videos, podcasts, and interactive modules are integrated into the modules and units to enhance learning.

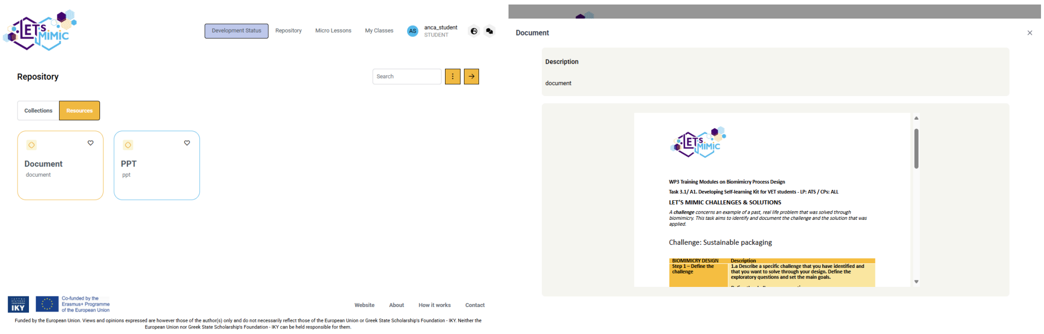

Figure 7. Let's Mimic Platform - Repository

8. Technology tools.

The Let's Mimic Platform forms the core of the SRL approach. The Platform integrates support features to motivate and engage learners across their self-regulated learning paths.

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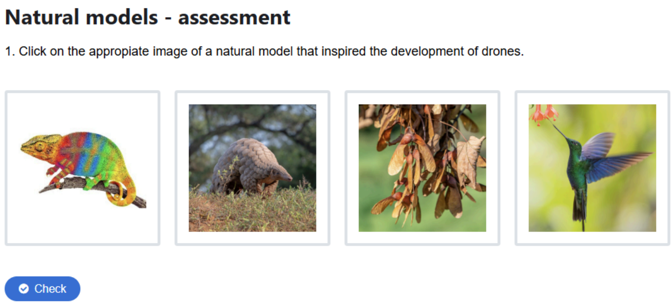

Figure 8. Let's Mimic Platform - assessment

9. Support networks.

- **Study groups:** The platform provides opportunities for collaborative learning, where teachers can monitor the learning process or allow students to create teams and monitor the collaboration. It also integrates chat functions.

Figure 9. Let's Mimic Platform – Teamwork module

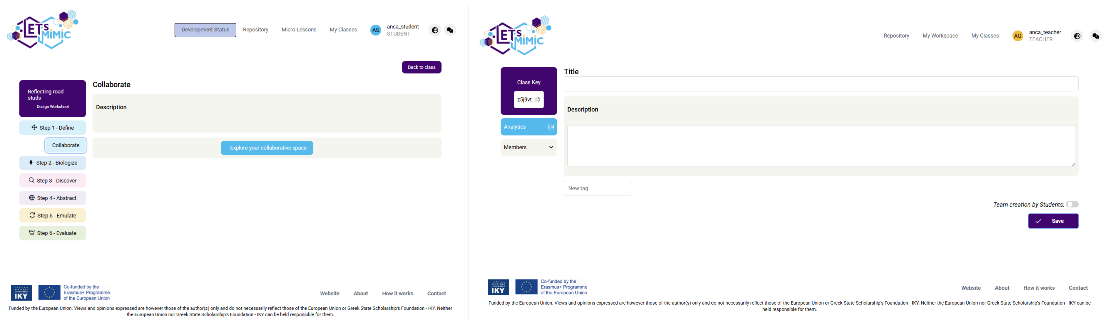

Figure 9. Let's Mimic Platform - Teamwork module

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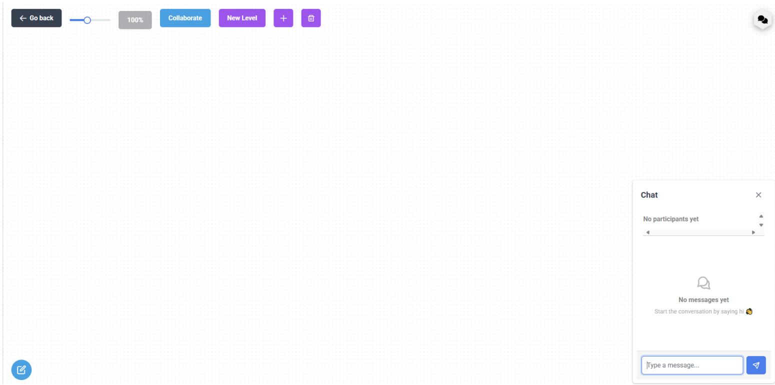

Figure 10. Let's Mimic Platform - Teamwork module. Chat

- **Guidance:** Learners can contact instructors for guidance and support.

In the context of the Let’s Mimic Project, the SRL Kit was designed to help learners develop 21st-century skills and habits essential to success, including critical thinking, creativity, collaboration, communication, information literacy, and technology literacy.

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3. Let’s Mimic SRL units

This section provides a summary description of Let’s Mimic learning units, which include:

- **Challenges and solutions** inspired by nature presented as good biomimicry practices.
- **Open case studies** to be addressed by students through biomimicry.

3.1 Challenges and solutions inspired by nature

Within the LET’S MIMIC project, a **challenge** is defined as an example of a past, real-life problem that has been solved through biomimicry.

Defining the challenge is a crucial first step in the Biomimicry design process, with the primary goal of setting a solid foundation for the subsequent steps. It is essential to frame the challenge in a way that opens up possibilities for innovative and effective solutions. In Biomimicry, solutions focus on emulating nature’s time-tested patterns and strategies.

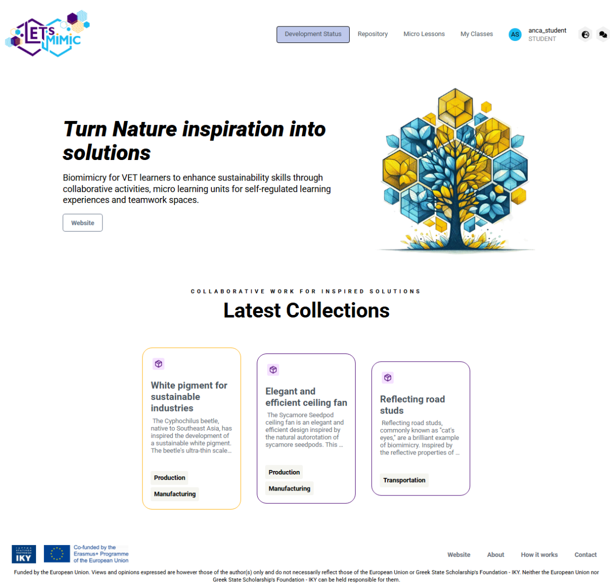

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Figure 11. Let's Mimic Platform - collections

The summaries below present the challenges and solutions that were identified and documented by the Let's Mimic partners. A total of 21 summaries were created, comprising 70 challenges, 70 solutions, and 70 case studies. The full content of all units is provided in the annexe attached to this report.

3.1.1 Let's Mimic challenges and solutions summary

C01_Colour changing 3D prints

3d printers that can automatically produce multiple colours from the same ink can be used in different industries and have a wide range of uses. For example, the 3d prints can be used for: adaptive camouflage in military technology, wearable technology and fashion, medical devices and implants, and consumer electronics. Its design must consider various aspects to develop this printer, such as a multi-colour extruder, advanced firmware, software, and compatible materials.

S01_The secret of chameleon colour change

In nature, the chameleon changes colour using specialised cells called chromatophores, which rapidly adjust pigment and reflect different wavelengths of light. External stimuli control this process and do not require much energy. The design concepts for the colour-changing 3d printer largely align with the design challenge criteria, particularly regarding innovation and sustainability. However, challenges in technical implementation and cost management must be addressed.

C02_White pigment for sustainable industries

To create an effective and safe white pigment for responsible production and consumption, it is necessary to find a safer and more environmentally friendly alternative to titanium dioxide (TiO2) as a white colourant. This is due to the health risks associated with Tio2 nanoparticles, which have been labelled as potential carcinogens, and which offer better performance in terms of brightness and durability. The white pigment can be used in various applications, including the food industry, cosmetics, paints and coatings, paper and packaging, textiles, and plastics.

S02_The natural white pigment of the cyphochilus beetle

Some organisms, such as the cyphochilus beetle, efficiently reflect light through specialised structures, including microscopic scales or nanostructures, that manipulate light at a wavelength level. These adaptations allow them to blend seamlessly into their environment, reflecting the colours and patterns around them. They also help them

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improve their camouflage while using minimal energy, allowing them to conserve resources while maximising their survival.

C03_Building design for efficient cooling and ventilation

In densely populated cities, where high-rise and multi-use buildings are the norm, the growing need to maintain a stable and comfortable internal climate within buildings without relying on traditional fuel-based air-conditioning systems is an increasingly pressing challenge. To maintain a controlled internal climate for buildings in urban areas, it is necessary to design urban buildings that significantly reduce energy consumption while providing comfort.

S03_The termite mounds' tunnels

The termite mounds have tunnels that draw in cool air from the base and expel warm air from the top, utilizing convection currents. The mounds harness natural airflow, utilising temperature differences to create circulation. Even in extreme heat, termite mounds maintain a stable internal environment. The mound structure provides cooling and airflow with zero energy input, relying solely on the design and natural airflow dynamics.

C04_Nature-inspired ceiling fans

The ideal ceiling fans can operate at low speeds while providing high airflow with minimal turbulence and noise, ultimately offering a more efficient and cost-effective solution for residential and commercial settings. This type of ceiling fan can be implemented in residential homes, offices, and commercial buildings, as well as in eco-homes, green buildings, sustainable architectural projects, public buildings, and institutions, especially in regions with limited access to reliable electricity.

S04_Aerodynamics of sycamore tree seeds

In nature, the shape of the sycamore seed's wings allows it to glide through the air, creating a spiral motion. A design inspired by the sycamore seed for a ceiling fan leverages natural models and strategies to achieve efficiency, sustainability, and functionality, all while aligning with the goals of low speeds, minimal turbulence and noise, and a cost-effective solution that offers efficient air movement, quiet operation, strength, adaptability, and environmental sustainability.

S05_Evapotranspiration in plants

To provide safe, accessible, and effective sanitation solutions for the 2.6 billion people globally who lack proper toilet access and focus on addressing the needs of vulnerable communities, one must turn to nature for inspiration. Nature-inspired design needs to address the specific needs of vulnerable communities and ensure hygiene without

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relying on power or plumbing. Additionally, it should be rapidly deployable in off-grid, rural, and post-crisis areas, offering a sustainable and environmentally safe way to manage human waste.

S05_Evapotranspiration in plants

Nature provides several solutions to sanitation challenges through efficient waste management and resource recycling. For instance, Wetlands filter pollutants from water through the action of plant roots and microbial activity. This principle can be applied to sanitation systems that treat waste and recycle water, ensuring cleanliness and ecological balance.

C06_Safety and efficiency of aeroplanes

Experts found inspiration in how birds fly to ensure the safety and efficiency of aeroplanes. When examining the flight mechanics of birds for advanced applications, such as the "V" formation in military and commercial aviation, they discovered that birds conserve energy and can fly longer distances. By applying the V formation of birds to commercial and military aviation, we can achieve significant energy savings and reduce fuel consumption.

S06_V Flight formation of migrating birds

As we look up into the sky, we notice a flock of birds flying toward the south, arranged in a V-shaped formation. There's quite a fascinating science behind why particular species of large birds organise themselves in this manner, and it has everything to do with efficiency, especially for the long-haul flights of migration. This flying pattern helps all the birds preserve energy. When large birds flap their wings, air circulations are generated, called vortices, which have both rising and sinking segments, pockets of swirling air.

C07_Drones to become more agile

One must look to natural inspiration to create a high-precision and stealthier drone that can operate in complex environments, such as urban areas, forests, natural terrains, disaster zones, and military zones. The primary goal of this challenge is to enhance drones' agility and adaptability, enabling them to operate efficiently in complex and dynamic environments.

S07_Swift and precise flight of a hummingbird

Evolution is the best inventor, with hundreds of millions of years of work and the natural world as its canvas. The swift and precise flight of hummingbirds, some of the tiniest birds in the world, has inspired scientists, researchers, and the drone industry to

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develop flying devices capable of intricate manoeuvres. Hummingbirds fly like insects but have the musculoskeletal system of birds. Their small, lightweight torsos and relatively large wings allow them to fly remarkably fast and with incredible precision.

C08_Fastest high-speed trains. The bullet train

The main goal of this challenge is to design a high-speed train that addresses the noise pollution issue, particularly the "tunnel boom," while enhancing energy efficiency and maintaining high-speed performance. This design should also reduce air resistance to improve overall performance, reduce noise generated by aerodynamic factors, and enhance the train's speed and energy efficiency, allowing it to travel faster while consuming less electricity.

S08_The Kingfisher, the Owl and the Penguin

Owls are silent hunters, relying on their unique feather structures to reduce noise during flight. Their concave faces and downy bodies absorb sound, making their flight nearly silent. Adelie penguins are exceptional swimmers, spending about 75% of their time in the water. Their torpedo-shaped bodies and rear-placed legs minimise drag by fluffing their feathers and releasing bubbles, enabling speeds of up to 25 mph, but they can also triple it. The Kingfisher's head and beak shape allow it to glide through the air and dive into water efficiently, seamlessly transitioning from air to water.

C09_Design a subway or railway network less prone to disruption

The main goal of this challenge is to create a highly efficient, resilient, and adaptable transportation network inspired by nature that can dynamically adjust to varying passenger loads and traffic conditions.

S09_Adaptive behaviour and learning in slime moulds

Despite lacking a brain, Physarum polycephalum, commonly known as slime mould, displays complex behaviour. It forms a tubular network to transfer nutrients efficiently. Slime moulds forage broadly and then optimise their network for nutrient transport. In optimal conditions, they can grow over 30 cm in diameter. Slime moulds solve complex problems, like finding the shortest path in a maze or balancing nutrient levels.

C10_Flexible and durable backpacks

The primary objective of this challenge is to design a backpack that offers robust protection for its contents, while allowing for flexibility and adaptability. It should utilise tough and resilient materials to withstand various conditions, incorporate sustainable materials to promote environmental responsibility, and possess a visually appealing and comfortable design.

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S10_Strong and durable protection of the Pangolin scale

Pangolins' scales are made of keratin, providing strength and adaptability. The overlapping, hexagonal scales allow flexibility and robust protection, enabling pangolins to roll into a ball. These scales are rigid yet elastic, bending without cracking and adapting to various terrains. The interlocking scales distribute stress evenly, offering insights for designing flexible, durable products, such as backpacks.

C11_Multi-functional biodegradable shoes

The main goal of this challenge is to develop versatile, eco-friendly shoes by utilising renewable, biodegradable materials and innovative design techniques that ensure durability, comfort, and adaptability for various uses, while minimising environmental impact throughout the product lifecycle. The design should explore methods for replacing traditional synthetic materials with biodegradable options, such as algae-based foam, natural rubber, and organic fibres, to be easily recyclable or compostable. Additionally, it should incorporate non-toxic, eco-friendly adhesives and dyes.

S11_Biodegradability of algal organic matter

Algae produce biodegradable materials through photosynthesis, converting sunlight, carbon dioxide, and water into organic compounds such as carbohydrates, proteins, lipids, and even biopolymers like alginate, agar, and carrageenan, which can replace synthetic polymers. These compounds are inherently biodegradable and environmentally friendly. Researchers are enhancing the properties of algal materials to improve strength, flexibility, and water resistance, making them suitable for products like biodegradable shoes.

C12_Reflecting road studs to increase safety on public roads

The result of this challenge should be a design that utilises resistant materials to withstand heavy traffic and harsh weather conditions, ensures maximum visibility, provides adequate warning to drivers, ensures continuous operation, features a smooth, enveloping profile without sharp edges to prevent damage to vehicles, and, if possible, allows for automatic operation.

S12_Cat eyes glow in the dark

Animal eyes reflect light efficiently through specialised adaptations that enhance vision in various lighting conditions. Many animals have a high density of rod cells in their retinas, which are sensitive to low light, and large, rounded pupils that allow more light to enter. Some animals also have reflective pigments in their eyes, which enhance vision in dark or murky environments. These adaptations improve vision across diverse lighting conditions, supporting survival in the wild.

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C13_Sustainable packaging

The result of this challenge should be a design that incorporates biodegradable, compostable, or recyclable materials, features a minimalist aesthetic, is reusable and durable, efficient in production, and includes clear information on the packaging about how to dispose of it correctly, as well as whether it can be recycled, composted, or reused.

S13_How nature inspired the circular economy

Nature has developed remarkable strategies to maintain biodiversity and balance in ecosystems. Protection mechanisms are evident in various species, such as turtle shells. Durability is another key factor in sustaining ecosystems. Plant roots, for example, anchor plants firmly in the soil, providing stability and resistance to adverse conditions like strong winds and heavy rains. Biodegradability plays a crucial role in nutrient cycling and soil health.

C14_Design of a sponge-like battery to support a carbon-neutral future

The challenge is set within the broader context of transitioning to a carbon-neutral future. As the demand for sustainable energy solutions grows, there is a pressing need for innovative battery designs that can store energy efficiently, are durable, and have minimal environmental impact. The result of this challenge should be a sponge-like battery that provides a larger surface area for energy storage, potentially increasing the battery's capacity and supporting a carbon-neutral future.

S14_The bone structures of mammals

Mammalian bone, consisting of the inner "Spongy bone" and the hard "Compact bone," is an excellent structural composite, allowing for strength and flexibility. The inner "Spongy bone" is the soft inner part of the bone and is structurally stabilised by the hard "Compact bone" surrounding it. The Spongy bone possesses a surface area ten times higher than the Compact bone, creating the classic soft-hard composite effect, which allows the bone to flex under stress while structurally supporting the body's load.

C15_The original "stealth" B-2 bombers

The result of this challenge is to design a stealthy, subsonic flying wing heavy strategic bomber in the context of modern warfare, geopolitical strategy, and technological advancement. To design a stealthy, subsonic flying wing heavy strategic bomber, several key requirements must be addressed and solved, including radar evasion, infrared signature reduction, fuel economy, payload capacity, aerodynamic efficiency, *structural integrity, multi-role capability, adaptability to future technologies, and survivability in modern combat.*

S15_The flight of a peregrine falcon

The peregrine falcon is built for speed, with wings and body designed for aerodynamic efficiency. When hunting, it can reach speeds close to 200 miles per hour by folding its wings to minimise drag. This incredible speed allows it to dive bomb prey with precision, unfolding its wings at the last moment to catch its target. Peregrines use proportional navigation, slightly adjusting wing position and speed before impact. This method, combined with high-speed diving, enhances their manoeuvrability and accuracy.

C16_A sustainable and more efficient agriculture for self-sustaining crop production

This challenge aims to design an agricultural system that can sustainably produce enough food to meet the growing population's needs without depleting natural resources or causing significant environmental harm.

S16_Mimicking prairie ecosystems

The variety of species in a prairie ecosystem enables plants to use water and nutrients efficiently. Additionally, natural systems exhibit greater resilience to disturbances, possess self-regulating capabilities, maintain more stable soils, and enhance carbon sequestration, nutrient cycling, food production, and biodiversity. Perennial grain cropping, or permaculture, is a form of agriculture that mimics natural systems. This approach leverages the benefits found in natural systems, such as pest control, fertility and nutrient cycling, erosion control, drought resistance, water management, and carbon sequestration.

C17_Lightweight highly efficient stealth robotic MAV

The result of this challenge is to design a system that addresses the demands of modern conflict, leveraging cutting-edge technologies to ensure operational efficiency, adaptability, and the safety of military personnel. The design must address several key aspects, including minimising detectability, enhancing mobility and adaptability, reducing risk to personnel, optimising resource use, countering emerging threats, achieving technological superiority, and being able to integrate with military ecosystems.

S17_The fly of a bat

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Their calls can reach 140 decibels, ranging from 14,000 to over 100,000 Hz. Bats' ears are sensitive to prey sounds and can construct a mental image of their environment through repeated scanning. Bats have evolved specialised features for flight, like flexible wings and strong muscles. Bats have good vision adapted to their environment, with some relying more on echolocation than sight.

C18_Filtering plastic pollution

The result of this challenge should be a design that solves the problem of removing fine plastic particulate matter from various environments and focuses on capturing microplastics and nanoplastics, reduces the presence of toxic chemicals and plastic particles in drinking water, prevents plastic particles from harming wildlife and disrupting natural habitats, alleviates the adverse economic effects of plastic pollution on industries such as tourism, fisheries, and agriculture by maintaining cleaner environments and improves the overall quality of water and soil by removing plastic contaminants.

S18_A novel non-clogging feeding mechanism of manta rays

Manta rays are filter feeders and macropredators, consuming large quantities of zooplankton and small to medium-sized fish. They filter feed by swimming with their mouths open, using specialised filtering organs to trap food particles. Their filtration system is highly efficient and resistant to clogging, using leaf-like lobes to bounce food particles away from the filter. Manta rays play a crucial role in their ecosystems by concentrating biomass and removing excess nutrients from the water.

C19_Preservative packets to reduce waste

This challenge aims to identify a solution for maintaining the freshness of food in areas without access to cold storage and cold supply chain facilities. The result should be a design that extends the shelf life of harvested produce in these areas.

S19_The unique signalling substances of fruits and vegetables

When fruits and vegetables are detached from the parent plant, they activate several defence mechanisms to protect themselves from spoilage and microbial attacks. The design aims to develop innovative sachets that leverage the natural defence mechanisms of fruits and vegetables to extend their shelf life by looking into the unique signals of plants. These sachets should extend the shelf life of the targeted fruits and vegetables by 40 to 60 per cent. This will reduce food waste, improve food security, and support the livelihoods of small-scale farmers, local communities, and affected areas.

C20_Hydrogen sensors powered by light

This challenge aims to design a new generation of hydrogen sensors that are effective, reliable, environmentally friendly, and sustainable.

S20_The surface of butterfly wings

Butterflies have evolved fascinating mechanisms to absorb light and reflect almost none, primarily through the unique structures on their wings. The wings have some anti-reflective properties, which are highly efficient at trapping light, making them appear almost black.

C21_Self-healing concrete

Over time, concrete can crack and deteriorate. The development of a more solid and long-lasting material could lead to the adoption of sustainable construction practices, the creation of maintenance-free or low-maintenance infrastructures, and the production of stronger and more durable concrete that can enhance the resilience of buildings and roads.

S21_Natural bone healing through osteoblastic mineralisation

By incorporating three biological principles of Osteoclasts and osteoblasts, self-healing capability, crack detection, and response, and restoration of structural strength, the design of this challenge aims to create a new concrete that can not only autonomously repair cracks but also sense or respond to the formation of cracks, triggering the self-healing mechanisms at the right time. It is also essential that this self-healing process not only fills the cracks but also restores the original strength of the concrete, ensuring that the repaired material can withstand similar loads and stresses as before.

C22_Velcro invention for fastening and securing almost anything

This challenge will result in a design that needs to provide a fastening solution that offers strong, reliable adhesion while being easy to use and adaptable for various applications. Additionally, the solution should be environmentally friendly, incorporating sustainable materials and processes to align with modern ecological standards.

S22_Ability to grab tenaciously like a cocklebur

The cocklebur is a plant seed belonging to the burdock family. It clings firmly to the fur of passing animals thanks to a special structure of tiny, hook-like projections on its exterior. Each hook is bent and flexible, which causes it to attach to fibres and organic textures with little effort. As animals move, the cocklebur's attachment strategy enables it to cover great distances, efficiently dispersing seeds to new locations. The design of Velcro, which has hooks on one surface and loops on the other that mimic the

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fibrous texture of fur, was inspired by this natural hook-and-fibre interlock and produces a robust, reusable fastening device.

C23_Fastskin swimsuit

This invention addresses the need for a suit that minimises drag and allows swimmers to achieve faster speeds with less effort. Many examples of species that move through water effectively in nature might inspire strategies to reduce drag and maximise movement. These observations might direct the development of innovative structural and material designs.

S23_Shark skin to reduce drag

The inspiration behind this product is the unique texture of shark skin, specifically the dermal denticles that cover its surface. These tiny, tooth-like structures create a natural "drag-reduction" system, allowing sharks to move efficiently through water by minimising turbulence and resistance. The main points of this design are to improve swimming speed, reduce water resistance, and offer a flexible and comfortable fit.

C24_Stronger and tougher ceramics

The result of this challenge is a design that addresses the challenge of creating a ceramic material that can withstand high stress without breaking. Despite their strength, traditional ceramics are brittle and can break when exposed to harsh environments or impacts. By increasing toughness and resilience, this new design must overcome its brittleness and better withstand strain and stress.

S24_Inspiration from the nacre of abalone, a single-shelled marine mollusc

Mollusc shells have a hierarchical structure of layered aragonite and organic material arrangements, giving them exceptional flexibility and toughness. Thanks to their special design, molluscs can withstand impacts and defend themselves against predators and environmental obstacles. The material designs should incorporate elements that replicate the efficient layering found in mollusc shells to ensure resilience against damage, thereby improving durability and performance.

C25_Adhesive patches that don't harm

The result of this challenge should be a design that addresses the issue of developing a skin patch that adheres securely to various surfaces, including human skin, without causing discomfort or irritation. To ensure reliable adhesion during physical activities or exposure to moisture, the patch must be sufficiently flexible to accommodate body

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movements. The patch should also be simple to apply and remove without causing skin damage or residue.

S25_Suckers found along the underside of octopus tentacles

Due to their special structure, octopus suckers can adhere securely to a variety of surfaces, enabling efficient skin contact. Even in difficult situations, thanks to this ability, octopuses can maintain a firm grip. On the other hand, a poorly made medical patch might not have the required adhesive qualities, resulting in insufficient skin contact and decreased efficacy. A medical patch design should include elements that replicate the effective attachment mechanisms of octopus suckers to maximise its performance in medical applications and guarantee optimal adhesion and treatment efficacy.

C26_More efficient wind power

The result of this challenge should be a design that maximises energy capture by increasing the efficiency of wind turbine blades in turbulent conditions. The current turbine blades' energy output is limited by drag and decreased performance during variable wind speeds. The solution must improve aerodynamic efficiency without sacrificing durability or structural integrity.

S26_Bumps on the leading edge of the humpback whale's flipper

Humpback whale fins possess a specialised structure, with tubercles along the leading edge that enhance lift and reduce drag, allowing efficient movement through water. This adaptation enables the whale to navigate fluid environments with stability and control. Incorporating features inspired by the structure of whale fin tubercles can improve wind turbine performance by increasing lift and lowering drag, resulting in greater energy capture and operational reliability.

C27_ Efficient fog collection

The result of this challenge should be a design that tackles the issue of efficiently capturing and utilizing fog as a water resource to support industrial processes and improve water sustainability in arid regions. To reduce dependency on conventional water sources and minimise environmental impact, systems that can efficiently collect moisture from fog and convert it into usable water must be developed.

S27_Lizard-skin-inspired nanofibrous capillary network

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The unique nanofibrous capillary network in lizard skin enables efficient temperature and moisture regulation, allowing lizards to flourish in a variety of environments. Replicating the adaptive properties of lizard skin through enhanced moisture regulation and thermal balance can lead to increased user comfort and improved performance.

C28_ Accurate underwater communication

The result of this challenge should be a design that tackles the issue of efficiently capturing and utilizing fog as a water resource to support industrial processes and improve water sustainability in arid regions. Systems that can effectively collect moisture from fog and convert it into usable water must be developed to reduce dependency on conventional water sources and minimise environmental impact.

S28_Inspiration from dolphins who can communicate complex information

To create a reliable underwater communication system that uses ideas from dolphin echolocation experts turn to nature for inspiration to offer a solution for this challenge, more specifically to dolphins for echolocation and communication; whales for low-frequency communication; frogs for noise filtering in choruses; electric fish for communication in murky waters; elephants for adaptive low-frequency rumbles and pistol shrimp for bubble snap communication.

C29_Camera to capture the faintest features of the galaxy

Creating a camera system that performs well in low-light conditions is crucial for enhancing data capture and overall efficacy as applications expand due to advancements in various industries. The solution to this challenge should be a design that addresses the issue of capturing high-quality images in low light, where conventional cameras often fail due to glare and noise. It should increase the sensitivity of imaging systems, allowing for more detailed and clearer images in conditions like low light levels, at night, or underwater.

S29_Inspiration from the moths' eyes

Natural models, such as moth eyes, nocturnal animals, deep-sea fish, fireflies, and scorpions, can serve as inspiration. The design's functions could be considered oppositely by prioritising light reflection instead of absorption, which is proper for applications requiring high visibility, like safety gear. It could also intentionally create glare to diffuse light for specific effects or deterrents. Rather than enhancing resolution in low-light, the design might reduce resolution in bright settings to prevent overexposure, optimising for stable, high-light conditions.

C30_ Heat insulation

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This challenge is centred around a growing emphasis on sustainability and energy efficiency, driven by concerns about climate change and the urgent need to reduce carbon footprints. As extreme weather patterns become more frequent, the need for insulation materials that function well in both hot and cold temperatures is growing. The result of this challenge should be a design that solves the problem of effective thermal insulation in extreme temperatures while prioritising lightweight and eco-friendly materials.

S30_Polar-bear-inspired material

The hollow structure of polar bear fur traps air, creating an insulating layer that minimises heat loss in extreme cold. This allows polar bears to retain warmth efficiently without needing a thick, heavy coat. Insulation without this type of air-trapping structure might fail to retain heat effectively, leaving the wearer vulnerable to cold. For instance, insulation made from solid, dense materials might lack sufficient air pockets, increasing bulk without providing adequate warmth. In this sense, insulation design should incorporate hollow, air-trapping features inspired by polar bear fur to maximise thermal efficiency in cold environments.

C31_Efficient water harvesting in arid environments

The result of this challenge should be a design that aims to provide a consistent and reliable source of clean water for communities in arid regions, utilise available local resources to ensure the system's affordability and ease of implementation, be easy to operate and maintain, even in resource-poor or remote areas and avoid over-reliance on external resources, ensuring the solution is robust in long-term, low-water scenarios.

S31_The beetles that drink water from the air

Experts look to nature for inspiration. More specifically, the Namib Desert Beetle utilises a combination of hydrophilic bumps and hydrophobic grooves to collect water. Cacti, on the other hand, employ ridges and spines to capture and channel dew and fog to their roots, while lichens and Moss absorb moisture directly from the air using capillary action. The design aims to efficiently capture moisture from fog or humid air, channel the collected water for storage or use, and utilise passive methods to harvest water without relying on external energy sources.

C32_Creating self-healing materials

The result of this challenge should be a design that utilises materials capable of detecting and autonomously repairing physical damage (such as cracks, tears, or abrasions). The design should restore the material's functionality (e.g., strength, conductivity, flexibility) to its original state after damage, enable the material to heal

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multiple times without degrading its properties over time, and possess a self-healing mechanism triggered by simple environmental factors (e.g., heat, moisture, UV light), requiring minimal external energy or intervention.

S32_Self-healing concrete inspired by the healing process of bones

Experts were once again able to find inspiration in nature to solve this challenge. They looked into bones because they can repair fractures using a three-step process of signalling, scaffold formation, and mineral deposition; tree bark because it heals itself by sealing wounds with new layers, preventing further damage; and seashells because they rebuild damaged areas by layering calcium carbonate.

C33_Efficient wastewater treatment in urban areas

The result of this challenge should be a design that efficiently treats wastewater, recovers valuable resources by capturing and repurposing by-products like clean water, biogas, and nutrients for reuse in agriculture, industry, or urban infrastructure, operates in space-limited areas, ensures affordability and ease of use, and supports climate resilience.

S33_Mussel-inspired adhesive filters

Experts turn to nature for inspiration to offer a solution for this challenge, specifically to mussels, which use protein-based adhesives that form robust bonds in wet, saline environments; barnacles, which create calcified, glue-like substances for permanent attachment to surfaces; and lotus leaves, which, although not adhesive, exhibit water-repellent properties that can inspire anti-clogging features for filters.

C34_Efficient and sustainable packaging

The result of this challenge is a design that aims to protect the contents from physical damage, contamination, and spoilage; reduce material waste by using less packaging, adopting minimalist designs, and utilising sustainable materials with a lower environmental footprint; and offer convenience to consumers with clear labelling and easy-to-open features. The design should also be easy to recycle, reuse, or compost, avoiding single-use plastics and materials contributing to landfill waste and cost-efficient and scalable.

S34_Inspiration from the nacre of abalone shells

To solve this challenge, experts drew inspiration from nature, specifically from the nacre in abalone shells, a layered construction of calcium carbonate and organic polymers that provides strength and flexibility; spider silk, which is a strong, lightweight, and flexible fibre that effectively absorbs stress; and human bones, which

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feature a hierarchical structure that combines complex mineral layers with soft collagen for enhanced strength and resilience.

C35_Increasing the efficiency of wind turbines

The result of this challenge is a design that maximises the efficiency of wind turbines, extracting as much energy as possible from the wind while maintaining stability and operational performance across different wind conditions; increase the lifespan of turbines by minimising wear and tear, reducing maintenance costs, and improving reliability, particularly for turbines in remote or offshore locations; reduces the environmental footprint of the turbine's lifecycle, from material sourcing to manufacturing, operation, and eventual decommissioning.

S35_Shark skin to reduce drag

To solve this challenge, experts drew inspiration from nature, specifically from shark skin, which possesses dermal denticles that streamline flow and resist fouling; dolphin skin, which is smooth and flexible, reducing turbulence and drag; and the lotus leaf, whose hydrophobic surface resists adhesion, thereby reducing fouling.

C36_Developing more durable and lightweight structures

The result of this challenge is a design that must achieve a balance between lightness and strength; use minimal materials while maintaining structural integrity; are adaptable, allowing for easy modifications or extensions without compromising the core integrity of the original design; are durable over a long lifespan and promote sustainability by using renewable, recyclable, or low-impact materials and reducing the carbon footprint during both construction and decommissioning.

S36_Spider silk for high-strength fibres

To solve this challenge, experts found inspiration in nature, specifically in spider silk, which combines strength and elasticity in a lightweight structure. Silkworm silk is also a source of inspiration, as it's produced efficiently by caterpillars for protective cocoons and tendons. Additionally, ligaments, which are the human connective tissues that balance tensile strength and elasticity, also provide insight.

C37_Building energy-efficient roofs and facades

The result of this challenge is a design that must improve the insulation of roofs and facades to reduce heat loss in cold weather and limit heat gain in hot weather, integrates renewable energy solutions, incorporates passive ventilation strategies, enables innovative energy control systems that can automatically adjust the roof and facade features, is low-maintenance, durable, and use environmentally friendly

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materials, reducing the long-term environmental impact of the building's energy systems.

S37_Inspiration from the Lotus effect

Experts turn to nature for inspiration to offer a solution for this challenge, specifically to lotus leaves, which possess micro- and nanostructures. These nanostructures create superhydrophobic surfaces that repel water and dirt, similar to those found on butterfly wings. Lotus leaves have hydrophobic scales, allowing them to stay dry and clean during flight in humid conditions. Water striders, on the other hand, possess legs coated with nanostructures, enabling them to repel water and float on its surface.

C38_Sustainable energy generation

The result of this challenge is a design that converts natural resources like sunlight, wind, or heat into electricity efficiently and consistently; reduces greenhouse gas emissions during energy production and across the system's lifecycle; provide an affordable energy solution for communities with varying economic resources; delivers consistent power even in challenging or fluctuating environmental conditions; is flexible enough to work in decentralised grids, microgrids, or off-grid systems.

S38_Electric eel-inspired energy storage

Experts turn to nature for inspiration to offer a solution for this challenge, more specifically to electric eels, which use electrolytes arranged in series to generate significant voltage outputs; electric rays, which generate electricity through specialised electric organs for defence and predation; and mitochondria, which are cellular powerhouses that efficiently convert energy through chemical gradients.

C39_Minimizing shock and vibration in transport systems

The result of this challenge is a design that effectively reduces the impact of vibrations and shocks, no matter the cause; employs advanced suspension or damping mechanisms capable of adjusting to different load types and conditions, thus reducing wear and tear on vehicles and minimising discomfort for passengers or cargo; incorporates innovative monitoring systems that assess shock and vibration levels continuously, adjusting suspension settings or damping mechanisms as needed to respond to changes in terrain or road conditions.

S39_The shock absorption capabilities of animal limbs

Experts turn to nature for inspiration to offer a solution for this challenge, more specifically to kangaroo tendons because they store and release energy efficiently

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during hopping, minimising strain; woodpecker skulls because they absorb high-impact forces while protecting the brain using layered bone and cartilage; and elephant feet because they utilise a spongy fat pad for shock absorption to support heavy loads.

C40_Designing efficient filtration systems

The result of this challenge is a design that is capable of targeting and capturing specific contaminants; efficiently manages fluid (air or water) flow while maintaining low pressure drops, reducing energy demand and enhancing system efficiency; maintains a high filtration efficiency over time and, if possible, include options for filter regeneration or extended service life to reduce waste and maintenance frequency; equips the filtration system with monitoring technology to track filter performance, contaminant load, and maintenance needs.

S40_Inspiration from the sieve-like structure of the whale's baleen

Experts turn to nature for inspiration to offer a solution for this challenge, more specifically to whale baleen, because its keratin bristles create a flexible, semi-permeable barrier for filtering krill and plankton from water; mangrove roots, which trap sediments while allowing water to flow, aiding in natural filtration; and spiderwebs, which capture fine particles like dust and pollen with intricate, overlapping fibre patterns.

C41_Eco-friendly noise reduction in urban spaces

The solution will focus on areas with high noise pollution, such as busy streets, near industrial zones, or around transport hubs. Urban centres with significant traffic congestion and dense populations will benefit the most. The main goals of this challenge are to reduce noise levels in urban areas by 20-30 decibels, develop a low-maintenance and environmentally friendly solution, and ensure scalability and adaptability for various urban landscapes.

S41_Nature noise barriers

The design aims to passively absorb or deflect urban noise, inspired by nature's strategies for sound management. Consider how nature addresses the noise pollution problem. For example, one can observe that it is very quiet in the middle of the forest or that owls have a silent flight, even though some species are quite large.

C42_Reducing water consumption in urban landscapes

Urban areas often experience high water consumption due to landscaping, irrigation, and recreational water features, putting pressure on local water resources. Traditional irrigation methods are inefficient and waste water. The main goals of this challenge are

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to develop water-efficient urban landscaping solutions and to enhance water conservation without sacrificing green space or visual appeal.

S42_Cactus water storage and distribution systems

Once again, the experts turn to nature for inspiration. Desert plants, such as cacti and succulents, have evolved to store water in their tissues and minimise evaporation. Some animals, like the Namib desert beetle, can capture water from fog through structures on their bodies. Certain plants, like the agave, have deep roots that access water below the surface and are adapted to dry climates.

C43_Enhancing urban waste management with biomimicry

The result of this challenge should be a design that improves waste sorting, processing, and recycling to reduce landfill dependency and environmental harm. The challenge is set in cities, which often face waste accumulation problems due to high population densities and limited space for waste management.

S43_Nature recycling system

In nature, fungi break down organic matter and recycle nutrients in soil. Ants and termites efficiently sort and transport materials within their colonies. Microorganisms in composting systems work together to decompose waste and create fertile soil. The design aims to create an efficient and self-sustaining waste sorting and recycling system inspired by natural processes. The system must identify different types of waste, sort them accordingly, and facilitate the recycling process with minimal human intervention.

C44_Sustainable water management in urban areas

Urban environments, particularly those with rapid population growth, poor drainage systems, or insufficient rainwater harvesting infrastructure, require a solution that optimises water usage, ensures adequate water storage, and reduces excess runoff during rainfall. The design should address water scarcity, especially in areas facing droughts, while managing excessive rainwater to prevent flooding.

S44_Cactus water storage and distribution systems

Cacti are excellent models for efficient water collection and storage. Their unique structure allows them to capture moisture from the air and funnel it into their roots, even in arid conditions. The result of this challenge should be a design capable of capturing and storing water from rainfall or humidity in urban settings while minimising water loss and optimising storage for later use during dry periods.

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C45_Reducing energy consumption in industrial processes

This challenge applies to energy-intensive industries such as steel, cement, paper, and automotive manufacturing. These industries are key to the global economy, but are responsible for significant carbon emissions and energy consumption. The result of this challenge should be a design that focuses on lowering energy use in the industrial sector, particularly in manufacturing. The solution must minimise energy waste and improve overall efficiency without increasing production costs or slowing operations.

S45_Termite mounds that regulate temperature and humidity

Nature solves cooling challenges through various biological strategies. For instance, termites build mounds with intricate internal structures that regulate temperature and humidity effectively despite extreme external conditions. These mounds stay cool in high temperatures due to their natural ventilation system. The design aims to reduce the energy consumption required for cooling systems in industrial plants by replicating nature's strategies for passive cooling and, more specifically, to optimise internal temperature control without relying on energy-intensive air conditioning or refrigeration systems.

C46_Reducing water waste in agriculture through efficient irrigation Systems

The result of this challenge should be a design that reduces the water usage in agricultural irrigation systems, especially in regions where water scarcity is an issue. This solution would be applied in areas with water shortages or regions that rely heavily on irrigation for crop production.

S46_Nature precision irrigation system

Nature's ecosystems use water efficiently through various mechanisms, such as water distribution via plant root systems and rainwater absorption techniques of certain plants. Cacti store water and use it strategically, while moss absorbs and retains moisture efficiently. The design needs to ensure that water is distributed precisely and efficiently across agricultural fields, minimizing waste and ensuring each plant receives the appropriate amount of hydration based on its needs and the surrounding environment.

C47_Designing structures to withstand extreme weather events

The design must focus on creating structurally sound buildings during extreme weather while minimizing energy consumption for heating or cooling. The solution should prioritise sustainable materials and adaptable designs for various geographic regions. This solution would apply to hurricane-prone coastal areas, regions facing frequent *tornadoes, and urban zones experiencing increasingly extreme weather due to climate change.*

S47_Resilient structure of Palm trees

Palm trees are highly flexible and resilient structures that withstand extreme winds in tropical storms and hurricanes. Their long, slender trunks and aerodynamic fronds allow them to bend without breaking, dispersing wind forces efficiently. Their deep and expansive root systems provide a strong anchor in loose or sandy soils. The solution aims to design resilient buildings inspired by the structural properties of palm trees, integrating flexibility, aerodynamic design, and deep anchoring systems and to create energy-efficient, weather-resistant structures capable of withstanding high winds and extreme weather events.

C48_Enhancing building insulation inspired by nature

The result of this challenge should be a design that enhances thermal regulation in buildings, reducing the need for artificial heating and cooling. This is applicable in urban and rural settings, especially in regions with extreme temperatures where energy consumption for heating or cooling is high.

S48_Nature efficient insulation and thermal regulation

The natural world offers a variety of examples of efficient insulation and thermal regulation, one of the most well-known being the structure of animal burrows. The European rabbit burrow remains at a relatively stable temperature, even during extreme seasonal temperature fluctuations, due to the insulating properties of the surrounding soil. The polar bear's fur provides excellent thermal insulation against freezing temperatures through dense underfur and hollow guard hairs that trap air.

C49_Wastewater treatment system

The result of this challenge should be a design that aims to provide a more sustainable approach to wastewater treatment, particularly in urban areas, rural communities, or developing countries where conventional treatment methods may be costly, energy-intensive, or inaccessible. This design should integrate natural processes that purify water while reducing environmental pollution.

S49_Natural filtration systems for purifying water

Natural filtration systems, such as wetlands, utilize plants, microorganisms, and natural processes to clean and purify water. Wetlands filter out pollutants using plant roots to absorb nutrients and contaminants, while microorganisms break down organic matter. The slow movement of water through wetland soil also helps trap particles and reduce

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pollutants. Soil and riverbed biofiltration effectively removes toxins through natural biochemical processes.

C50_Enhancing urban air quality through natural filtration systems

The design should focus on improving air quality in densely populated urban areas, where air pollution is a significant health concern. The solution should be able to filter harmful particles and gases without requiring complex or high-energy systems. This solution would be implemented in cities, especially those with high levels of air pollution, and could be scaled for use in public spaces and residential areas.

S50_Nature's natural air purification systems

The solution draws inspiration from nature's natural air purification systems. Specifically, spiders and peace lilies have been shown to filter indoor air by absorbing harmful chemicals and particulates through their leaves and roots. Certain species of moss and algae can capture fine particulates in the air, while some trees, such as the silver birch and urban ash, are known to absorb carbon dioxide and other air pollutants through their leaves and bark.

C51_Gecko-inspired adhesives

The primary objective of this challenge is to develop a non-toxic, reusable adhesive suitable for applications such as robotics and medical devices. The resulting adhesive should provide a reliable bond for both smooth and uneven surfaces. The developed adhesive will be utilised in various settings, including healthcare (e.g., bandages) and industrial applications (e.g., robotic grips).

S51_Gecko-inspired adhesives

Microstructures on gecko toes use Van der Waals forces to stick to surfaces without leaving residue. These structures maintain adhesion even on dusty surfaces. This challenge aims to develop surfaces or materials with microscopic structures that can adhere to smooth or uneven surfaces without the need for glue or residue, ensuring reusability and durability for consumer or industrial applications.

C52_Termite-inspired ventilation systems

The main goal of this challenge is to design a passive cooling and ventilation system for sustainable architecture. The resulting design should reduce the need for HVAC systems by regulating building temperatures passively. The design will primarily be targeted at buildings in hot climates or regions with limited energy resources.

S52_Termite-inspired ventilation systems

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Termite mounds use a network of vents and chambers to maintain stable internal temperatures, even in extreme climates. The challenge aims to design ventilation systems that regulate air movement and temperature by utilising a network of interconnected pathways, thereby reducing reliance on energy-intensive cooling systems.

C53_Humpback whale flipper-inspired wind turbines

The primary objective of this challenge is to develop a design that enhances wind turbine performance and lifespan while minimising environmental impact. The result of this challenge should be a design that enhances turbine aerodynamics and reduces mechanical stress. This design will be implemented in wind farms, particularly in noise-sensitive areas.

S53_Humpback whale flipper-inspired wind turbines

The tubercles (bumps) on humpback whale flippers streamline movement through water, improving energy efficiency. The goal of the challenge is to create aerodynamic structures with strategically placed ridges or contours to reduce drag and improve performance in wind or water flow applications.

C54_Firefly-inspired LED efficiency

The primary objective of this challenge is to reduce energy consumption in lighting systems worldwide. The goal is to design a solution that enhances light output while minimising heat loss. This design will be implemented in both urban and rural lighting systems, encompassing streetlights and household applications.

S54_Firefly-inspired LED efficiency

The microstructures on firefly lanterns prevent internal reflection and maximise light output. The challenge aims to develop lighting solutions with surface textures or materials that reduce energy loss and enhance brightness. Focus on optimising angles and reflectivity. Designers could improve brightness in energy-efficient LEDS for homes and vehicles or create outdoor lighting systems with minimal energy loss.

C55_Moth eye-inspired anti-reflective coatings

The primary objective of this challenge is to enhance visibility and efficiency in optical devices and energy systems. The result of this challenge should be a design that reduces glare in devices and enhances light absorption in solar panels. This design could be implemented in various devices, including smartphones, tablets, and outdoor solar installations.

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S55_Moth eye-inspired anti-reflective coatings

Moth eyes have nanoscale structures that minimize glare and reflection, allowing them to see clearly in low light. The challenge is to design surfaces with nano-patterned coatings to minimize reflection and enhance clarity in optical devices, displays, or solar panels. For example, solutions may apply coatings to reduce glare on smartphone screens or improve the efficiency of solar panels by reducing reflection.

C56_Kingfisher-inspired bullet trains

The primary objective of this challenge is to minimise noise pollution and improve train speed efficiency. The goal is to design a solution that ensures high-speed trains operate efficiently and quietly. This design could be implemented on high-speed rail networks in densely populated regions.

S56_Kingfisher-inspired bullet trains

The pointed beak of the kingfisher reduces the shockwave created when diving into water, enabling silent and efficient motion. The challenge's goal is to design transportation systems with tapered shapes to minimise noise and energy loss, improving efficiency in high-speed travel or underwater vehicles. Solutions may include quiet and efficient high-speed trains, or the concept may be adapted for use in aeroplanes or underwater vessels.

C57_Spider Silk-inspired synthetic fibres

The main goal of this challenge is to design fibres for protective gear and medical sutures. The goal is to create a design that yields durable, lightweight materials suitable for extreme conditions. The design of this challenge could be applied in various settings, including hospitals and protective clothing.

S57_Spider silk-inspired synthetic fibres

Spider silk is a protein-based fibre with a unique molecular structure that combines high tensile strength and flexibility. The challenge aims to develop lightweight, strong, and flexible materials for construction, safety gear, or medical applications, focusing on molecular alignment for durability. Solutions could include the formulation of lightweight cables for construction or the creation of medical sutures that are both strong and flexible.

C58_Boxfish-inspired car design

The primary objective of this challenge is to develop a design that enhances car designs to improve fuel economy and stability. The result of this challenge should be a design that improves aerodynamics and energy efficiency in cars. The design developed

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through this challenge could be implemented in fuel-efficient vehicles, particularly in urban and highway settings.

S58_Boxfish-inspired car design

The boxfish's streamlined body shape balances drag reduction with stability, enabling efficient movement in water. The challenge's goal is to design vehicles or structures with rounded, streamlined shapes for improved stability and efficiency in fluid or air movement. We could design compact cars with improved fuel efficiency, or we could use the shape underwater.

C59_Namib desert beetle-inspired water harvesting

The main goal of this challenge is to develop water-harvesting solutions for desert communities. The result of this challenge should be a design that increases water access in regions with limited rainfall. This design could be implemented in water-scarce areas, such as deserts.

S59_Namib desert beetle-inspired water harvesting

The Namib Desert beetle has hydrophilic (water-attracting) bumps on its back that capture moisture from fog, channelling it to its mouth. The challenge's goal is to create materials or structures with moisture-attracting surfaces for water collection in dry areas, integrating passive systems for water harvesting. We could develop portable water-harvesting devices for arid regions or integrate the devices created through this challenge into buildings for passive water collection.

C60_Pinecone-inspired building materials

The main goal of this challenge is to develop materials for passive building ventilation. The result should be a design that optimises building ventilation to reduce energy consumption. This design could be effectively implemented in urban buildings in humid or variable climates.

S60_Pinecone-inspired building materials

Pinecones open or close their scales based on humidity levels, using their structure to regulate seed dispersal. The challenge's goal is to design building materials or structures that adjust to humidity changes, improve ventilation, and reduce the need for mechanical systems in climate control. Solutions may include smart building facades that open or close based on weather conditions, or utilise the designs created through this challenge for greenhouses or climate-sensitive buildings.

C61_Energy-efficient cooling inspired by beetles

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Energy-intensive cooling systems are widespread and contribute significantly to greenhouse gas emissions. In regions with hot climates, passive cooling is critical, especially where energy infrastructure is lacking. Biomimetic inspiration from beetles, such as the Namib Desert beetle, which captures moisture and regulates body temperature, offers a pathway to sustainable cooling.

S61_Passive cooling system inspired by desert beetles

The Namib Desert beetle manages heat and water loss using unique physical adaptations. For instance, it uses a combination of hydrophilic bumps and hydrophobic channels on its back to collect and funnel water from morning fog. Additionally, some beetles regulate body temperature through reflective shell coatings, behavioural shading, or microstructural surface adaptations that minimize heat absorption.

C62_Efficient underwater propulsion systems

The result of this challenge should be a design that provides smooth, energy-efficient propulsion in underwater environments, minimises noise to avoid disrupting marine life or detection and allows precise manoeuvring in tight or complex spaces. Traditional propeller-driven systems create noise and turbulence, disturbing ecosystems and reducing energy efficiency. In contrast, natural swimmers like manta rays achieve silent, graceful, and highly efficient propulsion.

S62_Manta ray-inspired underwater propulsion

Manta rays and similar marine animals propel themselves using undulating fin movements, generating thrust with minimal turbulence. Their flexible, wing-like pectoral fins allow silent, stable, and energy-efficient gliding through water. Experts turn to nature for inspiration to offer a solution to this challenge, specifically drawing on manta rays, stingrays, and eagle rays, as well as cephalopods like squids and octopuses, and fish like tuna and eels.

C63_Self-healing building materials

Infrastructure deteriorates over time due to weather, mechanical stress, and ageing. Traditional maintenance is costly and disruptive. In contrast, biological systems like bones or tree bark naturally repair themselves. Inspired by this, self-healing building materials could revolutionise long-term resilience in urban environments.

S63_Bio-inspired self-healing concrete

Nature responds to damage through autonomous repair mechanisms, like human bones regenerating fractures via mineral deposition; skin closing wounds through cellular signalling and plants sealing bark wounds with resins. Bacteria-activated *healing, as seen in some microbial interactions, where calcite-producing bacteria fill voids in living systems. Develop concrete embedded with capsules or spore-forming bacteria that release calcite or binding polymers when cracks form and moisture enters, effectively healing the structure before significant damage occurs.*

C64_Bio-inspired anti-fouling surfaces

Traditional anti-fouling paints rely on heavy metals and toxins, harming marine life and ecosystems. Nature offers clean, passive resistance strategies, such as the microstructured surface of shark skin, that deter the attachment of microorganisms without harming the environment. The result of this challenge should be a design that prevents the settlement of algae, barnacles, or bacteria; eliminates or minimises the use of toxic coatings or cleaning chemicals; and is adaptable to ships, offshore structures, medical devices, or water systems.

S64_Shark-skin inspired anti-fouling surfaces

Sharks avoid biofouling without the use of secretions or chemicals. Their skin is covered in microscopic riblet structures (dermal denticles) that create a rough, flowing surface, preventing microorganisms from settling. Experts turn to nature for inspiration to offer a solution for this challenge, more specifically to shark skin because of its ribbed texture that prevents attachment, dolphin skin because it's constantly regenerating and has low friction, lotus leaves because of its superhydrophobic and self-cleaning properties and fish scales because they're flexible and protective.

C65_Bio-inspired urban air purification

Air pollution is a growing concern in densely populated cities. Forests provide a proven model for passive, chemical-free air purification. Translating these natural principles into the built environment can enhance liveability and sustainability.

S65_Forest-inspired urban air filtration

The result of this challenge should be a design that removes air pollutants passively using forest-mimicking surfaces; functions in dense urban environments, and improves human health and biodiversity. Experts turn to nature for inspiration to offer a solution for this challenge, more specifically to forests, because leaves capture dust, bark and soil bacteria break down pollutants, mosses and lichens absorb heavy metals and fine particles, and epiphytes like ferns grow vertically and filter air and soil microbiomes, transforming harmful gases into nutrients.

C66_Bio-inspired noise-reducing structures

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Noise pollution affects health, concentration, and social behaviour. Traditional soundproofing relies on dense, synthetic materials. In contrast, owls and other animals have evolved physical adaptations for silent flight and sound dampening, which can inspire quiet architectural elements. The result of this challenge should be a design that reduces or absorbs noise, is adaptable to indoor and outdoor environments, and offers scalable, energy-efficient solutions without the use of power-consuming tech.

S66_Owl feather-inspired acoustic panels

Experts turn to nature for inspiration to offer a solution for this challenge, more specifically to owl feathers, which possess fringe-like structures on the leading and trailing wing edges that scatter air turbulence and suppress sound. Additionally, pine trees and bamboo are considered, as they absorb and diffuse wind-generated sound through their flexible, porous canopies. Furthermore, mosses and ferns are also considered due to their soft, layered structures that absorb vibration and noise.

C67_Bio-inspired anti-icing surfaces

The main goal of this challenge is to create passive, non-toxic, and energy-efficient anti-icing surfaces that reduce ice build-up for applications in transportation, infrastructure, and public safety. Traditional de-icing methods (e.g., heaters, salt, glycol sprays) are energy-intensive, polluting, or damaging. Nature offers passive, durable alternatives, such as the micro/nanostructures on lotus leaves or the feather microstructure of penguins, that resist water retention and ice adhesion.

S67_Lotus leaf and penguin feather-inspired anti-icing surfaces

Experts turn to nature for inspiration to offer a solution for this challenge, more specifically to lotus leaf because of its superhydrophobic micro/nano structures that cause water to bead up and roll off, preventing freezing; penguin feathers because of their overlapping barbs that trap air and reduce contact with water, limiting freezing and promoting rapid drying; butterfly wings and springtail skin because they repel moisture through patterned scales and roughness.

C68_Bio-inspired water-repellent textiles

The primary objective of this challenge is to design nontoxic, durable, and breathable water-repellent textiles by mimicking the structures and functions found in nature. The resulting design should repel water passively, even under light pressure or exposure, maintain breathability and softness, and avoid the use of perfluorinated chemicals (e.g., PFAS).

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S68_Lotus leaf and butterfly wing-inspired water-repellent textiles

Experts turn to nature for inspiration to offer solutions for this challenge, more specifically to lotus leaves because they have micro-papillae covered in nanostructures that trap air and reduce water contact; butterfly wings because their scales form patterns that create superhydrophobicity and iridescence; duck feathers because water rolls off thanks to their layered, waxy barbs; and spider silk because it features beads and channels that direct water away.

C69_Enhancing wind turbine efficiency with biomimicry

The primary objective of this challenge is to enhance wind turbine efficiency and reliability by mimicking biological adaptations that improve lift and reduce drag in unsteady flow environments. The result of this challenge should be a design that maximises aerodynamic lift and torque, operates more efficiently in low-wind and turbulent conditions, and reduces mechanical noise and vibration.

S69_Whale-inspired wind turbine blades

Experts turn to nature for inspiration to offer solutions for this challenge, specifically drawing on the humpback whale's flippers, which feature tubercles on their leading edges, creating alternating pressure zones that increase lift and delay stall. Bird wings also adjust their shape dynamically for efficient gliding or flapping, and fish fins, with their passive flexibility, enhance propulsion and steering.

C70_Reducing microplastic pollution using biomimicry

The primary objective of this challenge is to develop passive, scalable, and eco-friendly systems for capturing and removing microplastic particles from freshwater and marine ecosystems. The outcome of this challenge should be a design that captures microplastic particles (sizes <5 mm), minimises the introduction of new pollutants or the requirement for high energy, and is adaptable to urban water treatment or coastal defence systems.

S70_Bio-inspired by mussels' microplastic filtration

Experts turn to nature for inspiration to offer solutions for this challenge, more specifically to mussels because they filter out particles and secrete sticky threads (byssus) to anchor and trap; sponges because they filter water through porous canals using passive flow and choanocytes; and oysters and clams because they trap suspended solids while protecting themselves. Additionally, mangrove roots and seagrass trap debris in natural fibre webs.

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3.2 Let's Mimic case studies summaries

CS1_Self-cleaning, long-lasting solar panel

The design needs to maintain high solar panel efficiency by preventing or removing surface build-up that reduces light absorption over time; prevent dust, sand, and pollutants from accumulating on the surface to avoid frequent drops in energy output; respond to environmental conditions by initiating cleaning or protective measures automatically, even in locations with minimal human maintenance; extend the operational life of the panels by reducing wear and tear that traditional cleaning methods might cause; function across diverse climates, including arid, polluted, or remote areas, without relying heavily on water, energy, or regular maintenance.

CS2_Self-non-toxic antifouling solutions for ships

The design must prevent marine life, such as algae, barnacles, and mussels, from adhering to ship hulls. This could avoid the discharge of hazardous chemicals into the ocean and minimise drag, increasing ships' fuel efficiency. The design will be used in global ocean environments, including commercial shipping routes, port areas, and coastal waters.

CS3_Self-healing road infrastructure.

Roads capable of self-repairing minor cracks and damage must be designed. As a result, roads would last longer, be safer, and require less regular maintenance. The road surface could self-heal by employing self-healing materials, thereby avoiding cracks, reducing repair expenses, and minimising disruptions. This design will be applied to urban and rural roads, highways, and other paved areas where heavy traffic and weather lead to frequent wear and tear. Roads in areas with extreme climates are especially vulnerable and would benefit from self-healing technology.

CS4_Waste-free packaging alternatives

The design must include packaging that preserves the product while generating no waste after use. This could imply designing packaging that can be completely recycled, reused, or even composted. The objective is to protect goods during storage and transportation while ensuring that packaging doesn't contaminate the environment or wind up in landfills.

CS5_Efficient micro-plastic removal from oceans

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The design must detect and remove microplastic particles from the ocean water. Despite being too small to see, these particles have a significant negative impact on ocean health and marine life. The solution must particularly target microplastics without harming fish, plants, or other aquatic life. It must also be effective and operate on a broad scale to have a significant effect.

CS6_Sustainable light production without electricity

The design needs to provide a source of light that doesn't use electricity or require a connection to the power grid. It should be safe, long-lasting, and ideally work in any environment. This type of light could be beneficial in areas without reliable electricity or during emergencies when power is unavailable. The design of this challenge could be utilised in off-grid locations, disaster areas, outdoor spaces, and environmentally conscious residences worldwide, which could all benefit from the idea.

CS7_Safe and silent wind energy generation for urban areas

The design must produce wind energy systems that generate power from the wind in metropolitan locations while avoiding noise pollution or safety issues. These systems must be effective, blend seamlessly with the urban environment, and function well in urban settings where wind patterns can change suddenly. The objective is to make wind energy a practical choice for urban areas, offering a sustainable and clean energy source that does not interfere with day-to-day activities.

CS8_Wildfire prevention and early detection

The design must prevent wildfires from starting or identify them in their early stages, allowing them to be contained quickly. This entails developing systems that can monitor things, detect fire threats, and notify people before a fire gets out of control. The objectives are to reduce wildfires, minimise damage, and safeguard people, property, and ecosystems.

CS9_Urban flood management systems

The design should assist cities in controlling or reducing floods during large rainstorms by identifying safe ways to manage excess water. These might include devices that absorb water, reduce its flow, or divert it from potentially troublesome regions. The objective is to prevent flood damage to houses, businesses, streets, and neighbourhoods.

CS10_Enhanced medical diagnostic tools

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The design must make medical instruments more precise, quick, and user-friendly to help physicians identify illnesses. Better methods of disease testing, systems that display results quickly, or instruments that can detect diseases even in their early stages could all fall under this category. The intention is to improve health outcomes by providing physicians and healthcare teams with the information they need to treat patients more quickly and efficiently.

CS11_Microplastic pollution in oceans prevention

The primary objectives of this challenge are to prevent microplastics from entering aquatic ecosystems and to develop a scalable, low-maintenance solution. The design must capture microplastics from wastewater systems or other sources before they reach natural water bodies. The solution will be primarily implemented in industrial wastewater treatment plants, residential washing machines, and urban drainage systems, with a particular focus on coastal areas that experience significant plastic waste leakage.

CS12_Urban flooding management

The primary objective of this case study is to mitigate the risk of urban flooding during extreme weather events, to promote water infiltration and retention in urban areas, and to deliver a scalable, cost-effective solution that seamlessly integrates into existing urban infrastructure. The design should emulate natural water retention and drainage systems that efficiently absorb excess rainwater, thereby reducing the need for expensive and extensive infrastructure upgrades, such as large-scale stormwater tunnels or reservoirs.

CS13_Reducing noise pollution in urban areas

The primary objective of this case study is to mitigate the effects of noise pollution in urban areas, particularly in residential zones, schools, and healthcare facilities. It aims to deliver a cost-effective and scalable solution that integrates seamlessly with city infrastructure and ensures the solution supports overall environmental and public health objectives. The design should mimic natural sound-dampening systems that absorb or block unwanted noise. The solution should provide a passive, low-maintenance approach to reducing sound pollution in various urban settings, including streets, parks, and buildings.

CS14_Optimising water management in agriculture

The primary objective of this case study is to create an irrigation system that reduces water wastage and increases efficiency, develop a scalable solution that can be implemented in different agricultural settings, particularly in regions with water scarcity, and minimise the environmental impact and cost of water usage in farming.

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The design should mimic natural water distribution and conservation strategies. The solution should enhance water retention in the soil and ensure even water distribution to crops, thereby reducing reliance on extensive irrigation systems.

CS15_Reducing industrial energy consumption

The primary objective of this case study is to reduce energy consumption in industrial operations, enhance energy efficiency by emulating natural systems, and lower carbon footprints and operational costs through sustainable energy solutions. The design should mimic the energy-efficient mechanisms found in nature, such as heat regulation in animals, energy conservation in plants, or optimal movement in animals. The solution should minimise energy waste, reduce carbon emissions, and adapt to different industrial processes.

CS16_Wastewater treatment and resource recovery

The primary objective of this case study is to reduce the energy footprint of wastewater treatment processes, enable the recovery of valuable resources (water, nutrients, and energy) from wastewater, and improve the sustainability of wastewater treatment by mimicking nature's recycling and purification processes. The solution would primarily be applied to municipal and industrial wastewater treatment plants. It could also be extended to agricultural wastewater management systems, where water quality and resource recovery are critical concerns. Urban and rural areas with growing water scarcity and environmental concerns are key focus regions.

CS17_Sustainable cooling inspired by nature

The primary objectives of this challenge are to develop a sustainable cooling solution that minimises energy consumption and eliminates the use of harmful refrigerants. The design must replicate natural cooling methods to regulate indoor temperatures in residential, commercial, and industrial buildings. The solution should be applicable in both urban and rural areas with high temperatures, particularly in regions prone to heat waves. It should also align with modern building standards.

CS18_Preventing soil erosion in agriculture

The primary goals of this challenge are to stabilise soil and maintain its fertility, prevent loss due to wind or water erosion; to develop a cost-effective and eco-friendly solution suitable for farmers worldwide; and to minimise environmental impact while preserving long-term soil health. The solution primarily targets regions prone to soil erosion due to heavy rains, droughts, or overcultivation, and is applicable to diverse agricultural settings, ranging from smallholder farms in developing countries to large-scale agricultural operations in industrialised nations.

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CS19_Improving urban noise reduction

The primary objectives of this challenge are to mitigate the impact of noise pollution on human health and well-being, design sustainable and aesthetically pleasing noise-dampening systems for urban areas, and develop a solution that integrates seamlessly into existing urban infrastructure. The design must effectively absorb or diffuse sound, reducing noise levels in urban environments, while being sustainable, cost-effective, and easy to implement in diverse urban contexts.

CS20_Enhancing water desalination efficiency

The primary objective of this case study is to develop an energy-efficient desalination process that minimises environmental impact, particularly brine discharge. It provides an affordable and scalable solution for water-scarce regions. The design must effectively remove salt from seawater while using minimal energy and ensure the process is environmentally sustainable, with no harmful brine discharge. The solution would target water-scarce regions globally, particularly in areas where current desalination processes are cost-prohibitive or ecologically damaging.

CS21_Efficient heat dissipation in electronics inspired by nature

The primary objective of this case study is to develop a bio-inspired solution for heat management in electronics, enhance energy efficiency, mitigate the risk of overheating in electronic devices, and create a design that is sustainable, scalable, and compatible with diverse electronic applications. This solution can be implemented globally in the electronics industry, addressing challenges in both high-tech sectors and emerging markets. Effective heat dissipation improves device efficiency, prolongs usability, and supports environmental sustainability.

CS22_Nature-inspired solutions for reducing urban heat islands

The primary objective of this case study is to develop bio-inspired designs that reduce heat absorption and enhance cooling in cities, to increase the use of sustainable and eco-friendly materials and techniques in urban planning, and to improve the quality of life for city dwellers by creating cooler, more livable environments. The design must reduce heat absorption in urban areas by utilising bio-inspired materials, structures, or landscaping methods, while also enhancing natural cooling through shading, wind flow optimisation, or water retention. Furthermore, it must be practical, scalable, and sustainable for urban planners and developers to implement.

CS23_Anti-reflective surfaces for enhanced solar panel efficiency

Solar panels convert sunlight into electricity but lose efficiency due to reflection, especially during low-angle sunlight conditions or in cloudy weather. Creating

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anti-reflective surfaces can optimise light absorption, increase energy output, and make solar power more cost-effective and sustainable. The design of this challenge needs to reduce the amount of light reflected off solar panel surfaces, be durable and functional in various weather conditions, and be compatible with existing solar panel manufacturing processes.

CS24_Bio-inspired traffic flow optimisation in smart cities

Traffic congestion is a significant issue in modern cities, leading to wasted time, increased pollution, and economic losses. Natural systems demonstrate remarkable efficiency in managing large-scale movement without collisions or bottlenecks. Mimicking these systems can help create more intelligent, more responsive traffic networks.

CS25_Improved structural stability for bridges using biomimicry

Bridges are critical infrastructure that must endure heavy loads, dynamic forces, and environmental challenges like wind, floods, and earthquakes. Inspired by nature's efficient designs, such as the internal structure of bones or the branching patterns of trees, we can create lightweight and highly resilient bridges.

CS26_Sustainable water transportation methods inspired by marine life

Food storage and refrigeration systems are critical for preventing spoilage and reducing waste. However, they are energy-intensive and often rely on materials or processes with a high environmental impact. Natural insulation mechanisms—such as polar bears' hollow fur or birds' layered feathers—can inspire designs that enhance thermal performance and sustainability.

CS27_Enhanced food storage systems with nature-inspired insulation

Food storage and refrigeration systems are critical for preventing spoilage and reducing waste. However, they are energy-intensive and often rely on materials or processes with a high environmental impact. Natural insulation mechanisms—such as polar bears' hollow fur or birds' layered feathers—can inspire designs that enhance thermal performance and sustainability. The solution is applicable globally, particularly in regions with high energy costs, hot climates, or underdeveloped cold chain systems.

CS28_Nature-inspired methods to reduce urban light pollution

Light pollution disrupts ecosystems, affects human health, and obscures the night sky. Urban lighting systems often prioritise brightness over efficiency, leading to unnecessary light scatter and energy wastage. Nature offers models for efficient light

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management, such as the directional bioluminescence of fireflies or the reflective structures in the eyes of nocturnal animals.

CS29_Anti-erosion techniques for coastal protection based on mangroves

Coastal erosion threatens communities, ecosystems, and economies worldwide. Mangroves' dense root systems and ability to dissipate wave energy naturally protect coastlines while supporting rich biodiversity. However, mangrove deforestation and human activities have reduced these natural defences. Biomimetic solutions can recreate the protective benefits of mangroves in areas where restoring them may not be immediately feasible.

CS30_Durable, lightweight exoskeletons for worker safety

Many industries, including construction, manufacturing, and healthcare, require workers to perform repetitive, physically demanding tasks, which can lead to fatigue, injuries, and long-term health issues. Inspired by natural exoskeletons found in insects and crustaceans, biomimetic designs can create robust yet lightweight systems that assist workers in handling heavy loads and repetitive motions safely and effectively.

CS31_Develop the smallest, lightest, fastest

The primary objective of this case study is to design efficient and cooperative robots that can operate in demanding environments or address issues such as warehouse monitoring, gas leak detection, and pest detection in greenhouses. The design must enable tiny robots to navigate efficiently over long distances with minimal computational power by mimicking ants' pheromone trail-following behaviour. These robots must exhibit cooperative behaviours, working together seamlessly to achieve tasks and be versatile enough to handle various applications, such as warehouse monitoring, gas leak detection, and pest detection in greenhouses.

CS32_Create a new rigid, flexible, and highly protective armour

The primary objective of this case study is to develop lightweight, flexible, and highly protective armour that can adapt to various threats and potentially have applications in high-risk fields. The design aims to provide high levels of protection while maintaining mobility and comfort, making it suitable for soldiers, law enforcement, and civilians in high-risk environments.

CS33_Design a digital mobile phone camera with a wide-angle

The primary objective of this case study is to deliver high-quality and versatile imaging experiences for both casual and professional mobile phone users, including those utilising augmented reality applications. The design aims to overcome limitations of

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mobile phone cameras in terms of narrow fields of view, motion blur, and wide-angle distortion, making it more suitable for casual and professional use.

CS34_Create an online algorithm for more efficient transportation routes

The primary objective of this case study is to develop a self-organising online routing system that efficiently manages the dynamic complexity of individual vehicle traffic in large-scale traffic systems. The design aims to reduce traffic congestion, thereby minimising economic and ecological costs. A proposed solution is a self-organising online routing system that utilises autonomous agents (navigators) to coordinate area information through a multi-layer communication structure.

CS35_Create a new self-cleaning, antibacterial and waterproof surface

The primary objective of this case study is to develop surfaces that replicate the self-cleaning properties of specific creatures and plants, thereby reducing microbial contamination and the need for maintenance. The design must address the issue of microbial contamination, minimise the requirement for frequent cleaning and the use of harsh chemicals, and prevent frost and moisture accumulation on surfaces.

CS36_Design a micro-drone that can be carried

The primary objective of this case study is to develop a portable micro-drone that combines a substantial operational range with the ability to handle turbulent wind conditions effectively. The design aims to enhance wind stability, optimize power efficiency with cutting-edge materials and power systems, ensure portability by being lightweight and compact, and adapt to various applications such as emergency response, military operations, environmental monitoring, agriculture, and recreational activities.

CS37_Create a soft power cell device that could power artificial human organs

The primary objective of this case study is to develop safer, biocompatible power sources for medical implants. The design must be flexible, safe for use within the human body without causing adverse reactions, and capable of harnessing chemical energy from biological systems, thereby eliminating the toxicity, bulk, and frequent recharging associated with traditional batteries.

CS38_Design a non-disruptive and energy-efficient underwater robot

The primary objective of this case study is to develop advanced underwater robots that can effectively sample and transport organisms and litter from waterbodies, to aid in environmental protection and pollution mitigation. The design must ensure flexibility *and agility to navigate complex terrains and access hard-to-reach areas, while operating quietly to minimise disturbance to marine life. These robots should efficiently collect samples of organisms and litter without causing harm, and be constructed from durable, environmentally friendly materials to withstand harsh conditions and minimise ecological impact.*

CS39_Develop a new space x-ray telescope

The primary objective of this case study is to significantly enhance our ability to study gravitational wave sources and contribute to a deeper understanding of the universe. The design needs to capture a wide field of view and focus light from a broad area into a single image to detect transient astronomical events with high sensitivity and resolution. Additionally, the design must enable the telescope to continuously survey the entire sky in X-rays, allowing for the identification and monitoring of transient events.

CS40_Create a super elastic material

The primary objective of this case study is to develop a super-elastic material suitable for thermal insulation. This material should ideally combine the properties of elasticity, lightweight, and practical thermal insulation. The design needs to ensure adequate thermal insulation while maintaining super-elastic properties for flexibility and durability in various applications. Additionally, it should be lightweight for ease of use in garments and other portable items. Furthermore, it should be durable and washable, retaining its insulating properties after washing.

CS41_Create a tough adhesive for diverse wet surfaces

The primary objective of this case study is to develop a robust adhesive that can effectively bond to various wet surfaces. The design must enable an effective bond to damp surfaces without compromising strength, be non-toxic and safe, and remain flexible and stretchy. Scientists have developed a super-strong surgical adhesive inspired by the slime of the garden slug, Arion subfuscus. This adhesive, composed of a gummy-like gel and a glue inspired by the slug, is non-toxic, stretchy, sticky in wet environments, and strong enough to hold onto a beating heart, allowing it to stay in place and absorb body movements without tearing. It offers a less painful alternative to stitches and promotes healing.

CS42_Coordinated robot swarm

The primary objective of this case study is to develop a swarm of robots that can autonomously and efficiently coordinate their movements in dynamic and challenging environments. The design must enable a swarm of simple robots to coordinate their movements in dynamic environments without relying on a central control system. It

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must ensure energy efficiency, responsiveness to environmental changes, and effective collision avoidance, all while maintaining autonomy.

CS43_Tangle-proof grooming brush

The primary objective of this case study is to develop a brush that effectively detangles hair without causing pain or breakage, while addressing user comfort, safety, market demand, environmental sustainability, and the diverse needs of various users and settings. The challenge is situated within the broader context of enhancing the grooming experience for pets and individuals with long hair, considering key aspects such as user comfort, detangling effectiveness, material safety, market demand for innovative grooming tools, environmental sustainability, and the diverse needs of different users and settings.

CS44_A better sewage treatment

The primary objective of this case study is to develop a robust, efficient, and sustainable solution for removing microplastics from sewage treatment plants, effectively capturing and removing microplastics of various sizes and types, and minimising environmental and health risks associated with microplastics. The challenge arises from the increasing presence of microplastics in the environment, which conventional sewage treatment processes do not effectively remove. Microplastics can originate from various sources, including synthetic textiles, personal care products, and industrial processes. They pose significant risks to aquatic life and human health as they can accumulate in the food chain.

CS45_Sunblock-inspired by compounds in our eyes

The primary objective of this case study is to minimise the environmental footprint by focusing on biodegradable ingredients, eco-friendly packaging, and sustainable production practices. This approach utilises biodegradable ingredients that do not harm terrestrial and marine life. The context of the challenge lies at the intersection of several growing global trends and concerns, which include health and wellness, environmental sustainability, skin inclusivity, and consumer demand for more ethical products. These broader themes shape the need for innovative, effective, eco-friendly sun protection products.

CS46_Developing more energy-efficient artificial light sources

The primary objective of this case study is to reduce the environmental footprint of artificial lighting, including the materials used and the energy consumed. The context of this challenge is framed against the backdrop of rising global energy consumption and growing environmental concerns. With the increasing demand for sustainable

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practices, this challenge addresses the urgent need for more energy-efficient and environmentally friendly lighting solutions.

CS47_High-performance materials for industry innovation

The main goal of this challenge is to find a way to combine wood's sustainability with composite materials' functionality and versatility. This would allow for more innovative and fluid architectural designs while maintaining wood's environmental benefits. Essentially, it's about creating construction materials that are both eco-friendly and capable of supporting complex, resilient structures.

CS48_Smart fishing nets to avoid capturing threatened species

The primary objective of this case study is to develop and deploy smart fishing nets equipped with advanced sensors inspired by nature that can accurately identify and avoid capturing threatened species in real-time. This technology aims to significantly reduce bycatch, enhance the sustainability of fishing practices, and protect marine biodiversity by ensuring that only target species are captured. In contrast, non-target and endangered species are safely guided away from the nets.

CS49_Miniaturized and light-weight sensors to assist unmanned underwater vehicles

The primary objective of this case study is to develop advanced unmanned underwater vehicles (UUVS) that can efficiently navigate and operate in confined, hazardous underwater environments. These UUVs should be capable of performing detailed inspections and maintenance tasks, thereby improving operational efficiency and reducing the risks associated with human intervention.

CS50_Enhancing aeroplane gliding efficiency to reduce greenhouse gas emissions

The primary objective of this case study challenge is to reduce greenhouse gas emissions from aviation by enhancing the efficiency of aeroplanes' gliding. This involves optimising flight operations to minimise fuel consumption, contributing to a more sustainable and environmentally friendly aviation industry. Globally, air travel accounts for approximately 2.5% of total carbon dioxide (CO_2) emissions. Transportation emissions, specifically aviation, account for approximately 11.6% of the total emissions. Although not the largest contributor, aviation remains a significant contributor to transportation-related emissions.

CS51_Affordable carbon capture and storage

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The primary objective of this case study is to develop a scalable and affordable carbon capture solution for industrial and urban settings. In response to this challenge, we aim to create a method that captures CO_2 while utilising minimal energy and resources. The design of this challenge could be effectively implemented in industrial zones and urban areas with high air pollution levels.

CS52_Efficient vertical farming for urban food production

The primary objective of this case study is to reduce energy and water consumption in vertical farming systems. The design needs to provide effective pest control without ecological harm. The design of this challenge could be implemented in diverse farming environments, from small farms to industrial agriculture.

CS53_Eco-friendly pest control

The primary objective of this case study is to minimise crop losses while reducing chemical pesticide use. The goal is to design a system that provides effective pest control without ecological harm. This design could be implemented in diverse farming environments, from small farms to industrial agriculture.

CS54_Sustainable building materials inspired by nature

The primary objective of this case study is to develop building materials that reduce reliance on non-renewable resources while enhancing efficiency and longevity. The goal is to create a design that offers an alternative to traditional, resource-intensive construction materials. This design could be implemented in residential and commercial construction sites worldwide.

CS55_Increasing the efficiency of light-emitting devices while reducing energy waste

The primary objective of this case study is to reduce energy consumption in lighting systems globally. The result of this challenge should be a design that provides an alternative to traditional, resource-intensive construction materials. This design could be implemented in residential and commercial construction sites worldwide.

CS56_Reducing glare and improving visibility in optical devices and solar panels

The primary objective of this case study is to develop a design that increases visibility and efficiency in optical devices and energy systems. The resulting design should reduce glare in devices and improve light absorption in solar panels. This challenge's design could be implemented in various devices, including smartphones, tablets, and outdoor solar installations.

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CS57_Renewable energy harvesting from slow-moving water

The primary objective of this case study is to develop low-impact, efficient systems for harnessing energy from slow-moving rivers and streams. The result should be a design that meets energy demands in regions lacking high-flow water bodies while preserving aquatic ecosystems. The design of this challenge could be implemented on small rivers, canals, and irrigation systems in energy-scarce regions.

CS58_Lightweight, durable materials for space exploration

The primary objective of this case study is to enhance material performance under extreme conditions while reducing launch costs. The result should be a design that provides innovative materials for space exploration. The design of this challenge could be implemented in spacecraft, space habitats, and extraterrestrial environments.

CS59_Smog-reducing urban infrastructure

The primary objective of this case study is to reduce smog levels in urban environments through biomimetic design. The outcome of this challenge should be a design that addresses air pollution in cities with high vehicular emissions and industrial activity. The design of this challenge could be effectively implemented in High-density urban areas with poor air quality.

CS60_Bio-inspired solutions for efficient cargo movement

The primary objective of this case study is to reduce energy consumption in cargo transport and increase efficiency. The result should be a design that optimizes logistics for large-scale cargo movement while reducing emissions. The design of this challenge could be implemented on global shipping routes, including land, sea, and air.

CS61_Passive cooling for urban homes inspired by termite mounds

The primary objective of this case study is to create lightweight, flexible, and highly protective armour that can adapt to various threats and potentially have applications in high-risk fields. The design aims to provide high levels of protection while maintaining mobility and comfort, making it suitable for soldiers, law enforcement, and civilians in high-risk environments.

CS62_Preventing landslides inspired by tree root systems

The primary objective of this case study is to develop a structural system or surface treatment that mimics root systems to anchor soil on steep slopes and prevent landslides, especially in vulnerable or deforested areas. Landslides are a significant hazard in mountainous or deforested regions, causing loss of life, damage to infrastructure, and environmental degradation. Trees naturally stabilise soil with their *root networks. In many degraded environments, reforestation is too slow or impossible due to terrain or weather.*

CS63_Reducing vehicle drag using boxfish-inspired aerodynamics

The primary objective of this case study is to create an energy-efficient vehicle body design that minimises drag and turbulence while maximising stability, inspired by the boxfish's hydrodynamic properties. Aerodynamics plays a crucial role as the automotive industries strive for greater energy efficiency and reduced emissions. Streamlined, nature-inspired vehicle designs can reduce drag and improve fuel economy. Despite its angular shape, the boxfish demonstrates low drag and high stability due to unique flow dynamics around its body.

CS64_Anti-clogging medical stents inspired by shark skin

The primary objective of this case study is to develop medical stents with passive, drug-free surface structures inspired by shark skin to reduce the risk of clogging, bacterial growth, and complications in long-term use. Stents and catheters are commonly used medical devices that can become blocked by biological buildup. Current solutions use drug-eluting coatings, which may cause resistance or complications. In nature, shark skin prevents microbial build-up via a pattern of tiny, diamond-shaped scales (dermal denticles) that disrupt bacterial attachment.

CS65_Earthquake-resilient buildings inspired by bamboo flexibility

The primary objective of this case study is to develop building structures that flex and absorb seismic energy, reducing collapse risk, inspired by the segmented, flexible, and strong morphology of bamboo culms. Conventional buildings often fail under seismic stress due to their rigidity. In contrast, bamboo sways and bends during strong winds or tremors, reducing stress concentrations. Its natural segmentation, hollow structure, and fibre-reinforced nodes offer a model for designing earthquake-resilient structures that bend rather than break.

CS66_Pollution-filtering urban walls inspired by coral reefs

The primary objective of this case study is to develop multifunctional urban walls or facades that capture air and water runoff pollutants through coral-inspired surface complexity and bioactivity, improving urban environmental quality. Urban areas are affected by high levels of airborne and waterborne pollutants, often with limited space for traditional filtration systems. Coral reefs passively filter water, trap sediments, and even host microbes that break down contaminants. Urban architecture can adopt these design strategies to purify runoff and improve air quality with minimal energy use.

CS67_Noise-reducing barriers inspired by owl feathers

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The primary objective of this case study is to create passive acoustic barriers or panels that dampen environmental noise using surface structures inspired by the microgeometry of owl feathers. Noise pollution from traffic, trains, airports, and construction sites negatively impacts human health and quality of life. Traditional sound barriers are often bulky, unattractive, or ineffective at high frequencies. Owls use a combination of serrated leading edges, velvety surfaces, and fringed trailing edges on their wings to fly silently, offering a natural blueprint for sound-dampening design.

CS68_Light-capturing solar panels inspired by butterfly wings

Conventional photovoltaic (PV) panels lose efficiency under low light, shade, or oblique sun angles. Butterflies—especially species like the blue morpho—have evolved complex wing microstructures that scatter, trap, or manipulate light for visibility and heat absorption. These same principles can enhance light capture in solar panels, improving energy yields in real-world conditions.

CS69_Self-cleaning textiles inspired by lotus leaves

Washing textiles contributes to water consumption, chemical runoff, and microplastic pollution. Lotus leaves repel dirt and water by combining micro- and nano-scale surface textures with hydrophobic wax coatings. Mimicking this strategy could help create eco-friendly, low-maintenance clothing and technical fabrics for various applications.

CS70_Algae-inspired water collection in arid regions

Water scarcity is one of the most urgent global challenges, particularly in desert and mountain communities where groundwater and rainfall are unavailable. Algae (and other extremophile organisms) have evolved surface structures and hydrophilic molecules that allow them to collect water from the air and retain it for survival.

3.3 Synthesis of Let's Mimic topics

This section groups nature-inspired challenges and solutions by thematic area. The topics are organised to facilitate the effective integration of the SRL units into the Let's Mimic digital learning platform for biomimicry. The topics will be used as tags to facilitate access and support the planning of SRL activities in everyday formal and informal learning practices.

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3.2.1 Challenges and solutions

1. Architecture and infrastructure

Challenge identified	Nature solution
C03_Building design for efficient cooling and ventilation	S03_The termite mounds' tunnels
C16_A sustainable and more efficient agriculture for self-sustaining crop production	S16_Mimicking prairie ecosystems
C18_Filtering plastic pollution	S18_Food filtering of manta ray
C21_Self-healing concrete	S21_Natural bone healing through osteoblastic mineralization
C31_Efficient water Harvesting in arid environments	S31_The beetles that drink water from the air
C33_Efficient wastewater treatment in urban areas	S33_Mussel-inspired adhesive filters
C40_Designing efficient filtration systems	S40_Inspiration from the sieve-like structure of the whale's baleen
C41_Eco-friendly noise reduction in urban spaces	S41_Nature noise barriers
C42_Reducing water consumption in urban landscapes	S42_Cactus water storage and distribution systems
C43_Enhancing urban waste management with Biomimicry	C43_Nature recycling system
C44_Sustainable water management in urban areas	S44_Cactus water storage and distribution systems
C46_Reducing water waste in agriculture through efficient irrigation systems	S46_Nature precision irrigation system
C47_Designing structures to withstand extreme weather events	S47_Resilient structure of palm trees
C48_Enhancing building insulation inspired by nature	S48_Nature efficient insulation and thermal regulation
C49_Wastewater treatment system	S49_Natural filtration systems for purifying water
C50_Enhancing urban air quality through natural filtration systems	S50_Nature's natural air purification systems

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C52_Reducing energy consumption for heating and cooling buildings.	S52_Mimicking the natural ventilation in termite mounds enables buildings to maintain stable temperatures efficiently
C59_Collecting water in arid environments where traditional methods are ineffective	S59_The beetle's textured shell design captures moisture from fog, inspiring materials that can harvest water from the air.
C60_Creating building materials that respond adaptively to environmental moisture	S60_Pinecones' ability to open and close with humidity changes led to smart materials that support passive ventilation and energy efficiency
C65_Bio-inspired urban air purification	S65_Forest-inspired urban air filtration
C66_Bio-inspired noise-reducing structures	S66_Owl feather-inspired acoustic panels
C67_Bio-inspired anti-icing surfaces	S67_Lotus leaf and penguin feather-inspired anti-icing surfaces
C70_Reducing microplastic pollution using biomimicry	S70_Bio-inspired by mussels' microplastic filtration

2. Energy and renewable energy

Challenge identified	Nature solution
C14_Design of a sponge-like battery to support a carbon-neutral future	C14_The bone structures of mammals
C20_Hydrogen sensors powered by light	C20_The surface of butterfly wings
C26_More efficient wind power	S26_Bumps on the leading edge of the humpback whale's flipper
C27_ Efficient fog Collection	S27_Lizard-skin-inspired nanofibrous capillary network
C35_Increasing efficiency of wind turbines	S35_Shark skin to reduce drag
C37_Building energy-efficient roofs and facades	S37_Inspiration from the lotus effect
C38_Sustainable energy generation	S38_Electric eel-inspired energy storage
C45_Reducing energy consumption in industrial processes	C45_Termite mounds that regulate temperature and humidity
C53_Improving the efficiency and reducing the noise of wind turbines	S53_Adding tubercles (bumps) to turbine blades reduces drag and increases lift, enhancing performance.

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C54_Increasing the efficiency of light-emitting devices while reducing energy waste	S54_Mimicking firefly microstructures improves light output in LEDs, making them more energy-efficient.
C55_Reducing glare and improving visibility in optical devices and solar panels	S55_The nanoscale pattern on moth eyes minimises reflection, enhancing screen readability and solar panel efficiency.
C61_Energy-efficient cooling inspired by beetles	S61_Passive cooling system inspired by desert beetles
C69_Enhancing wind turbine efficiency with biomimicry	S69_Whale-inspired wind turbine blades

3. Production and manufacturing

Challenge identified	Nature solution
C01_3d Prints	S01_The secret of chameleon colour change
C02_Non-toxic pigments for sustainable industries	S02_The natural white pigment of the cyphochilus beetle
C04_Nature-inspired ceiling fans	S04_Aerodynamics of sycamore tree seeds
C05_Sustainable design for portable toilets	S05_Evapotranspiration in plants
C10_Flexible and durable backpacks	S10_Strong and durable protection: The pangolin's scale
C11_Multi-functional biodegradable shoes	S11_Biodegradability of algae organic matter
C13_Sustainable packaging	S13_How nature inspired circular economy
C19_Preservative packets to reduce waste	C19_The unique signalling substances of fruits and vegetables
C22_Velcro invention for fastening and securing almost anything	S22_Ability to grab tenaciously like a cocklebur
C23_Fastskin swimsuit	S23_Shark skin to reduce drag
C24_Stronger and tougher ceramics	S24_Inspiration from nacre of abalone, a single-shelled marine mollusc
C25_Adhesive patches that don't harm	S25_ Suckers found along the underside of octopus tentacles
C30_Heat insulation	S30_Polar-bear-inspired material
C32_Creating self-healing materials	S32_Self-healing concrete inspired by the healing process of bones
C34_Efficient and sustainable packaging	S34_Inspiration from the nacre of abalone shells

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C36_Developing more durable and lightweight structures	S36_Spider silk for high-strength fibres
C51_Creating a strong, reusable adhesive without using chemicals or leaving residue.	S51_Gecko-inspired dry adhesives solve the challenge by mimicking the microstructure of gecko feet for clean and reliable adhesion.
C57_Developing lightweight yet strong and elastic materials for protective and medical applications	S57_Synthetic fibres inspired by spider silk provide strength and flexibility ideal for sutures and body armour
C63_Self-healing building materials	S63_Bio-inspired self-healing concrete
C64_Bio-inspired anti-fouling surfaces	S64_Shark-skin inspired anti-fouling surfaces
C68_Bio-inspired water-repellent textiles	S68_Lotus leaf and butterfly wing-inspired water-repellent textiles

4. Robotics and technology

Challenge identified	Nature solution
C07_Designing more agile drones	S07_Swift and precise flight of a hummingbird
C09_Industrial CAD Design Tool	S09_Adaptive behaviour of slime moulds
C15_The original “stealth” B-2 bombers	S15_The flight of a peregrine falcon
C17_Lightweight highly efficient stealth robotic MAV	S17_The fly of a bat
C28_Accurate underwater communication	S28_ Inspiration from dolphins who can communicate complex information
C29_Camera to capture the faintest features of the galaxy	S29_Inspiration from the moths' eyes
C62_Efficient underwater propulsion systems	S62_Manta ray-inspired underwater propulsion

5. Transportation

Challenge identified	Nature solution
C06_A more fuel-efficient aircraft	S06_V Flight formation of migrating birds
C08_Fastest high-speed trains. The bullet train	S08_The kingfisher, the owl and the penguin
C12_Reflecting road studs to increase safety on public roads	S12_Cat eyes glow in the dark

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C39_Minimizing shock and vibration in transport systems	S39_The shock absorption capabilities of animal limbs
C56_Reducing noise and improving speed efficiency in high-speed trains	S56_Mimicking the kingfisher's streamlined beak allows the trains to cut through the air quietly and efficiently.
C58_Enhancing the aerodynamics and fuel efficiency of vehicles	S58_The boxfish's streamlined body shape inspired car designs that reduce drag and improve performance.

3.2.2 Case studies

Within the LET'S MIMIC project, a **case study** is defined as an example of a current, real-life problem that has not been solved and that we aim to solve through biomimicry. This section provides a summary list of case studies by thematic area.

1. **Architecture and infrastructure**

Title of case study
Self-Healing Road Infrastructure
Efficient Micro-Plastic Removal from Oceans
Wildfire Prevention and Early Detection
Urban Flood Management Systems
Microplastic Pollution in Oceans Prevention
Urban Flooding Management
Reducing Noise Pollution in Urban Areas
Optimizing Water Management in Agriculture
Wastewater Treatment and Resource Recovery
Sustainable Cooling Inspired by Nature
Preventing Soil Erosion in Agriculture
Improving Urban Noise Reduction
Enhancing Water Desalination Efficiency
Efficient Heat Dissipation in Electronics Inspired by Nature
Nature-Inspired Solutions for Reducing Urban Heat Islands
Bio-Inspired Traffic Flow Optimization in Smart Cities

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Improved Structural Stability for Bridges Using Biomimicry
Nature-Inspired Methods to Reduce Urban Light Pollution
Anti-Erosion Techniques for Coastal Protection Based on Mangroves
A better sewage treatment system
Sunblock inspired by compounds in our eyes
Efficient Vertical Farming for Urban Food Production
Eco-Friendly Pest Control
Sustainable Building Materials Inspired by Nature
Increasing the efficiency of light-emitting devices while reducing energy waste
Smog-Reducing Urban Infrastructure
Passive Cooling for Urban Homes Inspired by Termite Mounds
Preventing Landslides Inspired by Tree Root Systems
Earthquake-Resilient Buildings Inspired by Bamboo Flexibility
Pollution-Filtering Urban Walls Inspired by Coral Reefs
Noise-Reducing Barriers Inspired by Owl Feathers
Algae-Inspired Water Collection in Arid Regions

2. Energy and renewable energy

Title of case study
Self-Cleaning, Long-Lasting Solar Panels
Sustainable Light Production without Electricity
Safe and Silent Wind Energy Generation for Urban Areas
Reducing Industrial Energy Consumption
Anti-Reflective Surfaces for Enhanced Solar Panel Efficiency
Create a soft power cell device that could power artificial human organs
Affordable Carbon Capture and Storage
Reducing glare and improving visibility in optical devices and solar panels
Renewable Energy Harvesting from Slow-Moving Water
Light-Capturing Solar Panels Inspired by Butterfly Wings

3. Production and manufacturing

Title of case study

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Waste-Free Packaging Alternatives
Enhanced Food Storage Systems with Nature-Inspired Insulation
Durable, Lightweight Exoskeletons for Worker Safety
New tough, flexible and light material for body armours
Create a new self-cleaning, antibacterial and waterproof surface
Create a super elastic material that can be used for thermal insulation
Create a tough adhesive for diverse wet surfaces
Tangle-proof grooming brush
Developing more energy-efficient artificial light sources
High-performance materials for industry innovation
Smart fishing nets to avoid capturing threatened species
Lightweight, Durable Materials for Space Exploration
Anti-Clogging Medical Stents Inspired by Shark Skin
Self-Cleaning Textiles Inspired by Lotus Leaves

4. Robotics and technology

Title of case study
Enhanced Medical Diagnostic Tools
Develop the smallest, lightest, fastest ever built micro-robot that can also lift 2000 times its own weight
Design a digital mobile phone camera with a wide-angle field of view, high acuity to motion and an infinite depth of field
Design a micro-drone that can be carried, has a decent range and can deal with turbulent wind conditions
Design a non-disruptive and energy-efficient underwater robot that could clean up oceans
Develop a new space x-ray telescope in order to precisely locate, characterise, and alert other observatories to the source of gravitational waves
Autonomous coordination in dynamic robot swarms

5. Transportation

Title of case study
Non-Toxic Antifouling Solutions for Ships
Sustainable Water Transportation Methods Inspired by Marine Life

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Create an online algorithm for more efficient transportation routes
Miniaturized and light-weight sensors to assist unmanned underwater vehicles
Enhancing airplane gliding efficiency to reduce greenhouse gas emissions
Bio-Inspired Solutions for Efficient Cargo Movement
Reducing Vehicle Drag Using Boxfish-Inspired

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4. SRL Assessment

Assessing learners' self-regulation skills is essential for understanding how they approach their learning tasks, their motivation to learn independently, and the importance of essential collaboration tools, among other factors. This assessment also helps identify areas where they may require additional support.

4.1 H5P interactive activities for self-assessment

The H5P tool creates microlearning units for learning or assessment that can be integrated into all the steps of the Biomimicry methodology and support the self-regulated learning process. Completing the activities requires the learner's active participation through learning-by-doing in the digital space allocated in the platform, supporting the process of self-assessment.

Regarding assessment, H5P offers a wide range of interactive content types, such as quizzes, drag-and-drop activities, and interactive videos, which can engage learners more effectively than traditional assessment methods. H5P provides instant feedback on learners' responses. This helps reinforce learning and correct misconceptions immediately, which is crucial for effective self-assessment. Another important aspect regarding H5P is that the activities can be created to suit specific learning objectives and audiences. This customisation ensures the self-assessment is relevant and aligned with the learners' needs.

How does immediate feedback work in H5P?

- **Real-time responses:** As soon as a learner submits an answer, H5P provides instant feedback. This can be in the form of:

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- **Correct/incorrect indicators**: Simple messages or indicators are implemented at the Assessment level to indicate whether the answer was right or wrong.
- **Options provided by H5P** in case of work answer:
    - **H5P allow learners to see the correct answer**. This helps learners understand their mistakes and learn the correct information right away.
    - **H5P allow learners to try the activity again**. This encourages learners to think critically and attempt to correct their mistakes without immediately seeing the correct answer.

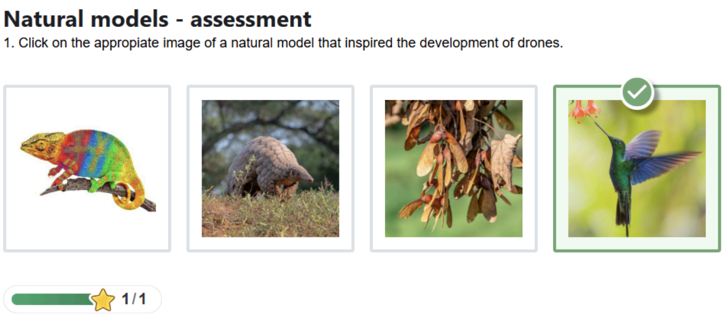

Figure 12. Validation – Correct answer

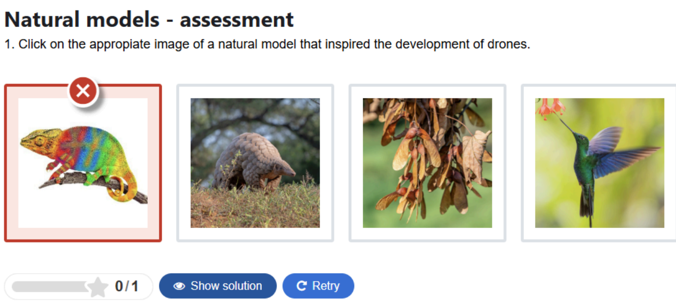

Figure 13. Validation – Incorrect answer

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- **Explanatory feedback:** Detailed explanations that help learners understand why their answer was correct or incorrect.

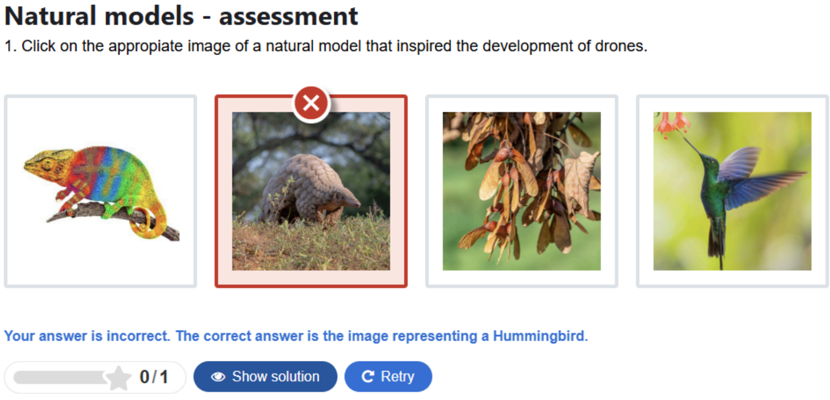

Figure 14. Validation - Incorrect answer with explanatory feedback

- **Adaptive learning:** Some H5P activities can adapt based on the learner's responses. For example, branching scenarios can lead learners down different paths depending on their choices, providing tailored feedback and learning experiences.
- **Score display:** Many H5P activities show scores immediately after completion, helping learners track their progress and identify areas for improvement.

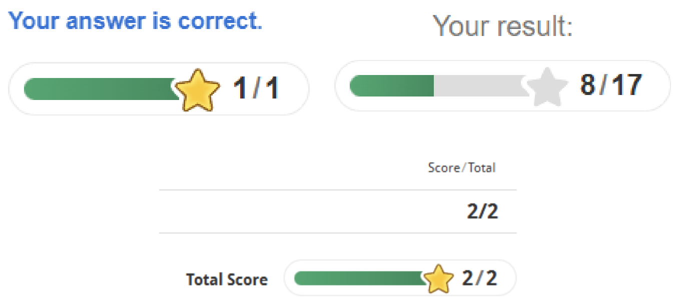

Figure 15. Examples of score display

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4.2 Benefits of using H5P for self-assessment

The active nature of H5P activities as evaluation tools offers significant benefits for knowledge reinforcement, described below:

- **Reinforcement of learning:** Immediate feedback helps reinforce both correct answers and misconceptions, which is crucial for effective learning.
- **Motivation:** Instant feedback can be motivating, as learners immediately see the results of their efforts and feel a sense of accomplishment.
- **Self-paced learning:** Learners can proceed at their own pace, reviewing feedback and revisiting content as needed to enhance their understanding.
- **Error correction:** By understanding mistakes immediately, learners can correct their errors and avoid repeating them in the future.

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6. Conclusions

In an ever-evolving educational landscape, learning independently and effectively is more crucial than ever. SRL is a process in which learners take control of their education, setting goals, monitoring progress, and reflecting on outcomes.

The evolving trend of remote learning also highlights the importance of Self-Regulated Learning (SRL). The virtual classroom setting requires even more planning and self-direction because online courses are often less structured. In these challenging times, when students are usually dealing with stress, having strong self-regulation skills can give them a sense of self-efficacy. This positive mindset is not just helpful for the current academic setting but continues to be beneficial long after graduation.

The SRL Kit, developed within the Let’s Mimic Project and supported by the project platform, is an approach that empowers students to become proactive, motivated, and adaptive in their learning journeys. By nurturing the development of skills such as time management, self-assessment, and strategic planning, the Let’s Mimic SRL Kit not only enhances academic performance but also prepares individuals for lifelong learning and success in various aspects of life.

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Annexes

Annex I – The template for documenting a challenge

BIOMIMICY DESIGN	Description
Step 1 – Define the challenge	**1.a Describe a specific challenge that you have identified and that you want to solve through your design. Define the exploratory questions and set the main goals.** ● ***Define the challenge as a question.*** *Examples to provide for students on how to define the challenge as a question:* - *How can we prevent land degradation in soils with sandy textures?* - *How can we improve plastic recycling?* **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience and which is the context of the challenge.** ● ***Describe the context.*** *Examples of possible question to ask students:* - *Which are the groups that might be or are affected by the challenge?* - *Which are the locations or settings in which your design will be implemented?* **1.c Identify the opportunities and/ or constrains that might impact achieving a successful outcome.** ● ***Identify the opportunities and the constraints.*** *Examples of possible question to ask students:*

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	- *Are there connections to other solutions or challenges?* - *Are there favourable circumstances, initiatives or legislations that might impact?* - *Are there specific limitations or risks that need to be considered?*
	Additional resources: *Can be links, document/articles, videos, etc*

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Annex II - The template for documenting a solution

BIOMIMICY DESIGN	**Description**
Step 2 – Biologize	**2.a Ask yourself "How can nature solve this?"** *Examples to provide for students on how to define the challenge from nature perspective:* - *How do leaves enrich the soil and improve the soil structure?* - *How do animals protect themselves from the sun?* **2.b Ask yourself "What do I want my design to do?"** **Determine the key functions of your design and identify contexts in nature. Functions can refer to the role played by an organism's adaptations or behaviours that enable it to survive. They can also refer to something you need your design solution to do.** ***2.c Flip the question.*** **Consider opposite functions.** *Examples of possible question to ask students:* - *How do animals protect themselves from the sun? vs. How do animals harvest sunlight?*
Step 3 – Discover	**3.a Search for natural models that match the same functions and context as your design solution. Get inspiration from scientific literature.** **3.b Identify experts and connect to communities of biologists and naturalists.**
Step 4 – Abstract	**4.a Summarize the key elements of the biological strategy. Highlighting the core functions and keywords. If possible, make a diagram/ drawing and/ or find images that can inform the design.** *e.g. shark skin*

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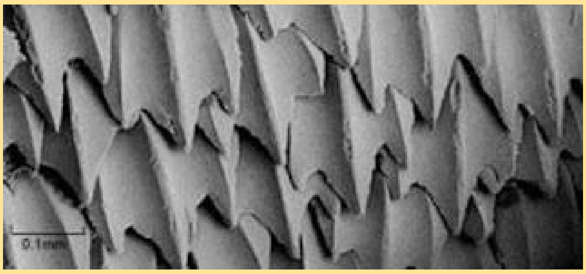
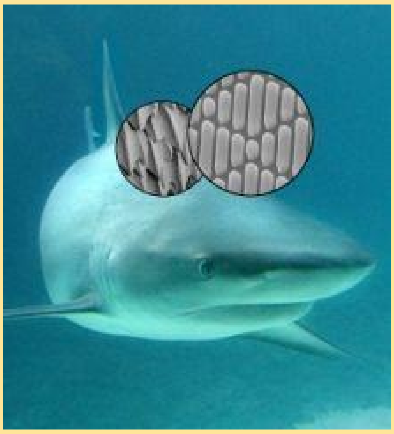


https://rcit2.blogspot.com/2012/07/speedo-super-fast-shark-skin-inspired.html

4.b Translate lessons from nature into design strategies. Rewrite the strategy without using biological terms and connect it to the functions and the context from a human perspective.

e.g. shark skin inspired swimsuit



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<td>Step 5 – Emulate</td>
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“Emulation is an exploratory process that strives to capture a “recipe” or “blueprint” in nature’s example that can be modelled in our own designs.”
<u>https://toolbox.biomimicry.org/methods/emulate/</u>

5.a List your key information and explore as many ideas as possible.

5.b Organize your ideas into categories that include the features, the context, the constraints, etc. and select the design concepts that best fit your solution.
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Step 6 – Evaluate	**6.a Evaluate the design concept(s) in relation to their alignment with the design challenge's criteria and constraints, as well as their compatibility with Earth's systems. Evaluate the feasibility of the technical and business model.** **6.b Revise and revisit previous steps as necessary to generate a viable solution.**

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Annex III – Let’s Mimic challenges

Annex IV – Let’s Mimic solutions

Annex V – Let’s Mimic case studies