WP3 Training Modules on Biomimicry Process Design

Task 3.1/ A1. Developing Self-learning Kit for VET students - LP: ATS / CPs: ALL

LETSMIMIC CHALLENGES & SOLUTIONS

A **challenge** concerns an example of a past, real life problem that was solved through biomimicry. This task aims to identify and document the challenge and the solution that was applied.

Challenge: Colour changing 3D prints

BIOMIMICRY 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** How can we build a 3d printer that automatically produces multiple colours from the same ink? **Exploratory questions** How can the colour-changing mechanisms of chameleons be replicated in printing processes? How can the thickness of photonic crystals be precisely controlled during the 3d printing process to achieve consistent colour outcomes? **Primary goal** Create multiple colours from a single ink by producing photonic crystals that reflect visible light. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience and what is the context of the challenge.** **Design needs** The design needs to include a multi-colour extruder, advanced firmware and software, precise filament management, accurate calibration, compatible materials, environmental control, an intuitive user interface, and ensuring structural integrity of printed objects. **Target audience** • **Students and teachers:** They will benefit from streamlined processes that allow them to experiment with multi-colour designs and projects without the hassle of changing filaments or managing multiple printers. • **Designers:** Those involved in making prototypes or finished products will appreciate the ability to quickly create and test

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multi-colour designs without using multiple materials, making the design process more efficient.

- **Product developers:** They can use the technology to streamline the prototyping process, especially for consumer goods, where aesthetic appeal and colour variety are key.
- **Entrepreneurs:** Startups and businesses will gain a competitive advantage with the ability to produce detailed, multi-colour prototypes in a single print cycle, saving time and resources.

Context

The 3D prints can be used for: adaptive camouflage in military technology, wearable technology and fashion, medical devices and implants, consumer electronics

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- Improvements in 3D printing technology.
- Support from military settings, healthcare and/or education.
- Growing demand for customization for personalised and tailored products.

Constraints

- Complexity of implementation.
- Materials availability.
- Development and production costs.

Favourable circumstances, initiatives or legislations

- Government support for innovation.
- Sustainability initiatives.
- Educational technology programs.
- Industry 4.0 and digital manufacturing.

Additional resources:

https://asknature.org/innovation/colourful-3d-printing-inspired-by-chameleons/

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LET'S MIMIC CHALLENGES & SOLUTIONS

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Challenges: White pigment for sustainable industries

BIOMIMICRY 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** How can we create an effective and safe white pigment for responsible production & consumption? **Exploratory questions** What are the environmental impacts associated with the production of white colourants from titanium dioxide? How do microstructures in nature differ from chemical pigments in their role in producing colour? **Main goal:** The main goal to solve the issue is to find a safer and more environmentally friendly alternative to titanium dioxide (TiO2) as a white colourant. **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.** **Design needs** The design must address the health risks associated with Tio2 nanoparticles, which have been labelled as potential carcinogens, while also improving their performance in terms of brightness and durability. **Target audience** • **Manufacturers:** Manufacturers of paints, cosmetics, and other products using white pigments, who are looking for safer, more sustainable alternatives. • **Consumers:** They are increasingly aware of the environmental and health impacts of the products they use and want safer, non-toxic options.

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- **Regulatory bodies and environmental organisations:** They concerned with reducing the use of harmful chemicals in industries.
- **Health-conscious individuals**, including parents and those with allergies or sensitivities, who seek non-toxic household items.

Context

The white pigment can be used in the food industry, cosmetics, paints and coatings, paper and packaging, textiles, and plastic.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- Growing demand for eco-friendly products.
- Environmental and health regulations.
- Innovation in material science.
- Market differentiation.

Constraints

- Scalability of production.
- Cost.
- Technological challenges.
- Industry resistance to change.

Favourable circumstances, initiatives or legislation

- Regulatory bans on TiO2.
- State-level bills in the USA.
- Consumer demand for clean labels.

Additional resources:

https://asknature.org/innovation/super-white-material-inspired-by-the-cyphochilus-beetle

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Challenge: Building design for efficient cooling and ventilation

BIOMIMICRY 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** How can we design urban buildings that significantly reduce energy consumption while providing comfort? **Exploratory questions** How can construction materials contribute to a building's climate control system? How do termite mounds maintain stable internal climates? **Primary goal** The primary objective is to maintain a controlled internal climate for buildings in urban areas, utilising passive and energy-efficient mechanisms. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Design needs** The design needs to solve the problem of maintaining a stable and comfortable internal climate within the building without relying on traditional fuel-based air-conditioning systems. The design should use passive climate control mechanisms, maximise energy efficiency, ensure cost-effectiveness, incorporate sustainable practices and provide comfort for occupants. **Target audience** • **Urban residents and office workers:** They experience the direct impact of energy consumption in buildings, including comfort levels, air quality, and lighting conditions. • **Local governments and urban planners:** They are involved in setting regulations and standards for building sustainability.

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Context

The design can be implemented in densely populated cities where high-rise and multi-use buildings are typical. Urban settings face unique challenges such as high energy demand, limited space, and varying climate conditions.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- Smart city initiatives.
- Renewable energy integration.
- Green building certifications.
- Government Incentives.
- Urban sustainability goals.

Constraints

- High initial costs.
- Long payback periods.
- Compatibility with existing systems.
- Technical expertise.
- Rigid building codes.
- Approval processes.

Favourable circumstances, initiatives or legislation

- LEED certification.
- BREEAM (Building Research Establishment Environmental Assessment Method).
- Zero-energy building initiatives.
- Tax breaks and incentives.
- Energy efficiency directives (In the EU, the Energy Performance of Buildings Directive (EPBD)).
- Green building funds.
- Urban heat island mitigation programs.
- Net-zero carbon commitments.
- Biomimicry in building regulations.
- Biophilic design policies.

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Additional resources:

https://asknature.org/innovation/passively-cooled-building-inspired-by-termite-mounds

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LET'S MIMIC CHALLENGES & SOLUTIONS

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Challenge: Stylish and efficient ceiling fan

BIOMIMICRY 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** How can we design an efficient ceiling fan that reduces energy consumption and has a lower environmental impact? **Exploratory questions** How does the blade design contribute to lower operating speeds and reduced turbulence? What are the unique structural features of sycamore seeds that enable them to disperse effectively? **Primary goal** The primary objective is to design ceiling fans that operate at low speeds while providing high airflow with minimal turbulence and noise, thereby offering a more efficient and cost-effective solution for both residential and commercial settings. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Design needs** The design needs to address the inefficiencies and drawbacks of conventional ceiling fans, which typically require high operating speeds to achieve adequate airflow. These high speeds create significant turbulence and wind noise, leading to a less comfortable environment. Furthermore, conventional fans often utilise multiple blades, which increases material costs and energy consumption. **Target audience:** • **Homeowners and residents:** The primary users of the fan in residential settings, who will benefit from enhanced energy efficiency, quieter operation, and improved air circulation.

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- **Environmental advocates:** This group would be interested in how the design reduces energy consumption, lowers carbon footprints and promotes sustainability.
- **Energy efficiency organizations:** Agencies promoting energy conservation may evaluate and endorse the fan design if it demonstrates clear benefits in reducing electricity usage.
- **Consumers in developing regions:** In regions with limited access to reliable electricity, an energy-efficient fan could have a significant positive impact, improving living conditions and reducing reliance on costly or scarce electricity.

Context

The design can be implemented in residential homes, offices and commercial buildings, buildings from tropical and hot climates, eco-homes, green buildings, sustainable architectural projects, public buildings and institutions.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities	Constraints
Growing demand for energy efficiency	High R&D and manufacturing costs
Green building certifications (LEED)	Competitive market saturation
Government energy-saving incentives	Consumer hesitation with new designs
Rising energy prices (cost-saving appeal)	Complex supply chain for eco-materials
Eco-conscious consumer base	Compliance with regional regulations
Integration with smart home systems	Difficulty in scaling manufacturing

Connections to other solutions or challenges

- Energy efficiency and smart home integration.
- Sustainability and eco-friendly design.
- Climate change and indoor air quality.

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Favourable circumstances, initiatives or legislation

- Government incentives for energy efficiency and green technologies.
- Legislation pushing for carbon reduction and sustainable building practices.
- Growing consumer demand for eco-friendly and smart home products.
- International agreements and corporate ESG goals promoting sustainability.
- Circular economy initiatives and waste reduction regulations that support the use of sustainable materials.

Limitations or risks

- Performance vs. aesthetics.
- Material durability.
- Market adoption and consumer behaviour.
- Consumer resistance to new technology.

Cost

- **Mid-range fan:** A sycamore seed-inspired fan designed for energy efficiency but manufactured with standard materials might cost around $150 - $300, similar to other high-quality ceiling fans.
- **Premium fan:** If positioned as a designer or luxury product using premium materials like carbon fibre or incorporating smart technology, the price could rise to $500 - $1,000 or more.
- **Eco-friendly/ smart options:** Models designed for energy conservation and featuring smart controls could fall in the $300 - $600 range, balancing technology and eco-friendly features.

Additional resources:

https://asknature.org/innovation/aerodynamic-ceiling-fan-inspired-by-sycamore-seedpods

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LET'S MIMIC CHALLENGES & SOLUTIONS

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Challenge: Portable toilets and waterless

BIOMIMICRY 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** How can we build safe portable toilets that effectively manage waste while conserving water and minimizing environmental impact at a low cost? **Exploratory questions** How can the design of portable toilets be optimized to reduce water usage without compromising hygiene? How can the principles of evapotranspiration be used to reduce water usage for hygiene further? **Primary goal** The primary goal is to provide safe, accessible, and effective sanitation solutions for the 2.6 billion people globally who lack proper toilet access, with a focus on addressing the needs of vulnerable communities. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Design needs** The design needs to provide safe, accessible, and effective sanitation solutions for communities lacking proper toilet access. It must address the specific needs of vulnerable communities and ensure hygiene without 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 method for managing human waste. **Target audience** • **Users:** Individuals with limited access to traditional sanitation facilities (rural communities, outdoor event attendees, and disaster relief victims).

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- **Local governments:** Authorities responsible for managing public health and sanitation, especially in regions with inadequate waste disposal systems.
- **Environmental organisations:** Groups focused on sustainability and reducing water usage, advocating for eco-friendly sanitation solutions.
- **Manufacturers:** Companies involved in producing portable sanitation solutions, which may need to adapt their designs to incorporate new technologies.
- **Health workers:** Professionals concerned with hygiene and sanitation, particularly in areas prone to disease outbreaks due to inadequate waste management.

Context

- **Rural areas:** Regions with limited infrastructure and access to traditional sewage systems.
- **Disaster relief zones:** Areas affected by natural disasters where rapid deployment of sanitation solutions is critical.
- **Outdoor events:** Festivals, concerts, and sports events where traditional facilities may be insufficient.
- **Developing urban areas:** Growing cities where rapid urbanisation outpaces sanitation infrastructure development.

1.c Identify the opportunities and/ or constraints that might impact achievin a successful outcome.

Opportunities

- Market demand.
- Sustainability focus.
- Technological advancements.
- Government support.
- Public health improvement.

Constraints

- **Cost:** Developing and deploying new technologies can be expensive, limiting accessibility for low-income communities.
- **Cultural acceptance:** Variability in cultural attitudes towards sanitation can impact the adoption of new toilet designs.
- **Technical challenges:** Ensuring the toilets are effective in different environments (e.g., varying climates and soil types) may present engineering challenges.

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- **Maintenance:** Users may need training on how to maintain and operate these toilets, which could be a barrier in some areas.
- **Regulatory hurdles:** Compliance with local health and safety regulations can complicate the design and implementation process.

Connections to other solutions or challenges

- Composting toilets.
- Rainwater harvesting.
- Biogas generation.
- Eco-friendly building materials.
- Mobile health clinics.

Limitations

- **Capacity constraints:** Portable toilets have limited waste storage capacity, which may require more frequent emptying and maintenance, especially in high-traffic areas.
- **Performance in extreme conditions:** Their effectiveness can vary based on environmental factors, such as temperature, humidity, and soil type, which may affect waste breakdown and odor control.
- **User education:** Users may need training to understand how to properly use and maintain the systems, which could limit adoption in some communities.
- **Initial costs:** The upfront investment for advanced technologies may be higher compared to traditional toilets, potentially limiting access in low-income areas.
- **Cultural resistance:** Variations in cultural practices and beliefs about sanitation can pose challenges to acceptance and widespread use.

Risks

- **Health risks:** Improper maintenance or malfunction of portable toilets could lead to health hazards, such as exposure to pathogens or odours.
- **Environmental impact:** If not designed properly, systems may leak or improperly treat waste, leading to soil and water contamination.
- **Regulatory compliance:** Navigating local health and safety regulations can be complex, and non-compliance may result in legal issues or project delays.

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	• **Vandalism and theft:** In some settings, portable toilets may be subject to vandalism, which can lead to additional costs and resources for repair or replacement. • **Sustainability of resources:** Reliance on specific materials or technologies may pose risks if those resources become scarce or if supply chains are disrupted.

Additional resources:

https://asknature.org/innovation/low-cost-portable-toilet-inspired-by-evapotranspiration-in-plants

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Challenge: Safety and efficiency of aeroplanes

BIOMIMICRY 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** How can we ensure the safety and efficiency of aeroplanes? **Exploratory questions** What potential energy savings can be achieved by flying commercial jets in a formation similar to migrating birds? How do birds produce lift and glide through the air? **Primary goal** The primary objective is to investigate the flight mechanics of birds, with applications ranging from advanced flight formations, such as the "V" formation, in military and commercial aviation, to achieving energy savings. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Design needs** The design needs to look into models of energy saving by taking advantage of the V formation of birds. The goal is to apply this principle to commercial aviation and military aviation to achieve significant energy savings and reduce fuel consumption. **Target groups** The groups that might be directly affected or are affected are The Military, more specifically the Air Force, commercial and passenger aeroplane transportation, and indirectly the entire human population. **Context** Sustainable aviation. **1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome. Identify the opportunities and the constraints.**

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Opportunities: advancements in technology, industry collaboration, regulatory oversight, and environmental considerations.

Constraints / Risks

- Coordination and communication challenges (precise positioning, autonomous control systems)
- Increased collision risk (tight spacing, emergency manoeuvres)
- Complex air traffic management (airspace congestion, disruptions to existing flight patterns)
- Fuel savings vs. practical constraints (marginal gains, varying aircraft sizes and speeds)
- Environmental conditions and weather hazards (turbulence and wind shear, impact of jet streams)
- Pilot workload and fatigue (increased pilot stress, fatigue risk)
- Infrastructure and regulatory challenges (new infrastructure requirements, regulatory approval)
- Operational flexibility (difficulty in adjusting flight plans, coordination between airlines)
- Increased maintenance and wear (wake turbulence and airframe stress, increased fuel for lead aircraft)
- Public perception and acceptance (passenger concerns, noise and environmental impact)

Additional resources:

https://chirpforbirds.com/nature-advocacy/biomimicry-and-birds/

https://en.wikipedia.org/wiki/V_formation

https://www.flyajetfighter.com/why-fighter-planes-fly-in-formation/

https://www.flyajetfighter.com/why-fighter-planes-fly-in-formation/

https://edition.cnn.com/travel/article/airbus-formation-flight/index.html

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Challenge: Designing more agile drones

BIOMIMICRY 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** How can we create a more precise and stealthier drone which can be used in complex environments? **Exploratory questions** How can enhancing drone agility improve search and rescue missions? What adaptations enable hummingbirds to achieve their high wingbeat frequency? **Primary goal** The primary goal is to enhance the agility and adaptability of drones to operate efficiently in complex and dynamic environments. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Design needs** The design needs to enhance agility and adaptability, improve manoeuvrability, increase stability, optimise energy efficiency, and adapt to Dynamic Environments **Target groups** • Military and other law enforcement organisations. • Emergency responders. • Regulatory bodies. • Environmental scientists and conservationists. • Farmers. • Urban planners and Infrastructure Inspectors. • General public. • Technology developers and researchers.

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- Delivery and logistics companies.

Context

Urban areas, forests, natural terrains, disaster zones, and military zones.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome. Identify the opportunities and the constraints.

Opportunities

- Stealth and silent operations.
- Urban air mobility and delivery systems.
- Environmental monitoring and wildlife observation.
- Search and rescue missions.
- Precision agriculture.
- Covert military and intelligence operations
- Energy efficiency and flight duration
- Navigation in complex environments
- Autonomous navigation and AI integration
- Medical applications and microdrones

Favourable circumstances, initiatives or legislations

- Government and military research initiatives.
- Legislation supporting drone innovation.
- Research and Development Funding - National Science Foundation (NSF), European Horizon 2020.
- Environmental and Conservation Initiatives.
- International Standards and Drone Safety, like the International Civil Aviation Organisation (ICAO).
- Technological Advancements in Materials and AI.
- Public Interest in Wildlife and Privacy Protection.
- Collaborations with Aviation Authorities and Industries.
- Commercial opportunities.
- The media and entertainment industries.

Constraints / Risks:

- Ethical development vectors.
- Public safeguarding.

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	• Privacy infringements and civil rights. • Environmental impact. • Public acceptance.

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Challenge: High-speed and quieter passenger trains

BIOMIMICRY 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** How can we design a faster and quieter passenger train? **Exploratory questions** How can we further minimize the noise generated by high-speed trains, especially when passing through tunnels? How does the kingfisher's beak shape reduce water resistance and noise during its dive? **Primary goal** The primary goal 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. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Design needs** The design must address the disruptive "tunnel boom" caused by high-speed trains passing through tunnels, which creates a loud sonic boom. It should also reduce air resistance to improve overall performance and reduce noise generated by aerodynamic factors, and enhance the train's speed and energy efficiency, allowing it to travel faster while consuming less electricity. **Target groups** Engineers and designers, railway operators, people who live near railways, and commuters. **Context:** High-speed rail systems. **1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.** **Opportunities**

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- Innovative design inspiration.
- Noise reduction.
- Energy efficiency.
- Speed and performance.
- Market differentiation.
- Cross-industry applications.

Connection to other solutions

- Aviation and aerospace.
- Automotive industry.
- Wind energy.
- Architecture and building design.
- Marine vessel design.
- Drones and UAVs (Unmanned Aerial Vehicles).
- Consumer products.
- Robotics.

Favourable circumstances, initiatives or legislations

- Environmental legislation and green transportation Initiatives.
- Technological innovation initiatives.
- The Society 5.0 initiative.
- Noise and environmental regulations.
- International cooperation and agreements.
- Public and political support for high-speed rail.
- Investment in next-generation Shinkansen (the ALFA-X Project).

Constraints / Risks

Technical and engineering challenges

- Scaling biological designs for high-speed travel.
- Material limitations.

Cost and economic considerations

- High R&D costs.
- Maintenance costs.

Environmental and operational risks

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	• Weather and climate impact. • Tunnel aerodynamics and pressure waves. **Biomimicry adaptations for different rail systems** • Transferability to different rail networks. • Adaptation to maglev and future technologies. **Regulatory and environmental constraints:** • Regulatory hurdles. • Environmental impacts.

Additional resources:

https://medium.com/@StammBio/what-is-biomimicry-the-train-and-the-kingfisher-1a459ef21af0

https://biomimicry.medium.com/the-man-made-world-is-horribly-designed-but-copying-nature-helps-43f182254615

https://askernaturereserve.co.uk/science/kingfisher-bullet-train/

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WP3 Training Modules on Biomimicry Process Design

Task 3.1/ A1. Developing Self-learning Kit for VET students - LP: ATS / CPs: ALL

LET'S MIMIC CHALLENGES & SOLUTIONS

A **challenge** concerns an example of a past, real life problem that was solved through biomimicry. This task aims to identify and document the challenge and the solution that was applied.

Challenge: Design a subway or railway network less prone to disruption

BIOMIMICRY 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** How can we design a subway or railway less prone to disruption? **Exploratory questions** How can a railway network dynamically adjust to varying passenger loads and traffic conditions? What mechanisms allow the slime mould to optimise its network without a central brain? **Primary goal** The primary goal is to establish a highly efficient, resilient, and adaptable transportation network. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Design needs** The design must look into network efficiency, disruption management, structural design, technological integration and environmental adaptation. **Target groups** Commuters and passengers, businesses and employers, tourists and leisure travellers, public transit authorities and operators, government and policy makers, logistics and supply chain companies, local communities and neighbourhoods, environmental advocates and sustainability groups, vulnerable populations, educational institutions (both students and staff) and emergency services. **Context** Urban transportation networks, disaster zones, smart city, military and emergency zones **1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.**

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Opportunities

- Optimised route planning.
- Resilient infrastructure.
- Smart systems.
- Innovative urban planning.

Connections to other solutions or challenges

- Urban planning and infrastructure design.
- Computer science and artificial intelligence (AI).
- Logistics and supply chain management.
- Telecommunications and network theory.
- Resilience and disaster management.
- Biomimicry in sustainability and resource management.
- Healthcare and biological systems.
- Traffic flow and road networks.
- Energy and power grid optimization.

Favourable circumstances, initiatives or legislations

- Sustainability and green infrastructure initiatives (Green New Deal, The Paris Agreement and local carbon reduction goals).
- Smart city initiatives (EU Smart Cities Marketplace and Japan's Society 5.0, National Infrastructure Investments).
- Innovation grants and research funding (EU Horizon 2020 or Horizon Europe, U.S. Federal Transit Administration (FTA), Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT)).
- Resilience and disaster management policies (National Disaster Resilience Programs, Resilience 2050).
- Urban mobility and transport innovation policies (EU Urban Mobility Framework, Urban Mobility Innovations).
- Technological innovation and biomimicry support (U.S. National Science Foundation (NSF), European Commission's Circular Economy Action Plan).
- Environmental regulations and low-emission zones.
- Public-private partnerships and infrastructure development.
- Public health and air quality initiatives.

Constraints / Risks

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	• Scalability and complexity of urban networks. • Dynamic human behaviour and traffic patterns. • Technological limitations. • Integration with existing infrastructure. • Initial Investment and development costs. • Adaptability to future urban growth. • Public acceptance and usability. • Regulatory and bureaucratic hurdles. • Security and vulnerability concerns. • Environmental and spatial constraints. • Ethical and environmental considerations.

Additional resources:

https://www.wired.com/2010/01/slime-mold-grows-network-just-like-tokyo-rail-system/

https://saugatadastider.medium.com/nature-as-an-innovator-lessons-from-slime-mold-to-tokyos-subway-265cdb1904ff

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LETSMIMIC CHALLENGES & SOLUTIONS

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Challenge: Flexible and durable backpacks

BIOMIMICRY 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** How can we design backpacks that are both flexible and durable? **Exploratory questions** In what ways does the use of recycled materials contribute to the sustainability of the backpack? How do the overlapping scales of a pangolin contribute to its defence mechanism? **Primary goal** The primary goal of the design is to create a backpack that is both resilient, adaptable and eco-friendly, offering at the same time excellent protection for the contents. **1.b Describe what the design needs to do or solve (not what you will make or design), who your target audience is, and what the context of the challenge is.** **Design needs** The design should provide robust protection for its contents, should allow for flexibility and adaptability, materials used must be tough and resilient to withstand various conditions, to make use of sustainable materials to promote environmental responsibility and to be visually appealing and comfortable to wear. **Target groups** Outdoor enthusiasts, students, professionals who commute, and travellers. **Context** Outdoor activities, travel, urban commuting, educational settings, and sustainable fashion. **1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome. Identify the opportunities and the constraints.**

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Opportunities

- Growing market for eco-friendly products.
- Technological advancements in materials science.
- Supportive regulatory environment.
- Collaborations with environmental organisations.
- Integration of smart technologies.

Connections to other solutions or challenges

- Adaptive materials in high-performance gear.
- Ergonomic designs in protective equipment.
- Sustainable design in industry.

Favourable circumstances, initiatives or legislations

- Growing demand for sustainable products.
- Advancements in materials science.
- Circular economy initiatives.
- Environmental responsibility programs.
- Sustainable fashion innovations.
- Product safety standards.
- Textile and manufacturing legislation.
- EU corporate sustainability reporting directive (CSRD).

Constraints / Risks

- Material cost and availability.
- Design complexity.
- Comfort and usability.
- Ethical implications.
- Durability testing.
- Market acceptance.

Additional resources:

https://asknature.org/innovation/durable-backpack-inspired-by-the-pangolin/

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LET'S MIMIC CHALLENGES & SOLUTIONS

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Challenge: Multi-functional biodegradable shoes

BIOMIMICRY 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** How can we create multi-functional, biodegradable fashion products? **Exploratory questions** What strategies can be implemented to ensure that biodegradable footwear is easily recyclable or compostable? What are the environmental benefits of using algae-based materials in the production of footwear? **Primary goal** 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. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Design needs** The design needs to explore methods for replacing traditional synthetic materials with biodegradable options, such as algae-based foam, natural rubber, and organic fibres, that are easily recyclable or compostable. It should also utilise non-toxic, eco-friendly adhesives and dyes. **Target audience** Eco-conscious consumers, fashion brands and sustainable fashion startups, outdoor and athletic gear manufacturers, educational institutions and research organisations. **Context** Footwear.

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1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome. Identify the opportunities and the constraints.

Opportunities

- Material innovation.
- Design and functionality.
- Production and manufacturing.
- Market expansion.
- Lifecycle management.

Connections to other challenges

- Circular economy.
- Material innovation.
- Sustainable manufacturing.
- Consumer trends.
- Waste reduction.
- Climate change mitigation.

Connections to other solutions

Outdoor apparel, activewear, casual wear, accessories, children's clothing, packaging, and manufacturing.

Favourable circumstances, initiatives or legislations

- Growing consumer demand.
- Technological advances.
- Research and development grants.
- Partnerships with environmental organisations.
- Stricter regulations on plastic use and waste management.
- Policies fostering a circular economy.

Constraints / Risks

- Durability of algae-based materials.
- Production costs.
- Supply chain challenges.
- Consumer perception.
- Ecological consequences of large-scale cultivation.
- Regulatory compliance.

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	• Competition in the sustainable market. • Consumer education.

Additional resources:

https://algaeplanet.com/ucsd-scientists-create-biodegradable-shoes/

https://phys.org/news/2020-08-science-biodegradable-algae-based-flip-flops.html

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Task 3.1/ A1. Developing Self-learning Kit for VET students - LP: ATS / CPs: ALL

LET'S MIMIC CHALLENGES & SOLUTIONS

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Challenge: Reflecting road studs

BIOMIMICRY 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** How can we create effective, durable, and eco-friendly reflecting road studs? **Exploratory questions** How can reflective road studs be integrated with other smart road technologies to create a comprehensive road safety system? What specific features of cat eyes are mimicked in the reflective road studs to enhance visibility? **Main goal:** The main goal is to improve road safety by enhancing visibility at night and in poor weather conditions. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Design needs** The design should look into using resistant materials to withstand heavy traffic and harsh weather conditions, and to ensure maximum visibility, to provide adequate warning to drivers, to ensure continuous operation, to have a smooth, enveloping profile without sharp edges to prevent damage to vehicles, and if possible, to have automatic operation. **Target groups** • **Road safety authorities:** They are responsible for implementing and maintaining the reflective road studs, identifying high-risk areas, and promoting public awareness about road safety measures. • **Drivers:** They benefit from the increased visibility provided by the reflective road studs, which help them navigate roads more safely, especially in poor weather conditions or at night.

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- **Pedestrians:** They also benefit from the enhanced visibility, making it easier for them to be seen by drivers, thereby reducing the risk of accidents.

Context

Rural roads, highways and expressways, sharp curves and intersections, mountainous or coastal roads, and urban areas with heavy pedestrian traffic.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome. Identify the opportunities and the constraints.

Opportunities

- Rural and country roads.
- Highways and expressways.
- Urban areas and smart cities.
- Pedestrian crosswalks and intersections.
- Sustainability initiatives.
- Infrastructure investment programs.

Connections to other solutions or challenges

- Integration with smart street lighting.
- Integration into smart city initiatives.

Similar solutions

Solar road studs, plastic and aluminium road studs, ceramic road studs, and glow-in-the-dark road marking.

Favourable circumstances, initiatives or legislations

- Vision Zero initiatives.
- Infrastructure investment programs.
- New road safety regulations.
- Vehicle safety regulations.
- Smart city initiatives.
- Public safety campaigns.

Constraints / Risks

- Initial installation and maintenance costs.
- Impact of extreme weather conditions.
- Driver over-reliance.

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	• Visual landscape changes in urban settings. • Lack of driver and pedestrian education. • Overcrowding and visual clutter. • Vandalism and damage.

Additional resources:

https://www.road-stud.com/shining-light-on-road-safety-the-ingenious-invention-of-the-cats-eye-road-stud/

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LET'S MIMIC CHALLENGES & SOLUTIONS

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Challenge: Sustainable packaging

BIOMIMICRY 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** How can we replace single-use packaging with sustainable, reusable or biodegradable solutions? **Exploratory questions** How can we design packaging that supports a circular economy, much like the nutrient cycles found in nature? How does nature manage waste and resources efficiently? **Primary goal** The primary goal is to minimize environmental impact. This involves reducing waste, conserving resources, and lowering carbon emissions throughout the packaging lifecycle. **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.** **Design needs** The design should look into the use materials that are biodegradable, compostable, or recyclable, to have a minimalist design, to be reusable and durable, to have an efficient production, to include clear information on the packaging about how to dispose of it properly, whether it can be recycled, composted, or reused. **Target groups** • **Food businesses:** These businesses rely heavily on single-use packaging for takeout and delivery. They need affordable, durable, and functional alternatives that don't compromise the customer experience or increase costs significantly. • **Consumers**: Individuals who regularly order food for delivery or takeout, accustomed to the convenience of single-use packaging. The design should be appealing, easy to use, and

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promote awareness about the environmental impact of their choices.

- **Waste management and environmental** organizations: These groups are affected by the accumulation of plastic waste and are invested in promoting more sustainable practices. They can support the initiative by advocating for or assisting in the implementation of new systems.
- **Local governments and policymakers**: These stakeholders can help enforce regulations or provide incentives for businesses and consumers to adopt eco-friendly packaging solutions.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- Growing consumer awareness.
- Government policies and regulations.
- Technological advancements.
- Collaboration and partnerships.

Constraints

- Cost barriers.
- Consumer behaviour.
- Scalability issues.
- Performance limitations.

Favourable circumstances, initiatives or legislation

- Sustainable Packaging Coalition (SPC).
- EU Packaging and Packaging Waste Regulation (2025/40).
- Extended Producer Responsibility (EPR) policies.
- Plastic bag bans.

Additional resources:

https://asknature.org/collection/life-friendly-packaging/

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LET'S MIMIC CHALLENGES & SOLUTIONS

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Challenge: Design of a sponge-like battery to support a carbon-neutral future

BIOMIMICRY 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** How can we design a battery to enhance energy storage capacity, improve mechanical stability, and support a carbon-neutral future? **Exploratory questions** What are the benefits of the bone-like architecture in sodium-ion batteries? How do the compact and cancellous tissues in bones contribute to their overall function and strength? **Primary goal** The primary goal is to design a sponge-like battery which could provide a larger surface area for energy storage, potentially increasing the battery's capacity and supporting a carbon-neutral future. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Design needs** • **Energy storage capacity:** The battery needs to have a high energy density to store more energy in a compact form. • **Mechanical stability:** It should be resilient and durable, able to withstand physical stresses without degrading. • **Porous structure:** The design should facilitate efficient ion transport and improve overall battery performance. • **Sustainability:** The materials and manufacturing processes should be environmentally friendly to support a carbon-neutral future. **Target groups** • Battery manufacturers.

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- Renewable energy sector.
- Electric vehicle (EV) industry.
- Consumer electronics.

Context

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.

Potential benefits

- Enhanced energy storage (increased capacity, efficient ion transport).
- Improved mechanical stability (durability, flexibility).
- Sustainability (eco-friendly materials, support for carbon-neutral goals).
- Versatility (wide range of applications).
- Innovation and competitive advantage (market differentiation, technological advancement).

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome. Identify the opportunities and the constraints.

Opportunities, favourable circumstances, initiatives or legislations

- Government initiatives and funding.
- Environmental regulations and policies.
- Market trends and consumer demand.
- Technological advancements.
- International collaboration.

Constraints / Risks

- Material challenges.
- Manufacturing complexity.
- Performance issues.
- Environmental and safety concerns.
- Economic factors.
- Regulatory and compliance issues.

Additional resources:

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https://asknature.org/innovation/sponge-like-battery-structure-inspired-by-mammalian-bones/

https://pubs.aip.org/aip/apr/article/7/4/041410/832047/Biomimetic-composite-architecture-achieves

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LET'S MIMIC CHALLENGES & SOLUTIONS

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Challenge: Design an aerodynamic efficient, subsonic, stealthy, manoeuvrable and silent flying wing heavy strategic bomber

BIOMIMICRY 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** How can we design a stealthy, subsonic flying wing heavy strategic bomber? **Exploratory questions** How does stealth technology enhance the survivability of a strategic bomber? What are the benefits of subsonic speeds in terms of fuel economy and payload capacity? What characteristics of the peregrine falcon inspired the design of the B-2 Spirit? **Primary goal** The primary goal is to design a stealthy, subsonic flying wing heavy strategic bomber in the context of modern warfare, geopolitical strategy, and technological advancement. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Design needs** To design a stealthy, subsonic flying wing heavy strategic bomber, the design must address and solve several key requirements, 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. **Target groups** • Military and defence forces. • The defence industry and contractors. • Governments and policymakers.

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- Non-governmental organizations (NGOs) and advocacy groups.
- Research and academic institutions.
- Global economy and trade.
- Environmental systems.
- Future generations.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- Technological advancement.
- Strategic military advantage.
- Economic and industrial growth.
- Geopolitical influence.
- Environmental optimization.

Constraints

- High costs.
- Technical challenges.
- Time constraints.
- Geopolitical risks.
- Public and political scrutiny.
- Environmental Impact.
- Integration challenges.
- Limited market constraints.

Connections to other technological solutions

- Aerospace Engineering Innovations: unmanned aerial systems (UAS), Hypersonics and advanced materials.
- Artificial intelligence and machine learning.
- Energy efficiency propulsion systems**.**

Additional resources:

https://en.wikipedia.org/wiki/Strategic_bomber

https://en.wikipedia.org/wiki/Northrop_B-2_Spirit#Design

https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104482/b-2-spirit/

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Dictionary

Subsonic - A subsonic aircraft is an aircraft with a maximum speed less than the speed of sound. The term technically describes an aircraft that flies below its critical Mach number, typically around Mach 0.8. All current civil aircraft, including airliners, helicopters, future passenger drones, personal air vehicles and airships, as well as many military types, are subsonic.

Flying wing - A flying wing is a tailless fixed-wing aircraft that has no definite fuselage, with its crew, payload, fuel, and equipment housed inside the main wing structure.

Heavy Bombers- Heavy bombers are bomber aircraft capable of delivering the largest payload of air-to-ground weaponry (usually bombs) and longest range (take off to landing) of their era.

Strategic bomber - A strategic bomber is a medium- to long-range penetration bomber aircraft designed to drop large amounts of air-to-ground weaponry onto a distant target to debilitate the enemy's capacity to wage war. Unlike tactical bombers, penetrators, fighter-bombers, and attack aircraft, which are used in air interdiction operations to attack enemy combatants and military equipment, strategic bombers are designed to fly into enemy territory to destroy strategic targets (e.g., infrastructure, logistics, military installations, factories, etc.).

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LET'S MIMIC CHALLENGES & SOLUTIONS

A **challenge** concerns an example of a past, real life problem that was solved through biomimicry. This task aims to identify and document the challenge and the solution that was applied.

Challenge: A sustainable and more efficient agriculture for self-sustaining crop production

BIOMIMICRY 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** How can we develop a sustainable and efficient agricultural system that ensures self-sustaining crop production while minimising environmental impact and maximising resource use efficiency? **Exploratory questions** How can we improve water management practices to ensure efficient use and conservation of water resources in agriculture? **Primary goal** The primary goal is 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. **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.** **Design needs** • **Enhance soil health:** Implement practices that improve soil structure, fertility, and microbial activity to ensure long-term productivity. • **Optimise water use:** Develop efficient irrigation systems and water management practices to conserve water resources. • **Increase crop yields:** Utilise advanced technologies and precision farming techniques to boost crop production sustainably. • **Reduce chemical inputs:** Promote the use of organic fertilisers, biopesticides, and integrated pest management to minimise chemical usage. • **Promote biodiversity:** Encourage crop rotation, intercropping, and agroforestry to enhance ecosystem diversity and resilience.

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- **Integrate renewable energy:** Incorporate solar, wind, and other renewable energy sources to power agricultural operations and reduce greenhouse gas emissions.

Target groups

- Farmers and agricultural workers.
- Local communities.
- Consumers.
- Environmental groups.
- Policy makers and governments.
- Researchers and scientists.
- Agribusinesses and supply chain stakeholders.
- Future generations.

Context

The challenge is set within the broader context of creating a sustainable and more efficient agriculture for self-sustaining crop production, considering aspects such as environmental concerns, climate change, population growth, resource scarcity, economic pressures, and global food security.

Potential benefits

Environmental protection, Resource conservation, Economic viability, Food security, Health benefits, Biodiversity enhancement, Climate resilience, Community and social benefits, Technological innovation, Global impact

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome. Identify the opportunities and the constraints.

Opportunities

- Technological advancements.
- Government support.
- Market demand.
- Research and development.
- Education and training.
- Collaboration and partnerships.
- Climate adaptation.

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	Constraints / Risks • Economic barriers. • Knowledge gaps. • Infrastructure limitations. • Policy and regulatory challenges. • Market access. • Climate variability. • Cultural resistance.

Additional resources:

https://asknature.org/innovation/sustainable-industrial-agriculture-inspired-by-prairie-ecosystems/

https://asknature.org/strategy/natural-ecosystem-demonstrates-sustainability/

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WP3 Training Modules on Biomimicry Process Design

Task 3.1/ A1. Developing Self-learning Kit for VET students - LP: ATS / CPs: ALL

LET'S MIMIC CHALLENGES & SOLUTIONS

A **challenge** concerns an example of a past, real life problem that was solved through biomimicry. This task aims to identify and document the challenge and the solution that was applied.

Challenge: Design a new lightweight, highly efficient and stealth robotic micro-air vehicle (MAV) for military applications

BIOMIMICRY 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** How can we design a new, lightweight, highly efficient, and stealthy robotic micro-air vehicle (MAV) for military applications? **Exploratory questions** How can the design of MAVs be optimised to reduce their visual and acoustic signatures during covert operations? How do bats maintain sustained flight over long distances without experiencing fatigue? **Primary goal** The primary goal is to address the demands of modern conflict, leveraging cutting-edge technologies to ensure operational efficiency, adaptability, and the safety of military personnel. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Design needs** The design of a lightweight, highly efficient, and stealth robotic micro-air vehicle (MAV) for military applications needs to address several key aspects such as to minimise detectability, to enhance mobility and adaptability, to reduce risk to personnel, to allow the optimisation of resource use, to counter emerging threats, to achieve technological superiority and to be able to be integrated with military ecosystems. **Target groups** Military and defence forces, defence industry and researchers, residents in conflict zones, and regulatory and policy stakeholders. **Context** Military settings.

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1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- Tactical advantages: stealth and covert operations.
- Technological innovation: biomimicry and AI integration.
- Multifunctionality.
- Reduced risks and costs: low risk to personnel; economic efficiency.

Constraints

- Energy limitations.
- Counter-drone measures: adversary responses.
- Ethical and legal issues: privacy concerns.
- Resource constraints: funding and development time.
- Operational constraints: signal vulnerabilities.

Favourable circumstances, initiatives or legislations

- Advancements in technology, like the miniaturization of components.
- Increased defence budgets.
- Global security environment.
- Research and development programs like the US DARPA's MAV projects.
- International collaborations.
- Private sector engagement.
- Government support for UAV development.
- Arms export regulations.
- Environmental and energy legislation.

Additional resources:

https://record.umich.edu/articles/com-bat-research-takes-flight/

https://www.defencetalk.com/researchers-study-bats-to-enhance-micro-air-vehicles-16047/

https://ohgizmo.com/university-of-michigan-college-of-engineering-to-develop-a-bat-like-spy-plane-for-the-us-army

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WP3 Training Modules on Biomimicry Process Design

Task 3.1/ A1. Developing Self-learning Kit for VET students - LP: ATS / CPs: ALL

LETSMIMIC CHALLENGES & SOLUTIONS

A **challenge** concerns an example of a past, real life problem that was solved through biomimicry. This task aims to identify and document the challenge and the solution that was applied.

Challenge: Design a fine plastic particulate matter filter

BIOMIMICRY 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** How can we design a high-quality filter for fine plastic particulate matter? **Exploratory questions** How can we ensure the filter maintains high efficiency while minimising the reduction in water flow? What adaptations enable manta rays to filter feed efficiently without clogging their gills? **Primary goal** The primary goal of the challenge is to develop an efficient and effective filter that can remove delicate plastic particulate matter, specifically microplastics and nanoplastics, from various environments such as surface water and groundwater. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Design needs** The design needs to solve the problem of removing fine plastic particulate matter from various environments and it should focus on capturing microplastics and nanoplastics, reduce the presence of toxic chemicals and plastic particles in drinking water, prevent plastic particles from harming wildlife and disrupting natural habitats, alleviate the adverse economic effects of plastic pollution on industries such as tourism, fisheries, and agriculture by maintaining cleaner environments and Improve the overall quality of water and soil by removing plastic contaminants. **Target group** • Environmental advocacy and sustainability groups. • Public health sector.

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- Manufacturing and industrial sectors.
- Government and regulatory bodies.
- Urban and industrial planning.
- Marine life and biodiversity conservation groups.
- Consumers.
- Research and academia.

Context

Water treatment plants, industrial wastewater systems, ocean and river pollution control systems, air filtration systems in urban areas, environmental cleanup initiatives, and consumer products.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- Public-private partnerships.
- Technological innovations.
- Market demand.
- Industry applications.
- Sustainability initiatives.
- Research and development initiatives.

Favourable circumstances, initiatives or legislations

- Global environmental agreements (The Paris Agreement (2016), United Nations Sustainable Development Goals (SDGs)).
- Plastic pollution legislation (European Union Single-Use Plastics Directive (2019), Microbead-Free Waters Act (2015, U.S.)).
- Clean air and water initiatives (Clean Air Act (U.S.) and Air Quality Standards set by the Environmental Protection Agency (EPA), EU Water Framework Directive).
- Government funding and research initiatives.
- Corporate social responsibility (CSR) programs and green certifications like ISO 14001.
- Public and private sector partnerships (Global Plastic Action Partnership (GPAP)).

Constraints / Risks

- **Technical limitations:** Efficiency and scalability, material durability.

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	• **Cost considerations:** Development and implementation costs, maintenance and operation costs. • **Regulatory challenges:** Compliance with environmental regulations, testing and certification. • **Environmental risks:** Unintended ecological impact, waste disposal issues. • **Public perception and acceptance:** Scepticism towards new technologies, education and awareness. • **Integration with existing systems:** Compatibility issues.

Additional resources:

https://biomimicry.org/

https://asknature.org/innovation/rticulate-matter-filters-inspired-by-manta-rays/

https://creation.com/manta-filter

https://asknature.org/innovation/plastic-filtering-device-inspired-by-the-manta-ray-and-basking-shark/

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LET'S MIMIC CHALLENGES & SOLUTIONS

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Challenge: Preservative packets to reduce waste

BIOMIMICRY 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** How can we keep harvested produce fresher for longer? **Exploratory questions** How feasible is it to implement smart packaging solutions that do not rely on electricity? How do environmental factors (e.g., temperature, humidity) influence the hormonal signalling and defence responses in detached produce? **Primary goal** The primary goal is to identify a solution for maintaining food freshness even in areas without access to cold storage and cold supply chain facilities. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Design needs** The design solution aims to extend the freshness of harvested produce in areas lacking access to cold storage and cold supply chain facilities. **Target groups** Small-scale farmers, Local communities, Transitional populations, Local vendors, Low-income households, Street vendors, Farmers and agricultural workers, Local markets, Nomadic families, Pastoralists, Disaster-affected populations, Relief organizations, Displaced populations, Humanitarian aid workers, Island communities, Local farmers and fishermen **Context** Rural and remote areas, peri-urban areas, urban slums, developing regions, nomadic and pastoralist communities, disaster-prone areas, conflict zones, and isolated islands.

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1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome. Identify the opportunities and the constraints.

Opportunities

- Local implementation (community cold storage, educational workshops).
- Technological integration (smart packaging).
- Policy and support (government subsidies, research and development.
- Commercial opportunities (partnerships with retailers, innovative products production).

Connections to other solutions or challenges

- Food preservation techniques (fermentation, drying and dehydration, curing and salting).
- Sustainable agriculture (agroecology, permaculture).
- Renewable energy solutions (solar-powered coolers, biogas systems).
- Technological innovations (evaporative cooling devices, smart packaging).
- Community-based initiatives (cooperative storage facilities, education and training).
- Policy and infrastructure development (investment in rural infrastructure, supportive policies).
- Climate change adaptation (resilient crop varieties, disaster preparedness).

Favourable circumstances, initiatives or legislations

- Increased awareness of food waste.
- Technological advancements.
- Community engagement.

Initiatives

- Champions 12.3.
- Global Food Cold Chain Council.
- Efficiency for Access.

Legislation

- European Union's Farm to Fork Strategy.

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	• National policies on food security. **Constraints / Risks** • **Spoilage and contamination:** Microbial growth, pest infestation). • **Limited shelf life:** Shorter preservation period, quality degradation. • **Environmental factors:** Temperature fluctuations, humidity levels. • **Resource constraints:** Water availability, material accessibility. • **Knowledge and training:** Lack of awareness, cultural acceptance. • **Economic factors:** Initial costs, maintenance costs. • **Legal and regulatory issues:** Food safety regulations, market access.

Additional resources:

https://greenpodlabs.com/

https://www.youtube.com/channel/UCilmiV8719puQI1NwnBQoPA

https://asknature.org/innovation/natural-produce-preservative-packets-inspired-by-plants/

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LET'S MIMIC CHALLENGES & SOLUTIONS

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Challenge: Hydrogen sensors powered by light

BIOMIMICRY 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** How can we design and develop hydrogen sensors that are efficiently powered by light to ensure accurate, reliable, and sustainable hydrogen detection? **Primary goal** The primary goal is to design a new generation of hydrogen sensors that are not only effective and reliable but also environmentally friendly and sustainable. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Design needs** • **Hydrogen detection:** accurately detect the presence of hydrogen gas at various concentrations and provide real-time monitoring and quick response times to changes in hydrogen levels. • **Power efficiency:** Efficiently harvest and utilize light (e.g., solar energy) to power the sensor and ensure that the sensor operates reliably with the energy provided by the light source. • **Sensitivity and selectivity:** Achieve high sensitivity to detect low concentrations of hydrogen while maintaining selectivity to distinguish it from other gases and avoid false positives. **Target groups** Chemical plants and refineries, manufacturers of hydrogen sensors, hydrogen production and storage facilities, renewable energy companies, government agencies, safety inspectors, scientists and engineers, academic institutions, industrial workers, the general public, and advocacy organisations.

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Context

- **Technological context:** Advancements in sensor technology and integration of photovoltaics
- **Environmental context:** Sustainability goals and climate change mitigation
- **Industrial and safety context:** Safety in hydrogen handling and regulatory compliance
- **Economic context:** Cost-effectiveness and market demand
- **Research and development context:** Interdisciplinary collaboration

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Favourable circumstances, initiatives or legislations

- **Government initiatives and funding:** The Clean Hydrogen Partnership, The CEF supports infrastructure projects, the IPCEI Hy2Tech initiative, Horizon Europe, and Individual EU member states.
- **Environmental regulations:** Climate change mitigation policies, safety standards.
- **Technological advancements:** Innovative detection methods, renewable energy integration.
- **Market demand:** Growth in the hydrogen economy.

Constraints / Risks

- **Technical limitations:** Energy harvesting efficiency, sensor sensitivity and selectivity.
- **Environmental factors:** Variable light conditions, temperature and humidity.
- **Material and design challenges:** Durability and longevity, integration of photovoltaic components.
- **Economic and scalability concerns:** Cost of production, maintenance and lifespan.
- **Regulatory and safety risks:** Compliance with standards, risk of false positives/negatives.
- **Market and adoption barriers:** Market acceptance, infrastructure compatibility.

Additional resources:

https://asknature.org/innovation/precise-hydrogen-sensor-inspired-by-butterflies/

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https://pubs.acs.org/doi/10.1021/acssensors.0c01387

https://www.rmit.edu.au/news/all-news/2020/dec/hydrogen-sensor

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Task 3.1/ A1. Developing Self-learning Kit for VET students - LP: ATS / CPs: ALL

LET'S MIMIC CHALLENGES

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The description column provides guidelines with examples for filling in the information for the biomimicry design steps.

Challenge: Self-healing concrete

BIOMIMICRY 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** How can we make concrete more stable and resistant to cracks? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Describe the context** Over time, concrete is a material that can crack and deteriorate. The development of a more solid and long-lasting material will benefit the following target groups: • **Construction and civil engineering companies:** They would benefit from reduced maintenance and repair costs for concrete structures like bridges, roads, tunnels or buildings. • **Infrastructure owners (public or private):** Government agencies, municipalities, and private owners responsible for maintaining infrastructure can use this new and more durable concrete to ensure the safety and longevity of the works. • **Sustainability-focused organisations**: Environmental agencies and companies with sustainability goals can use the new material and technology to reduce the carbon footprint associated with concrete production and repairs. **1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.** **Are there connections to other solutions or challenges? Look into opportunities** • **Development of sustainable construction practices:** The creation of such a material would align with sustainable

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building practices since it would reduce the need for frequent repairs and replacements, which in turn would contribute to lower consumption of raw materials and energy associated with cement production.

- **Creation of maintenance-free or low-maintenance infrastructures:** We are facing a growing interest in “smart” materials that minimise the need for maintenance. As such, a more resilient material would allow for the creation of infrastructure that requires minimal upkeep.
- **Resilience and adaptation to climate change impact:** Climate change increases the risk of damage to infrastructure due to more frequent extreme weather events. In this sense, the development of stronger and durable concrete can enhance the resilience of buildings and roads, ensuring they can withstand harsh environmental conditions and repair any cracks caused by extreme temperature fluctuations or water infiltration.

Are there specific limitations or risks that need to be considered? Look into constraints

- **Technical challenges:** Developing an innovative construction material requires significant experimentation with various mechanisms to find a viable solution.
- **Material properties and limitations:** Since concrete is used in diverse environmental conditions, the invention must be prepared to work effectively under these different conditions while maintaining the material’s original properties, such as compressive strength and durability.
- **Environmental and safety concerns:** When creating a new material, it is important to consider its sustainability. Adding new components to the concrete mix had to be justified in terms of their environmental impact and resource availability.
- **High development and testing costs:** Developing a new material requires significant investment in research and testing to ensure it meets safety and performance standards.
- **Final cost:** For the solution to be widely adopted, it needs to be cost-competitive with traditional concrete. Thus, it is essential to find a balance between improving the material's toughness and keeping the cost of production within an acceptable range.

Are there favourable circumstances, initiatives or legislations that might impact?

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Yes, there are favourable circumstances, initiatives and legislation that could positively impact the development and implementation of a new and more resistant concrete:

- **Increased focus on sustainability and environmental regulations:** Environmental awareness has increased among governments, companies, and the general public, creating a favourable environment for innovations aimed at reducing the environmental impact of construction materials.
- **Regulations to lower carbon emissions:** Governments worldwide have introduced stricter regulations to reduce greenhouse gas emissions, particularly in industries such as construction, which is responsible for significant CO2 output due to cement production. The pressure to reduce emissions provided an incentive to develop more durable materials that would require less frequent repair and replacement, therefore lowering the carbon footprint of infrastructure projects.
- **Green Building initiatives and certification programmes**: Several programs promote the use of sustainable materials in construction.
- **Government and industry support for innovation:** Many countries provide funds and grants for research into advanced materials, sustainability and infrastructure resilience. Similarly, there are partnerships between government bodies, research institutions, and private companies aimed at developing resilient infrastructure, which provides a supportive framework for innovations in construction materials.
- **Legislation promoting resilient and long-lasting materials:** Some countries already have policies and guidelines that encourage the use of durable materials in construction projects.
- **Incentives for long-term cost savings:** Certain financial and economic policies encourage investment in materials and technologies that may have higher initial costs but offer long-term savings.

Additional resources:

https://www.rics.org/news-insights/building-a-sustainable-future-the-incredible-potential-of-self-healing-concrete

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WP3 Training Modules on Biomimicry Process Design

Task 3.1/ A1. Developing Self-learning Kit for VET students - LP: ATS / CPs: ALL

LET'S MIMIC CHALLENGES

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The description column provides guidelines with examples for filling in the information for the biomimicry design steps.

Challenge: Velcro invention for fasten and secure almost anything

BIOMIMICRY 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** How can we design a fastening system to ensure ease of use while maintaining strong adhesion? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Describe the context** The design 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. The target groups impacted by this invention would be: • **Textile manufacturers:** They can use a durable, eco-friendly fastening solution that withstands wear and washing, enhancing the lifespan of their products and appealing to environmentally conscious consumers. • **Outdoor gear companies:** A strong, weather-resistant fastening system could improve the performance and reliability of outdoor equipment, making their products safer and more effective. • **Automotive industry**: Manufacturers could incorporate lightweight and secure fasteners into vehicles, reducing weight while maintaining safety and durability.

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- **Home goods and furniture:** Versatile fasteners can provide aesthetic and functional solutions for upholstery and modular furniture.
- **Educational institutions and research organisations:** Access to innovative fastening solutions for research and development could support projects in biomimicry and sustainable design, fostering collaboration and advancements in these fields.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Are there connections to other solutions or challenges? Look into opportunities

- **Sustainable design alignment:** This product invention could reduce waste from disposable fasteners and enhance product longevity.
- **Versatile, cross-industry applications:** It can be applied across multiple industries, encouraging widespread adoption.
- **Lower maintenance and failure rates:** It can reduce mechanical failure risks, benefiting high-stakes applications such as the medical and aerospace fields, where reliability is essential.
- **Accessibility and usability:** A product like this could support accessibility, making it beneficial for individuals with limited dexterity and fostering inclusivity in product design.

Are there specific limitations or risks that need to be considered? Look into constraints

- **Material durability:** Ensuring the durability and strength of this material over repeated use is challenging, especially in high-stress applications.
- **Manufacturing consistency:** Precision is required to replicate the hook-and-loop structure at scale, which poses production challenges for maintaining quality and uniformity.
- **Cost of quality materials:** High-quality, durable materials can be costly, challenging the goal of affordability across different markets.

Are there favourable circumstances, initiatives or legislations that might impact?

Growing sustainability initiatives and customer demand for eco-friendly products are favourable conditions for a design of this kind, as they fuel interest in waste-reducing, reusable fastening methods. Laws that support accessibility requirements also encourage designs that help people with less dexterity. The adoption of this product throughout industries looking for more accessible and environmentally

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	friendly solutions would also be possible with regulatory backing for inclusive designs and sustainable materials.

Additional resources:

https://invention.si.edu/invention-stories/george-de-mestral-velcror-inventor

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LET'S MIMIC CHALLENGES

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Challenge: Fastskin swimsuit

BIOMIMICRY 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** How can we design a swimsuit that is resistant to drag and enhances the swimmer's speed in the water? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Describe the context** This invention is essential to address the need for a suit that minimises drag and allows swimmers to achieve faster speeds with less effort. The target audience would include competitive swimmers at all levels, from aspiring athletes to Olympic champions, who are looking for any legal, performance-enhancing advantage. **1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.** **Are there connections to other solutions or challenges? Look into opportunities** • **Natural insights:** There are many examples of species that move through water effectively in nature, which might serve as inspiration for strategies to reduce drag and maximise movement. These observations might direct the development of innovative structural and material designs. • **Competitive demand:** Designs that can lower swimmer effort and increase speed are highly sought after within the high-performance sports sector, especially in swimming, which is always looking for innovations that provide a legitimate competitive edge. • **Fabrication techniques:** With the help of new technologies like 3D printing and nanofabrication, materials' texture and

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structure can be precisely controlled, allowing for intricate shapes that may facilitate faster flow through water.

Are there specific limitations or risks that need to be considered? Look into constraints

- **Regulatory restrictions:** To maintain fair play, competitive swimming requires stringent regulations regarding swimsuit technology. Design options are limited, as suits that are thought to provide an undue advantage or alter buoyancy are frequently regulated.
- **Cost and complexity of manufacturing:** It can be costly and complex to replicate effective, drag-reducing structures, which could increase costs and restrict accessibility for all swimmers.
- **Comfort and durability in balance:** Although speed may be prioritised over comfort and durability in high-performance suits, athletes require suits that fit well and withstand the rigours of intense training.
- **Water resistance and lightweight design:** To reduce drag without adding weight, the suit should ideally repel water effectively. It might be challenging to achieve water resistance while maintaining the suit's flexibility and lightness.

Are there favourable circumstances, initiatives or legislations that might impact?

The development of a faster swimsuit could be positively influenced by several advantageous variables. Research into cutting-edge, high-performance materials is fueled by increased investment in sports science, and eco-friendly fabrics that improve performance are being developed in response to the growing demand for sustainable products. Collaborations between sports companies and academic institutions enable joint design and on-the-field athlete testing, guaranteeing that new suits are comfortable and quick. Fair competition and unambiguous material laws, meanwhile, provide limits for creativity and assist designers in concentrating on safe, legal materials that can improve sports performance while maintaining competitive standards.

Additional resources:

https://www.popsci.com/technology/article/2012-07/speedos-super-fast-sharkskin-inspired-swimsuit-actually-nothing-sharks-skin/

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LET'S MIMIC CHALLENGES

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The description column provides guidelines with examples for filling in the information for the biomimicry design steps.

Challenge: Stronger and tougher ceramics

BIOMIMICRY 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** How can we make ceramics more resistant? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Describe the context** The design needs to address the challenge of creating a ceramic material that can withstand high stress without breaking. Despite its strength, traditional ceramics are brittle and can break when exposed to harsh environments or impacts. By increasing toughness and resilience, this new design must get over its brittleness and be better able to withstand strain and stress. The target group consists of sectors such as aerospace, defence, and construction that rely on robust materials, where ceramics can be utilised in parts subjected to high-impact or high-stress conditions. **1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.** **Are there connections to other solutions or challenges? Look into opportunities** • **Wide-ranging industry applications:** High-impact industries where durability and lightweight materials are crucial, such as electronics, automotive, aerospace, and defence, may benefit from enhanced ceramics. This broad spectrum of applications promotes industry-wide investment and research. • **Demand for resilient, lightweight materials:** A competitive advantage can come from the ability to substitute a robust material for brittle ceramics or heavy metals.

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- **Sustainability and waste reduction:** By making ceramics less brittle, less material may be required for particular uses, decreasing waste and possibly lessening the impact on the environment. This is in line with industrial sustainability aims.

Are there specific limitations or risks that need to be considered? Look into constraints

- **High production costs:** Since it requires an intricate layering process, the ceramic may not be as widely available for application.
- **Manufacturing scalability:** It is difficult to replicate the structure of nacre at scale without sacrificing quality, which could postpone widespread production.
- **Material compatibility:** Improving toughness may have an impact on features like transparency or heat resistance, which could be problematic for applications with multiple uses.
- **Long-term durability:** There's some uncertainty over the material's capacity to withstand harsh circumstances or repeated stress.
- **Regulatory standards:** Adoption may be delayed and initially restricted to low-risk environments due to stringent testing requirements in sectors such as aerospace.
- **Dangers to the environment and human health:** Certain manufacturing procedures may present dangers to the environment or human health, which could affect adherence to safety regulations and sustainability objectives.

Are there favourable circumstances, initiatives or legislations that might impact?

The creation and adoption of more durable, bio-inspired ceramics may be positively impacted by a number of advantageous conditions and programs. Innovation is encouraged by increased financing for materials science research, and the qualities of these cutting-edge ceramics complement the growing need for strong, lightweight materials. Initiatives for sustainability also provide opportunities for environmentally friendly solutions that reduce waste and boost resource efficiency. Exploration of natural structures is encouraged by the growing interest in biomimetic design, which promotes cooperation between industry and scientists. In addition, by combining their knowledge, collaborations between academic institutions, research centres, and private businesses may accelerate progress. Lastly, funding programs and streamlined procedures are examples of regulatory support for innovation that can help promote the adoption of these new technologies in a variety of industries.

Additional resources:

https://www.livescience.com/44705-breaking-the-mold-nature-inspires-tougher-ceramics.html

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WP3 Training Modules on Biomimicry Process Design

Task 3.1/ A1. Developing Self-learning Kit for VET students - LP: ATS / CPs: ALL

LET'S MIMIC CHALLENGES

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The description column provides guidelines with examples for filling in the information for the biomimicry design steps.

Challenge: Adhesive patches that don't harm

BIOMIMICRY 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** How can we design a flexible, adhesive skin patch that utilises advanced suction technology to enhance adhesion and functionality for medical applications? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Describe the context** The design must address the challenge of creating a skin patch that adheres securely to various surfaces, including human skin, without causing discomfort or irritation. To provide reliable adhesion during physical activities or exposure to moisture, it must be sufficiently flexible to accommodate body movements. The patch should also be simple to apply and remove without causing any skin damage or residue. Patients in need of wound care, medical professionals, and researchers in the healthcare and medical device fields are among the intended audience. **1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.** **Are there connections to other solutions or challenges? Look into opportunities.** • **Growing market:** Increased demand for wearable health devices creates opportunities for innovative skin patch solutions. • **Healthcare collaboration:** Partnering with medical professionals provides valuable insights into user needs, guiding the development of effective design.

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- **Patient comfort focus:** Emphasis on patient-centred care drives demand for comfortable and easy-to-use products, improving compliance.
- **Regulatory support:** Regulatory bodies are increasingly supportive of innovative medical devices, facilitating quicker approvals.

Are there specific limitations or risks that need to be considered? Look into constraints.

- **Material limitations:** Balancing adhesion strength, flexibility, and skin compatibility can be challenging, especially under varying conditions.
- **Development costs:** High research and manufacturing costs may impact product affordability and accessibility.
- **Market competition:** Established products in the medical adhesive market create a competitive landscape, requiring effective differentiation.
- **User acceptance:** Ensuring proper application and understanding among healthcare professionals and patients is essential for successful adoption.

Are there favourable circumstances, initiatives or legislations that might impact?

Several advantageous conditions and initiatives may positively impact the creation and implementation of a flexible, adhesive skin patch. A significant market need has arisen due to increased investment in healthcare innovation and growing demand for wound care solutions, particularly as the population ages and chronic wounds become more prevalent. Furthermore, a focus on patient-centred care prioritises usability and comfort, and the increasing popularity of wearable medical technology encourages advancements in adhesive technologies. Additionally, regulatory agencies are assisting new medical devices by encouraging expedited approval procedures, and cooperative research projects between academic institutions, healthcare providers, and industry participants further develop these technologies and foster an atmosphere that is favourable for their adoption.

Additional resources:

https://newatlas.com/medical/amos-octopus-sucker-inspired-skin-patch/

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Challenge: More efficient wind power

BIOMIMICRY 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** How can we design wind turbine blades that use biomimetic features to improve efficiency and performance in turbulent wind conditions? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Describe the context** The design must address the challenge of maximising energy capture by increasing the efficiency of wind turbine blades in turbulent conditions. The energy output of current turbine blades is limited by drag and decreased performance during variable wind speeds. The solution must improve aerodynamic efficiency without sacrificing durability or structural integrity. The intended target group includes renewable energy companies, wind farm operators, and wind turbine design and installation engineers. The promotion of sustainable energy sources will also attract the interest of environmental groups and policymakers. **1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.** **Are there connections to other solutions or challenges? Look into opportunities** • **Increased investment in renewable energy:** As the world shifts to sustainable energy sources, funding and resources are being directed toward innovative wind energy technologies. • **Technological advancements:** In materials science and manufacturing processes can make turbine blades lighter and more durable, improving performance.

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- **Government Incentives:** Favourable policies and incentives for renewable energy projects can encourage the adoption of new technologies, making it easier to implement better designs.
- **Collaborative Research Opportunities:** Collaborations among academia, industry, and research institutions can promote innovation and accelerate the development of new turbine technologies.
- **Are there specific limitations or risks that need to be considered? Look into constraints**
- **Impact on existing infrastructure:** Changing or replacing current turbine systems with new designs may necessitate significant changes to existing infrastructure, resulting in additional costs and logistical challenges.
- **Maintenance and reliability:** New designs may present unexpected maintenance challenges, particularly if they necessitate specialised knowledge or tools for upkeep, potentially raising operational costs.
- **Public perception and acceptance:** Obtaining support from stakeholders, such as local communities and environmental groups, can be complex, especially if there are concerns about the impact of new turbine designs on wildlife or aesthetics.

Are there favourable circumstances, initiatives or legislations that might impact?

Favourable conditions for the development and adoption of new wind turbine blade designs include global commitments to renewable energy, which fosters innovation. Government incentives and subsidies for renewable energy projects make it more feasible to invest in advanced technologies. Research and development is also supported by financial opportunities from the public and private sectors that are devoted to clean technology projects. Through the sharing of resources and knowledge, partnerships between academic institutions, research centres, and industry stakeholders promote innovation. Additionally, the market is interested in more efficient wind energy solutions due to rising sustainability and climate change awareness. Advances in materials science help find new materials that enhance turbine durability and performance.

Additional resources:

https://www.technologyreview.com/2008/03/06/221447/whale-inspired-wind-turbines/

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Challenge: Efficient Fog Collection

BIOMIMICRY 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** How can we improve energy efficiency and reduce environmental impact in industrial processes by effectively utilising fog collection techniques? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience and what is the context of the challenge.** **Describe the context** The design should tackle the issue of efficiently capturing and utilising fog as a water resource to support industrial processes and improve water sustainability in arid regions. To reduce the dependency on conventional water sources and the impact on the environment, systems that can efficiently collect moisture from fog and transform it into usable water must be developed. The target group comprises municipalities seeking sustainable water solutions, agricultural producers, and businesses operating in water-scarce areas. Relevant stakeholders will also include environmental groups and legislators who are concerned with resource management and water conservation. **1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.** **Are there connections to other solutions or challenges? Look into opportunities** • **Growing water scarcity:** In many regions, rising water scarcity creates a strong demand for novel water collection solutions, such as fog harvesting. • **Technological advancements:** Innovations in materials and design techniques can increase the efficiency and effectiveness

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of fog collection systems, making them more viable for industrial use.

- **Supportive policies and initiatives:** Governments and organisations committed to sustainability and water conservation may provide funding, grants, or incentives for fog collection technology implementation.

Are there specific limitations or risks that need to be considered? Look into constraints

- **Limited water yield**: The amount of water that can be harvested from fog can be variable and may not meet the needs of larger industrial processes or communities, making it less reliable as a primary water source.
- **Maintenance and durability**: Fog nets and other collection materials may require regular maintenance to ensure functionality, which can incur additional labour and operational costs.
- **Possible ecological impact:** Although fog harvesting has the potential to be a sustainable solution, if it is not managed correctly, it may have unanticipated effects on nearby ecosystems, which may cause opposition from environmental organisations.

Are there favourable circumstances, initiatives or legislations that might impact?

An increased focus on water sustainability brought on by growing awareness of the world's water shortage creates favourable conditions for developing fog collection systems by encouraging the investigation of novel approaches like fog harvesting. While international climate agreements promote sustainable water management practices, government support in the form of grants and subsidies provides crucial funding for these technologies. Additionally, funding for research and development encourages creativity, and community-engaged projects can increase knowledge of the benefits of fog harvesting and garner local support. Partnerships with academic institutions can speed up technological advancements, and the growing emphasis on building resilient infrastructure allows for the incorporation of fog collection systems as additional water sources, which aligns with broader sustainability goals.

Additional resources:

https://projects.research-and-innovation.ec.europa.eu/en/projects/success-stories/all/mimicking-lizard-skin-save-energy-industrial-scale

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Challenge: Accurate Underwater Communication

BIOMIMICRY 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** How can we develop a reliable underwater communication system that leverages concepts from dolphin echolocation? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience and what is the context of the challenge.** **Describe the context** The design should tackle the issue of efficiently capturing and utilising fog as a water resource to support industrial processes and improve water sustainability in arid regions. To reduce the dependency on conventional water sources and the impact on the environment, systems that can efficiently collect moisture from fog and transform it into usable water must be developed. The target group consists of municipalities looking for sustainable water solutions, agricultural producers, and businesses situated in water-scarce areas. Relevant stakeholders will also include environmental groups and legislators who are concerned with resource management and water conservation. **1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.** **Are there connections to other solutions or challenges? Look into opportunities** There are several opportunities for advancing underwater communication systems, including rapid technological advancements in underwater acoustics and signal processing, which can significantly improve the effectiveness of natural-mechanism communication. The market for dependable underwater communication systems is expanding due to the rising need for environmental monitoring and marine research. Furthermore, government and private sector funding for the development of marine technologies can provide crucial

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support for innovative projects. While greater environmental consciousness stimulates investments in technologies that improve data collection and monitoring, cooperative partnerships with academic institutions, marine organisations, and technology companies can promote knowledge sharing and drive innovation.

Are there specific limitations or risks that need to be considered? Look into constraints.

However, several constraints may limit the success of such projects. Environmental obstacles that may reduce the efficacy of underwater communication systems include fluctuating acoustic conditions, noise pollution, and signal attenuation. The high cost of creating cutting-edge communication technologies may also compromise the project. Additionally, adhering to maritime standards and regulations could make the design and implementation procedures more difficult. Making systems that work consistently in a variety of marine environments is technically challenging, and making sure they are compatible with current underwater infrastructure and technologies can pose further obstacles to successful deployment.

Are there favourable circumstances, initiatives or legislations that might impact?

The development of underwater communication systems benefits from several favourable circumstances, including a strong emphasis on marine sustainability from both governments and the private sector, which results in increased funding and support for cutting-edge technologies. International agreements to protect aquatic ecosystems also encourage investments in research and development for efficient monitoring solutions. Furthermore, a climate that is favourable to the adoption of new communication technologies for underwater exploration and environmental protection is emerging as public awareness of ocean health and the significance of data collection in combating climate change increases.

Additional resources:

https://asknature.org/innovation/underwater-acoustic-communication-inspired-by-dolphins/

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Challenge: Camera to capture the faintest features of the galaxy

BIOMIMICRY 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** How can we design a high-sensitivity camera inspired by moth eyes to capture more explicit images in low light? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience and what is the context of the challenge.** **Describe the context** The goal of this design is to address the problem of capturing high-quality images in low-light conditions, where conventional cameras often fail due to glare and noise. It aims to increase the sensitivity of imaging systems, enabling more detailed and more precise images in conditions such as low light levels, at night, or underwater. In terms of target group, the audience includes photographers, wildlife researchers, security guards, and medical professionals who require reliable imaging capabilities in low-light conditions. Additionally, consumers seeking high-performance cameras for personal use would also benefit from these advancements. In this regard, the growing need for efficient imaging solutions in various industries, such as environmental monitoring, healthcare, and surveillance, highlights the necessity for cutting-edge technologies. Creating a camera system that performs well in low-light conditions is crucial for enhancing data capture and overall efficacy, as applications in these settings expand due to advancements in multiple industries. **1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.** **Are there connections to other solutions or challenges? Look into opportunities** There are several advantages to developing a high-sensitivity imaging system. Advances in materials science and optics have made new

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opportunities possible for producing extremely sensitive, low-glare camera components. The growing demand for improved imaging in fields such as security, medical diagnostics, and wildlife monitoring promotes industry-wide funding and collaboration. Furthermore, the market's need for creative solutions as consumer interest in low-light photography grows offers additional incentives for research and development.

Are there specific limitations or risks that need to be considered? Look into constraints

However, a few limitations may affect the design's effectiveness. The complexity and cost of the materials needed to create a high-sensitivity system may make it difficult to keep it small and economical. Engineering challenges also include developing a camera that consistently performs well in various low-light conditions without consuming excessive power or experiencing technical issues. Lastly, it could take a lot of testing and modification to make sure the new design works well with the current technology, which would prolong and increase the development process's cost.

Are there favourable circumstances, initiatives or legislations that might impact?

The development of high-sensitivity imaging systems is being supported by increased investment in advanced optics and imaging research, driven by growing demand from the consumer electronics, medical, and security sectors. These efforts are further supported by government funding for environmental monitoring and medical imaging, as well as sustainability programs that prioritise low-energy designs. Additionally, growing consumer demand for smartphones with high-performance imaging drives additional camera technology advancements.

Additional resources:

https://techcrunch.com/2016/12/20/moth-eyes-inspired-the-design-of-this-hypersensitive-camera/

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Challenge: Heat Insulation

BIOMIMICRY 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** How can we create a lightweight, eco-friendly insulation material that provides high thermal efficiency in extreme temperatures? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Describe the context** This **design** aims to address the issue of effective thermal insulation in extreme temperatures, prioritising lightweight and eco-friendly materials simultaneously. It should focus on improving heat retention and reducing energy loss, making it ideal for applications where conventional insulation often underperforms, such as in lightweight structures, cold-weather clothing, and energy-efficient buildings. The **target group** of this design will include architects and builders looking for sustainable building materials, manufacturers of outdoor gear for cold conditions, and organisations committed to enhancing energy efficiency in both residential and commercial settings. Finally, the **context for the 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. The need for insulation materials that function well in both hot and cold temperatures is growing as extreme weather patterns become more frequent. This context emphasises how crucial it is to create cutting-edge insulation solutions that satisfy performance requirements while also fitting in with current energy-saving and sustainability trends. **1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.**

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Are there connections to other solutions or challenges? Look into opportunities

The insulation material's successful development can be facilitated by a number of opportunities. Research and innovation spending has surged as a result of the increased focus on sustainable building methods and materials. Additional funding and resources may be made available through partnerships with environmentally conscious groups and government programs that support green technologies. A competitive market is created as a result of businesses exploring creative insulation solutions in response to the growing consumer demand for energy-efficient products. Furthermore, developments in material science open up new avenues for the development of lightweight, eco-friendly insulation.

Are there specific limitations or risks that need to be considered? Look into constraints

The development process could be compromised by certain limitations, though. It can be difficult to find sustainable materials that meet cost-effectiveness and performance requirements. Furthermore, developing an insulating material that strikes a balance between high thermal efficiency and lightweight characteristics may call for intricate engineering solutions, which can be costly and time-consuming. Extensive testing may be required to guarantee the material's efficacy and durability under a range of harsh conditions, which could lengthen the development period and raise expenses. Lastly, additional challenges that must be overcome during the design phase may arise from industry standards and regulatory requirements for insulation materials.

Are there favourable circumstances, initiatives or legislations that might impact?

The strong global emphasis on sustainability and energy efficiency, which results in government incentives like grants and tax credits for eco-friendly projects, is one of the favourable conditions for the development of this insulation material. Investment in energy-efficient products and renewable technologies is encouraged by international climate agreements like the Paris Agreement. Furthermore, energy efficiency is becoming a higher priority in local building codes, which is increasing demand for creative insulation solutions. Builders are encouraged to look for high-performance materials by environmental certifications like LEED, and manufacturers are forced to make investments in efficient insulation solutions by rising consumer demand and public awareness for sustainable products.

Additional resources:

https://projectscot.com/2020/07/engineer-creates-insulation-inspired-by-polar-bear-fur/

https://phys.org/news/2019-06-polar-bear-inspired-material-insulation.html#google_vignette

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Challenge: Efficient Water Harvesting in Arid Environments

BIOMIMICRY 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** How can you design an efficient and scalable system for harvesting and storing water in arid environments? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience and what is the context of the challenge.** **What the design needs to do** • 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. • Avoid over-reliance on external resources, ensuring the solution is robust in long-term, low-water scenarios. **Target audience** • **Rural communities in arid regions:** These populations face water scarcity and need a reliable and accessible water source. The design should be affordable, easy to install, and capable of providing water for drinking, agriculture, and basic sanitation. • **Governments and NGOs:** Organisations working on water access, climate adaptation, and poverty alleviation could adopt and distribute water harvesting systems in areas suffering from chronic water shortages.

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- **Agricultural producers:** Farmers in arid climates would benefit from a water harvesting system that provides irrigation for crops and livestock.
- **Urban planners and municipalities in dry areas:** Cities in arid regions, especially those growing rapidly in deserts or semi-arid zones, need scalable water harvesting systems to support their populations and infrastructure development.
- **Environmentalists and sustainability advocates:** Groups focused on water conservation and environmental sustainability may be interested in promoting and funding efficient water harvesting as a part of broader climate change mitigation strategies.

Context

- The growing threat of climate change exacerbates water scarcity, with more frequent droughts and increased evaporation rates. Many already water-stressed regions will see even more extreme weather patterns in the coming decades.
- Water scarcity in arid regions leads to migration, conflicts over water resources, and significant health challenges. Improving water access is crucial to the resilience and sustainability of these communities.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- **Advancements in water harvesting technology:** New materials such as hydrogels, bio-inspired surfaces, and advanced filtration technologies offer new ways to capture and store water more efficiently. These technologies can be adapted to local contexts and incorporated into the design.
- **Solar power integration:** Solar energy can power the water harvesting and filtration systems, making them more energy-independent and sustainable in remote areas with ample sunlight.
- **Government and NGO support:** Many international organisations and governments are already investing in sustainable water management projects, especially in drought-prone areas. These efforts can provide financial support and political will for scaling up water harvesting systems.
- **Public awareness and demand for sustainability:** As awareness about climate change grows, interest is increased in sustainable and green technologies. This creates an

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opportunity to introduce innovative water harvesting solutions that also contribute to global sustainability goals.

- **Collaboration with Academia:** Partnerships with research institutions can bring cutting-edge solutions to practical problems, allowing for innovations like bio-inspired designs or efficient filtration systems to be implemented in real-world settings.

Constraints

- **High initial investment:** Developing and implementing large-scale water harvesting systems, particularly new technologies, may require significant upfront investment, which could be a barrier for poorer communities or regions.
- **Climate and environmental factors:** Designing a system that works effectively in arid environments, where conditions can vary widely (e.g., desert vs. semi-arid) and unpredictable weather events may occur, presents a technical challenge.
- **Infrastructure and maintenance challenges:** Building systems that can operate autonomously and require minimal maintenance in harsh conditions is a significant challenge. Local capacity for maintenance and repair may also be limited in remote areas.
- **Scarcity of water resources:** While harvesting water from dew, fog, or humidity may be effective in some arid areas, these sources are often limited and unreliable. A system that depends on these sources may not meet the water needs in more extreme water scarcity regions.
- **Regulatory and land use constraints:** Legal and policy frameworks around water rights, land use, and environmental conservation may limit how and where water harvesting systems can be implemented. This includes water ownership and access issues in shared or contested regions.
- **Cultural and social barriers:** In some regions, cultural norms or resistance to new technologies may affect the adoption of water harvesting systems. Ensuring local communities accept solutions will require understanding local customs and involving them in the design process.

Favourable circumstances, initiatives, or legislation

- **International climate agreements:** Policies like the Paris Agreement encourage investment in sustainable technologies and adaptation solutions, which can drive funding and innovation in water harvesting technologies.
- **Water access initiatives:** Many governments and international organisations have set ambitious targets for improving water access in developing regions, particularly under the UN

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Sustainable Development Goals (SDGs), specifically Goal 6 (Clean Water and Sanitation).

- **Research funding and innovation grants:** There are growing funding opportunities for technologies that address global water scarcity challenges, including grants from entities like the Bill & Melinda Gates Foundation, the World Bank, and the European Union.
- **Policy support for sustainability:** Governments and organisations are increasingly adopting policies and incentives for sustainable resource management, which could provide an enabling environment for water harvesting projects, especially those that promote decentralised, community-based solutions.
- **Corporate responsibility and investment in water sustainability:** Major corporations are beginning to invest in water sustainability initiatives for their environmental, social, and governance (ESG) goals. This trend could result in private sector support for water harvesting technologies.

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WP3 Training Modules on Biomimicry Process Design

Task 3.1/ A1. Developing Self-learning Kit for VET students - LP: ATS / CPs: ALL

LET'S MIMIC CHALLENGES

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The description column provides guidelines with examples for filling in the information for the biomimicry design steps.

Challenge: Creating self-healing materials

BIOMIMICRY 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** How can you develop materials that autonomously repair damage without external intervention or energy input? **1.b Describe what the design needs to do or solve (not what you will make or design), who your target audience is, and the context of the challenge.** **What the design needs to do** • The material should be able to autonomously detect and repair physical damage (such as cracks, tears, or abrasions). • It must restore the material's functionality (e.g., strength, conductivity, flexibility) to its original state after damage. • The design should enable the material to heal multiple times without degradation of its properties over time. • The self-healing mechanism should be triggered by simple environmental factors (e.g., heat, moisture, UV light) and require minimal external energy or intervention. **Target audience** • **Manufacturers and industries:** Self-healing materials would benefit manufacturers in various sectors, including automotive, aerospace, construction, and electronics. They would extend the lifespan of products, reduce maintenance costs, and improve safety by preventing catastrophic failures. • **Product designers and engineers:** Designers working on consumer products, electronics, or medical devices could use self-healing materials to improve product reliability, reduce waste, and enhance user experience.

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- **Construction and infrastructure:** Self-healing materials can enhance the longevity and resilience of buildings, roads, bridges, and pipelines, reducing the frequency of repairs and maintenance.
- **Healthcare and biotech:** Self-healing materials could be used in biomaterials for medical implants, wound dressings, and prosthetics that require the ability to self-repair and maintain functionality over time.
- **Environmentalists and sustainability advocates:** By reducing the need for repairs, replacement, and disposal of damaged products, self-healing materials can contribute to a reduction in waste and resource consumption, supporting sustainability goals.

Context

- Materials used in many industries, such as electronics, transportation, and construction, are prone to wear and tear over time. Self-healing materials can provide significant cost savings and improvements in product performance by reducing the need for repairs and maintenance.
- There is a growing demand for advanced materials that are stronger, longer-lasting, and more sustainable. With global concerns over environmental impact, self-repair products could reduce waste and increase product lifecycles.
- Many existing materials, such as polymers, metals, and composites, have limitations preventing them from autonomously repairing damage. The challenge is to develop materials that can combine the desired properties with self-healing capabilities, ideally at a reasonable cost.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- **Advances in materials science:** Breakthroughs in polymers, nanomaterials, and smart materials provide new ways to incorporate self-healing capabilities. For example, microcapsules containing healing agents, reversible chemical bonds, and bio-inspired materials open up new possibilities.
- **Increased demand for sustainable products:** As industries and consumers become more environmentally conscious, there is a growing demand for durable, longer-lasting products. Self-healing materials could help reduce waste, improve recyclability, and lower the carbon footprint associated with product replacements.
- **Research and innovation grants:** Research funding and collaborative partnerships between universities, industries,

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and governments support developing advanced materials. Public and private investment in materials research is increasing, providing a favourable environment for innovation.

- **Integration with smart technologies:** The rise of the Internet of Things (IoT) and smart manufacturing could offer opportunities for embedding self-healing capabilities in devices that can communicate with their environment to trigger healing processes autonomously.
- **Cross-Industry applications:** Self-healing materials have applications across many industries, including automotive, aerospace, electronics, construction, and healthcare, creating a broad market potential.

Constraints

- **Material complexity and cost:** Developing self-healing materials that can be cost-effective and scalable for industrial use is a major challenge. Some self-healing processes may require expensive or rare materials that make the final product too costly for mass production.
- **Technological limitations:** While there has been progress in developing self-healing materials, most current solutions are limited in terms of the types of damage they can repair (e.g., minor cracks or surface abrasions), and there is still limited success in repairing larger or more complex damage autonomously.
- **Durability and performance trade-offs:** Some self-healing materials may heal quickly, but their healing cycles may diminish over time, leading to a decline in performance or the material's ability to recover again. Balancing durability with repeatability of the healing process remains a key challenge.
- **Environmental and safety concerns:** Some self-healing materials involve chemicals or processes that may be toxic or harmful to the environment. Ensuring that self-healing materials are safe and sustainable is a critical challenge.
- **Integration into existing manufacturing processes:** Incorporating self-healing capabilities into existing manufacturing processes without disrupting production or adding significant costs can be a difficult task. It may require new techniques or technologies not yet widely adopted in industry.
- **Regulatory hurdles:** Regulatory frameworks for materials and product standards may not yet account for new types of self-healing materials. Gaining approval for new materials in highly regulated industries (such as aerospace, automotive, or medical devices) may be slow and challenging.

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Favourable circumstances, initiatives, or legislation

- **Government investment in advanced manufacturing:** Many governments are investing in advanced manufacturing and materials science, including initiatives focusing on sustainable manufacturing and reducing waste. This can create funding opportunities for research into self-healing materials.
- **Industry 4.0 and smart manufacturing:** The rise of smart manufacturing technologies, which use sensors and automation, could make integrating self-healing materials into industrial products easier. Industry 4.0 initiatives encourage the development of innovative, high-performance materials that could include self-healing properties.
- **Corporate sustainability goals:** Many companies increasingly focus on sustainability, including reducing waste and extending product lifecycles. Self-healing materials align with these goals and may be prioritised as part of corporate responsibility initiatives.
- **Academic and industry collaboration:** Universities, research institutions, and private companies are increasingly collaborating on developing self-healing materials. These partnerships provide the expertise and resources necessary to accelerate the commercialization of such technologies.
- **Environmental regulations:** Stricter regulations related to waste, carbon emissions, and product lifecycle management are pushing industries to adopt more sustainable technologies, creating a favourable environment for the development and implementation of self-healing materials.

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WP3 Training Modules on Biomimicry Process Design

Task 3.1/ A1. Developing Self-learning Kit for VET students - LP: ATS / CPs: ALL

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Challenge: Efficient wastewater treatment in urban areas

BIOMIMICRY 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** How can we design an efficient, scalable, and sustainable wastewater treatment system for urban areas that supports resource recovery and minimises environmental impact? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and the context of the challenge.** **What the design needs to do** • **Efficiently treat wastewater:** Achieve high water purification standards, removing contaminants like organic matter, heavy metals, and pathogens. • **Recover valuable resources:** Capture and repurpose by-products like clean water, biogas, and nutrients for reuse in agriculture, industry, or urban infrastructure. • **Operate in space-limited areas:** Be compact and adaptable for use in high-density urban areas, including underground or integrated into existing infrastructure. • **Ensure affordability and ease of use:** Be cost-effective to implement, operate, and maintain, particularly in resource-limited urban areas. • **Support climate resilience:** Function effectively under changing environmental conditions and contribute to urban sustainability goals. **Target audience** • **Urban municipalities:** Governments responsible for managing urban water and sanitation systems.

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- **Developing urban communities:** Populations in rapidly urbanising areas that lack adequate sanitation infrastructure.
- **Industries:** Factories and businesses generating wastewater that need sustainable treatment solutions.
- **Environmental organisations:** Groups focused on reducing water pollution and promoting sustainable practices.
- **Urban planners and architects:** Professionals designing sustainable cities who seek to integrate wastewater treatment into urban ecosystems.

Context

- **Urbanisation and population growth:** With urban populations expanding, many cities struggle to manage wastewater effectively, leading to pollution and public health risks.
- **Climate change:** Increasing frequency of droughts and extreme weather events stresses water resources, necessitating wastewater reuse.
- **Aging infrastructure:** Many cities rely on outdated or overburdened wastewater systems that cannot meet current demands or environmental standards.
- **Resource scarcity:** Recovering water and nutrients is critical in water-stressed and food-insecure regions.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- **Emerging technologies:** Bioelectrochemical systems, AI for process optimisation, and advanced filtration technologies can enhance treatment efficiency and adaptability.
- **Integration with renewable energy:** Solar energy and biogas can power wastewater treatment, lowering costs and increasing sustainability.
- **Resource recovery potential:** Recovering water, biogas, and nutrients from wastewater aligns with circular economy goals and creates additional value.
- **Urban planning synergies:** Green infrastructure and smart city initiatives can incorporate compact wastewater treatment systems into urban landscapes.
- **Funding opportunities:** Climate adaptation funds, sustainability grants, and corporate ESG initiatives provide financial support for wastewater projects.

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Constraints

- **High initial costs:** Advanced technologies may require substantial investment, limiting accessibility for resource-poor regions.
- **Pollutant complexity:** Diverse urban wastewater contaminants like microplastics and pharmaceuticals require specialised treatments.
- **Space limitations:** Land availability in dense urban areas may challenge the placement of large-scale systems.
- **Maintenance and expertise:** Robust systems are needed to ensure minimal maintenance in regions with limited technical capacity.
- **Regulatory Barriers:** Approval processes for new systems may delay deployment in some regions.

Favourable circumstances, initiatives, or legislation

- **UN SDG 6:** International clean water and sanitation targets encourage innovation and funding.
- **Climate adaptation policies:** Government policies supporting resilience projects provide a favourable environment for wastewater initiatives.
- **Research and industry collaboration:** Partnerships between academia, businesses, and governments can foster the development and scaling of innovative solutions.
- **Corporate environmental commitments:** Companies investing in sustainable practices may support urban wastewater systems as part of their goals..

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WP3 Training Modules on Biomimicry Process Design

Task 3.1/ A1. Developing Self-learning Kit for VET students - LP: ATS / CPs: ALL

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Challenge: Efficient and sustainable packaging

BIOMIMICRY 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** How can we design efficient and sustainable packaging, minimising waste while maintaining the safety, functionality, and cost-effectiveness needed for products? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **What the design needs to do** • The packaging must protect the contents from physical damage, contamination, and spoilage during transit, storage, and use. • It should reduce material waste by using less packaging, adopting minimalistic designs, and utilising sustainable materials with a lower environmental footprint. • The packaging should be easy to recycle, reuse, or compost, avoiding single-use plastics and materials contributing to landfill waste. • It should offer convenience to consumers, with clear labelling and easy-to-open features, without compromising its sustainability goals. • The packaging system should be cost-efficient and scalable to be widely adopted by businesses, particularly in industries with high packaging volumes such as food and beverage, e-commerce, and consumer goods.

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Target audience

- **Consumers:** Increasingly, consumers are seeking eco-friendly products and packaging. There is a growing demand for brands to offer sustainable options that align with consumer values around sustainability and environmental impact.
- **Retailers and brands:** Companies in sectors like food, electronics, beauty, and e-commerce are under pressure to meet sustainability goals, reduce packaging waste, and improve brand image by offering sustainable packaging solutions.
- **Manufacturers:** Producers of packaging materials and products need innovative solutions that are cost-effective, scalable, and provide the necessary protection and shelf life for products.
- **Government and regulatory bodies:** Local and national governments are introducing regulations to curb plastic waste and promote sustainability. These organizations are key stakeholders in incentivizing the adoption of more sustainable packaging practices.
- **Environmental NGOs and activists:** Organizations focused on sustainability and waste reduction can support and promote efficient and sustainable packaging solutions, advocating for the elimination of harmful packaging materials and pushing for better environmental stewardship.

Context

- Packaging waste, particularly plastic waste, is one of the biggest environmental challenges globally. According to estimates, a significant portion of plastic waste ends up in landfills, oceans, and waterways, contributing to pollution and harming wildlife.
- Governments around the world are increasingly introducing policies to regulate packaging waste, such as bans on single-use plastics, mandatory recycling programs, and extended producer responsibility (EPR) schemes that require manufacturers to take responsibility for packaging waste.
- Consumer demand for sustainable products is growing. Many consumers are willing to pay more for products that come in eco-friendly packaging. Companies are responding to this demand by exploring innovative packaging solutions that are both functional and environmentally responsible.
- Industries such as food and beverage, e-commerce, and cosmetics rely heavily on packaging to protect and promote their products. However, the packaging industry also faces increasing scrutiny over its environmental impact. Finding

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packaging that meets the needs of these industries while reducing environmental harm is crucial.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- **Advancements in sustainable materials:** New materials such as biodegradable plastics, plant-based biopolymers, algae-based packaging, and compostable packaging options are becoming more widely available. These innovations offer opportunities to reduce reliance on petroleum-based plastics.
- **Circular economy focus:** There is growing support for circular economy models, where materials are reused, remanufactured, and recycled. Packaging designed for reuse or with a clear path to recyclability can align with this movement, contributing to reduced waste.
- **Consumer preferences for sustainability:** Many consumers are willing to pay a premium for products with eco-friendly packaging, creating a market incentive for businesses to invest in sustainable solutions.
- **Government regulations and incentives:** Increasingly strict environmental regulations, such as plastic bans and waste reduction mandates, create a strong market demand for sustainable packaging solutions. Governments also offer tax incentives or subsidies for businesses adopting greener practices.
- **Technology for packaging efficiency:** Advancements in technology, such as 3D printing for packaging design and AI for optimising packaging supply chains, can help reduce material waste and improve the efficiency of packaging production.
- Corporate Sustainability Goals: More companies are setting ambitious sustainability targets, including goals to reduce packaging waste, improve recyclability, and minimize carbon footprints. This presents a clear opportunity for designers to create packaging solutions that meet these goals.

Constraints

- **Cost of sustainable materials:** Some sustainable materials, such as bioplastics or compostable packaging, can be more expensive than traditional materials like petroleum-based plastics or cardboard. This price differential can be a barrier for widespread adoption, particularly in price-sensitive industries.
- **Supply chain challenges:** Sourcing sustainable materials at scale and ensuring they meet the required performance standards (e.g., durability, shelf life, water resistance) can be

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difficult. The supply chain for some sustainable materials is not as well-established as conventional packaging materials.

- **Consumer education and behaviour:** While there is growing demand for sustainable packaging, not all consumers know how to recycle or dispose of certain packaging types properly. Educating consumers on proper disposal and the environmental benefits of the packaging is crucial for success.
- **Material limitations:** Many sustainable packaging materials, such as bioplastics or plant-based fibres, may have limitations in strength, durability, or shelf life, making them unsuitable for certain types of products (e.g., perishable foods, electronic products).
- **Regulatory hurdles:** Different regions may have varying regulations for packaging materials, particularly concerning recyclability, compostability, or biodegradability. Navigating these complex regulations and ensuring compliance can challenge manufacturers and designers.
- **Balancing sustainability with functionality:** Packaging must serve several functions: it needs to protect products, ensure shelf life, be cost-effective, and provide a positive consumer experience. Balancing these needs with sustainability goals can be challenging, as more sustainable materials might not always perform at the same level as traditional options.

Favourable circumstances, initiatives, or legislation

- **Global plastic waste initiatives:** Many countries and organisations, including the UN, are pushing for action on plastic waste. This creates a favourable environment for developing sustainable packaging solutions, as the public and private sectors are motivated to reduce plastic pollution.
- **Corporate responsibility and ESG goals:** Many large corporations have set ambitious Environmental, Social, and Governance (ESG) targets, including reducing packaging waste and adopting sustainable materials. This has created a market for sustainable packaging solutions.
- **Government regulations on packaging waste:** Increasing legislation, such as plastic bans, Extended Producer Responsibility (EPR), and deposit-return schemes, encourages businesses to adopt sustainable packaging solutions.
- **Recycling infrastructure and innovation:** Investments in recycling technologies, such as chemical recycling and better sorting technologies, could help address some of the limitations of existing packaging materials and improve the circularity of packaging systems.

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- **International certifications and standards:** Standards such as ISO 14001 for environmental management and certifications like Cradle to Cradle and Forest Stewardship Council (FSC) for sustainable materials can help manufacturers and designers navigate sustainability practices and build trust with consumers.

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WP3 Training Modules on Biomimicry Process Design

Task 3.1/ A1. Developing Self-learning Kit for VET students - LP: ATS / CPs: ALL

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Challenge: Increasing efficiency of wind turbines

BIOMIMICRY 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** How can we design a more efficient wind turbine that maximises energy output while minimising costs, maintenance, and environmental impact? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **What the design needs to do** • The design must maximize the efficiency of wind turbines, extracting as much energy as possible from the wind while maintaining stability and operational performance across different wind conditions. • It must reduce the total energy cost per megawatt-hour (MWh) produced, ensuring that wind power remains competitive with other renewable energy sources and conventional fossil-fuel-based energy. • The design should increase the lifespan of turbines by minimizing wear and tear, reducing maintenance costs, and increasing reliability, particularly for turbines in remote or offshore locations. • Wind turbines must be adaptable to various geographical locations and climates, ensuring that the technology works in both low-wind and high-wind environments and offshore and onshore conditions.

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- The design should reduce the environmental footprint of the turbine's lifecycle, from material sourcing to manufacturing, operation, and eventual decommissioning.
- The design should incorporate innovations that reduce noise and visual pollution, improving the acceptance of wind energy in residential and rural areas.

Target audience

- **Wind farm developers and operators:** Developers who design, build, and maintain wind farms are looking for more efficient and cost-effective turbines to maximize their energy output and reduce operational costs.
- **Energy producers and utilities:** Companies that generate and distribute energy, especially those looking to increase the share of renewable energy in their portfolios, will benefit from turbines that produce more energy at lower costs.
- **Environmental and sustainability advocates:** Organizations focused on reducing global carbon emissions and promoting clean energy are stakeholders in improving wind turbine efficiency to make wind energy more competitive and scalable.
- **Government and regulatory bodies:** Governments that set renewable energy targets and regulate the wind energy industry are key stakeholders, particularly as they push for more efficient and cost-effective renewable energy solutions.
- **Manufacturers of wind turbine components:** Companies that produce turbine blades, generators, towers, and other components are interested in innovations that lead to better performance, lower costs, and longer-lasting materials.
- **Researchers and engineers in renewable energy:** Academics and engineers working on renewable energy technologies will benefit from advancements in wind turbine efficiency, as it will open new avenues for research and development.

Context

- The global demand for renewable energy is increasing as nations look for ways to reduce reliance on fossil fuels and mitigate the impacts of climate change. Wind energy, in particular, is a key component of the renewable energy mix due to its scalability and relatively low environmental impact.
- While wind energy is growing rapidly, the efficiency of wind turbines still faces technical limitations, particularly in harnessing energy in low-wind conditions, maximising energy capture across varying wind speeds, and reducing operational costs.

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- Offshore wind farms with higher energy potential due to stronger and more consistent winds face unique challenges, including harsh marine conditions, high installation and maintenance costs, and environmental concerns.
- The cost of energy from wind turbines has been steadily decreasing over the years, but further efficiency improvements are necessary for wind power to compete with other forms of energy, particularly in areas with limited wind resources or where subsidies for renewable energy are being phased out.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- **Technological advancements in materials:** The development of lighter, stronger, and more durable composite materials for turbine blades can improve efficiency by reducing weight and extending the lifespan of turbines. Materials like carbon fibre, advanced polymers, and aerogel are examples of promising innovations.
- **Smart control systems and AI:** Integrating AI and machine learning algorithms can optimise turbine operation by analysing real-time data on wind conditions, wear and tear, and energy output. Predictive maintenance powered by AI can help minimise downtime and extend turbine life.
- **Offshore wind energy expansion:** With the potential for higher and more consistent wind speeds offshore, there are opportunities to design more efficient and robust offshore wind turbines, which could generate a significant share of global wind power.
- **Distributed and decentralised energy systems:** With the rise of distributed energy systems, smaller and more efficient wind turbines tailored for local energy generation in communities, industrial parks, and remote areas offer opportunities to reduce grid dependency and enhance local energy resilience.
- **Government and private investment:** As countries and corporations increase their investments in renewable energy, wind energy technology development, including efficiency improvements, is receiving more funding, fostering innovation in turbine design and manufacturing.
- **Collaboration between sectors:** Partnerships between wind energy companies, material science researchers, and AI developers can lead to breakthroughs in turbine efficiency by combining expertise from different fields.

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Constraints

- **High initial capital cost:** While wind energy is cost-competitive over the long term, the high upfront costs associated with wind turbine installation (including equipment, construction, and grid connection) can limit widespread adoption, particularly in developing regions.
- **Technological barriers to low-wind efficiency:** Improving turbine efficiency in low-wind conditions remains a challenge. Current turbines are designed for medium to high wind speeds, and it is difficult to adapt them to perform effectively in lower winds without sacrificing overall efficiency.
- **Environmental impact and land use:** While wind turbines themselves have a low environmental impact, large-scale wind farms, especially onshore, can negatively affect local wildlife (e.g., birds, bats) and land use. Offshore turbines face environmental challenges related to marine ecosystems and navigation.
- **Intermittency of wind:** Wind is an intermittent energy source, meaning turbines cannot always produce power when demand is high. Improving the efficiency of wind turbines is essential, but advancements in energy storage or grid integration will also be needed to ensure a consistent power supply.
- **Complexity of offshore installation:** Offshore wind turbines face unique challenges, including harsher operating conditions, more difficult installation, and higher maintenance costs. Designing turbines that are both more efficient and more resilient in these conditions is a significant challenge.
- **Regulatory barriers:** Different regions have different regulations and incentives for renewable energy projects. These regulations can create obstacles to innovation if they do not keep pace with technological advancements or fail to provide the necessary support for scaling wind energy projects.

Favourable circumstances, initiatives, or legislation

- **Global push for renewable energy:** Many countries are setting ambitious renewable energy targets, and wind energy is seen as a critical component of meeting these goals. Policies and incentives, such as tax credits, grants, and feed-in tariffs, encourage wind energy development and expansion.
- **International climate agreements:** Agreements like the Paris Agreement have spurred governments to adopt more ambitious emissions reduction goals, creating a favourable regulatory environment for adopting clean energy technologies like wind turbines.

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- **Technological and market innovation:** As wind turbine manufacturers continue to innovate with larger, more powerful turbines, there is a growing market for more efficient systems to maximise the return on investment in wind energy projects.
- **Offshore wind development programs:** Many governments, particularly in Europe, the U.S., and China, are increasing investment in offshore wind energy. This sector's growth presents opportunities for developing specialised, high-efficiency turbines optimised for offshore environments.
- **Corporate sustainability goals:** Many companies are setting renewable energy goals to reduce their carbon footprint and meet sustainability targets. This drives demand for more efficient, cost-effective wind turbines that can help corporations meet their energy needs sustainably.

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Challenge: Developing More Durable and Lightweight Structures

BIOMIMICRY 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** How can we design durable and lightweight structures, ensuring long-term performance, reduced material usage, and cost efficiency in construction? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **What the design needs to do** • The design must balance lightness and strength, ensuring that structures are not only lightweight but capable of withstanding environmental stressors, such as wind, weight loads, and seismic forces, over time. • It should use minimal materials while maintaining structural integrity, ensuring that the design is cost-effective both in terms of initial construction and long-term maintenance. • The structure should be adaptable, allowing for easy modifications or extensions without compromising the core integrity of the original design. • It should be durable over a long lifespan, requiring minimal maintenance, and resist common forces that lead to wear and degradation, such as corrosion, fatigue, or abrasion. • It should promote sustainability by using renewable, recyclable, or low-impact materials and reducing the carbon footprint during construction and decommissioning. **Target audience**

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- **Construction industry:** Builders and contractors, particularly those involved in large infrastructure projects (e.g., bridges, skyscrapers, roads, and stadiums), are constantly seeking ways to reduce material costs and improve the durability of structures.
- **Architects and engineers:** These professionals design the structures and need lightweight materials that can support creative and innovative designs while ensuring safety, sustainability, and efficiency.
- **Aerospace and automotive industries:** Companies designing lightweight structures for aircraft, spacecraft, and vehicles, where reducing weight is essential for improving fuel efficiency, speed, and performance, will benefit from durable, lightweight materials and innovative structural designs.
- **Product designers:** Manufacturers of consumer goods, electronics, or other products that require durable, lightweight enclosures or casings (e.g., laptops, mobile phones, and sporting equipment) will be interested in new materials or designs that balance strength and lightness.
- **Military and defence:** The defence sector requires lightweight and durable structures for various applications, including vehicles, shelters, and equipment that must withstand harsh environments while remaining lightweight for mobility and efficiency.
- **Sustainability advocates:** Environmental organisations and researchers focused on reducing the carbon footprint of construction and manufacturing industries will be interested in solutions that reduce resource use and waste while enhancing the longevity of structures.

Context

- **Increasing demand for sustainability:** As industries strive to meet environmental and sustainability targets, there is growing demand for materials and designs that reduce resource consumption, energy use, and waste. Lightweight structures help reduce the carbon footprint of transportation and construction while still meeting performance standards.
- **Technological advancements in materials:** Recent advances in composites, nanomaterials, and 3D printing offer the potential to create stronger, lighter materials that could significantly reduce the weight of structures without compromising strength and durability.
- **Cost-pressure in construction:** The global construction industry faces significant cost pressures, especially with rising raw material prices and labour shortages. Lightweight structures can help reduce construction and transportation

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costs by minimising material use and simplifying the construction process.

- **Climate change and resilience:** Climate change leads to more extreme weather events, such as storms, floods, and earthquakes. Structures that can withstand these stresses while using fewer materials are needed. Lightweight structures offer the potential for flexibility in design and resilience to changing environmental conditions.
- **Global infrastructure needs:** Developing countries and regions with growing populations need efficient, durable, cost-effective solutions. Lightweight materials and modular construction techniques can provide affordable solutions for housing, schools, and roads in rapidly growing urban areas.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- **Advanced materials development:** New materials such as carbon fibre, graphene, and fibre-reinforced polymers (FRPs) offer the potential to create highly durable and lightweight structures. Research into nanomaterials, biomimicry, and self-healing materials can further enhance structures' longevity and strength-to-weight ratio.
- **Additive manufacturing (3D Printing):** 3D printing technologies can create complex, customised structural components that are lightweight and durable. This technology enables precise control over material distribution, optimising structures' strength-to-weight ratio.
- **Modular and prefabricated construction:** Modular construction and prefabricated components offer opportunities to reduce material waste, improve construction speed, and ensure precise, high-quality assembly. These methods can be used to create lightweight, durable structures more efficiently.
- **Sustainability trends:** Increasing emphasis on sustainability in construction and product design presents an opportunity for innovative lightweight materials that are also environmentally friendly (e.g., recyclable, biodegradable, or derived from renewable sources).
- **Cost Reduction in manufacturing:** New manufacturing techniques, such as automation and robotic assembly, can help reduce the cost of producing complex lightweight structures. These methods can lower the overall cost of materials and labour for building durable structures.

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- **Infrastructure revitalisation:** Many countries are investing in infrastructure improvement projects, creating opportunities for more durable and lightweight materials that can replace outdated and inefficient structures, such as bridges, roads, and buildings.

Constraints

- **Material cost and availability:** While advanced materials such as carbon fibre and composites offer great potential, they often have high production costs. The cost of raw materials and the complexity of manufacturing processes may limit widespread adoption.
- **Strength and durability trade-offs:** Achieving the right balance between weight reduction and maintaining structural integrity is challenging. Some lightweight materials may not have the same durability or load-bearing capacity as traditional materials like steel or concrete, which could limit their application in specific high-stress environments.
- **Manufacturing and scaling:** The advanced manufacturing processes needed to produce lightweight, durable materials (e.g., 3D printing, nano-engineering) may not be widely scalable or cost-effective for large construction projects. Scaling these innovations to meet global demand remains a significant challenge.
- **Regulatory and safety standards:** Structures must comply with a variety of regulatory standards, including safety and environmental regulations. Ensuring that new, lightweight materials meet these standards for different industries (e.g., construction, aerospace) can slow innovation and adoption.
- **Environmental impact of material production:** Some advanced materials, such as composites or specific high-performance polymers, may have environmental challenges in their production, use, or disposal. For example, carbon fibre production is energy-intensive, and many composites are difficult to recycle, which could limit their sustainability benefits.
- **Performance in extreme conditions:** Lightweight materials need to be tested rigorously to ensure they perform well in extreme conditions, such as high winds, heavy snow, seismic activity, and temperature variations. This could present engineering challenges, especially for critical infrastructure like bridges and buildings.

Favourable circumstances, initiatives, or legislation

- **Government support for innovation:** Many governments are offering grants, tax incentives, and other forms of support for the development of sustainable building materials and

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construction technologies. This funding can encourage innovation in lightweight and durable structures.

- **Sustainable Development Goals (SDGs):** The United Nations' SDGs, particularly Goal 9 (Industry, Innovation, and Infrastructure) and Goal 13 (Climate Action), support the development of sustainable, resilient infrastructure. Governments and corporations increasingly align their investments with these goals, providing incentives for using environmentally friendly, durable materials.
- **Industry push for green building standards:** With growing demand for sustainable **construction** practices, industry standards like LEED (Leadership in Energy and Environmental Design) are going for the use of materials and methods that reduce environmental impact. This creates a favourable environment for lightweight, durable, and sustainable materials.
- **Building resilience in the face of climate change:** With the rising impact of climate change, there is growing interest in building structures that can withstand extreme weather events, which presents opportunities for lightweight and durable design innovations.
- **Technological advancements in manufacturing:** The evolution of digital manufacturing, automation, and robotics will likely reduce the cost and complexity of producing high-performance, lightweight materials at scale..

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WP3 Training Modules on Biomimicry Process Design

Task 3.1/ A1. Developing Self-learning Kit for VET students - LP: ATS / CPs: ALL

LET'S MIMIC CHALLENGES

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Challenge: Building energy-efficient roofs and facades

BIOMIMICRY 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** How can we design roofs and facades that enhance building energy efficiency, reduce heating and cooling costs, and contribute to sustainable urban environments? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **What the design needs to do** • **Thermal insulation:** The design must improve the insulation of roofs and facades to reduce heat loss in cold weather and limit heat gain in hot weather, optimising indoor temperatures year-round without heavy reliance on HVAC systems. • **Energy generation:** The design should integrate renewable energy solutions, such as solar panels or photovoltaic glass, to help buildings generate clean energy and reduce dependency on external energy sources. • **Natural ventilation:** Incorporating passive ventilation strategies, such as vents, natural airflow patterns, and thermal chimneys, to reduce the need for mechanical ventilation and cooling. • **Smart energy management:** The design should enable smart energy control systems that automatically adjust the roof and facade features (e.g., shading, windows, ventilation) based on real-time weather and internal conditions to maximise energy savings. • **Aesthetics and integration with architecture:** The roof and facade designs must complement the building's overall

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architectural style while contributing to the urban aesthetic, ensuring that energy efficiency solutions do not detract from the visual appeal.

- **Sustainability and low maintenance:** The design should be low-maintenance, durable, and use environmentally friendly materials, reducing the long-term environmental impact of the building's energy systems.

Target audience

- **Architects and designers:** These professionals are responsible for incorporating energy-efficient roofing and facade systems into building designs. They are interested in innovative, functional solutions that maintain the building's aesthetic appeal while improving energy performance.
- **Builders and contractors:** Contractors who construct buildings will benefit from cost-effective, easy-to-install, and sustainable energy-efficient roofing and facade systems.
- **Building owners and property developers:** Owners of residential, commercial, and industrial buildings are interested in energy-efficient roofs and facades to reduce operating costs, improve tenant comfort, and meet sustainability goals.
- **Facility managers:** These professionals operate and maintain building systems. Energy-efficient roofs and facades can help reduce heating and cooling costs and minimise long-term maintenance needs.
- **Government and urban planners:** Policymakers and urban planners increasingly focus on creating energy-efficient, sustainable cities. They are interested in solutions that can help meet energy efficiency targets and reduce carbon emissions.
- **Sustainability advocates:** Environmental organisations and climate-conscious consumers are looking for innovative solutions to reduce buildings' carbon footprints and improve energy efficiency in the built environment.

Context

- **Global push for energy efficiency:** Governments and organisations worldwide are setting ambitious targets to reduce energy consumption in buildings as part of efforts to address climate change. Buildings are a significant source of global energy demand, and improving the energy efficiency of roofs and facades is a key part of these efforts.
- **Technological innovations:** Advances in materials science, smart technologies, and renewable energy integration offer new opportunities to improve the energy efficiency of roofs and facades. New materials, such as high-performance

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insulation, dynamic glazing, and photovoltaic glass, provide exciting possibilities.

- **Building regulations:** Increasingly stringent energy codes and regulations, particularly in regions with extreme climates, are requiring new buildings to meet higher energy efficiency standards. Retrofitting existing buildings is also becoming a priority for improving overall energy use in urban environments.
- **Urbanisation and climate change:** As cities grow, there is a greater need to address the environmental impact of buildings in urban areas. With climate change driving more extreme weather patterns, buildings must be designed to adapt to varying conditions while minimising energy demand.
- **Cost pressures and sustainability goals:** The construction industry is pressured to lower costs while meeting sustainability targets. Energy-efficient roofing and facade systems can offer long-term savings and contribute to carbon reduction goals.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- **Advances in building materials:** New materials, such as highly insulating aerogels, dynamic glass, and advanced coatings for roofs and facades, can drastically improve the thermal efficiency of buildings while also contributing to aesthetic goals. These innovations can also integrate energy-generating technologies, such as solar cells embedded in the facade.
- **Smart building technologies:** Integrating sensors, smart glass, and automated shading systems into roofs and facades allows buildings to adapt to changing weather conditions in real-time, optimising energy use and reducing reliance on HVAC systems.
- **Government incentives and regulations:** Many governments provide financial incentives (tax credits, rebates, subsidies) for energy-efficient construction and retrofitting. Stricter building codes and energy efficiency mandates drive innovation in energy-saving roofs and facades solutions.
- **Growth of green building standards:** The increasing adoption of green building certifications such as LEED (Leadership in Energy and Environmental Design), BREEAM, and WELL allows architects and builders to showcase their commitment to sustainability by incorporating energy-efficient roof and facade systems.
- **Building retrofit market:** Many existing buildings need retrofitting to meet modern energy efficiency standards. This

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presents a significant opportunity to upgrade roofs and facades with energy-efficient solutions that reduce energy consumption.

- **Renewable energy integration:** Incorporating solar panels, green roofs, or wind turbines into roofs and facades can contribute to energy generation and further reduce buildings' energy consumption, making them more self-sustaining and reducing reliance on the grid.

Constraints

- **Initial costs:** High-performance materials and advanced building technologies, such as smart windows and integrated solar systems, can have high upfront costs. This may be a barrier to widespread adoption, particularly for low-cost housing or commercial buildings with tight budgets.
- **Complexity in retrofitting:** Retrofitting existing buildings with energy-efficient roofs and facades can be challenging and costly, especially for older buildings or those with unique architectural styles. The integration of new materials or systems may require significant structural modifications.
- **Regulatory and building code challenges:** In some regions, building codes and zoning regulations may limit the use of certain materials or systems (e.g., solar panels or green roofs). Navigating these codes can slow the adoption of energy-efficient technologies.
- **Durability and maintenance:** Some energy-efficient technologies, such as smart glass or dynamic shading systems, may require ongoing maintenance or may not perform as expected over time, particularly in extreme weather conditions. Ensuring that these technologies have long lifespans and are low-maintenance is crucial for their long-term viability.
- **Aesthetic concerns:** Energy-efficient systems, such as solar panels or large green roof installations, may not always align with a building's desired aesthetic. Balancing energy performance with architectural design preferences can present challenges.
- **Energy demand fluctuations:** While energy-efficient roofs and facades can reduce overall energy consumption, buildings still need to be able to handle energy demand spikes, such as during extreme heat waves or cold weather. The design must balance efficiency with reliability in extreme conditions.

Favourable circumstances, initiatives, or legislation

- **Energy efficiency legislation:** Many countries and cities are setting ambitious energy efficiency targets, such as net-zero

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carbon buildings by 2030. This creates a favourable environment for innovation in building design and construction technologies.

- **Sustainability and green building movements:** A global push toward sustainability, urban resilience, and green building standards has created significant demand for energy-efficient building materials and systems.
- **International collaboration on climate goals:** Countries commit to reducing energy use and greenhouse gas emissions under international climate agreements (e.g., the Paris Agreement). Energy-efficient building technologies are central to meeting these goals, creating momentum for innovation and investment in energy-efficient roofs and facades.
- **Building retrofit incentives:** Many governments offer subsidies or tax incentives for retrofitting existing buildings with energy-efficient technologies, creating financial opportunities for developers and property owners to invest in energy-saving roof and facade upgrades.

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WP3 Training Modules on Biomimicry Process Design

Task 3.1/ A1. Developing Self-learning Kit for VET students - LP: ATS / CPs: ALL

LET'S MIMIC CHALLENGES

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Challenge: Name of the challenge

BIOMIMICRY 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** How can we design a sustainable, cost-effective energy generation system that minimises environmental impact and supports global energy needs? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **What the design needs to do** • **Generate renewable energy:** Convert natural resources like sunlight, wind, or heat into electricity efficiently and consistently. • **Minimise carbon footprint:** Reduce greenhouse gas emissions during energy production and across the system's lifecycle. • **Be cost-effective:** Provide an affordable energy solution for communities with varying economic resources. • **Ensure reliability:** Deliver consistent power even in challenging or fluctuating environmental conditions. • **Support decentralisation:** Be flexible enough to work in decentralised grids, microgrids, or off-grid systems. **Target audience** • **Remote and underserved communities:** Populations lacking access to stable energy sources who need affordable, sustainable electricity.

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- **Urban planners and smart city developers:** Cities aiming to reduce their carbon footprint by integrating renewable energy solutions into infrastructure.
- **Industrial and commercial enterprises:** Industries seeking sustainable energy sources to reduce operational costs and meet environmental goals.
- **Governments and policymakers:** Entities focused on achieving national and international energy and climate goals.
- **Environmental organisations:** Groups advocating for the transition to renewable energy to combat climate change.

Context

- **Energy demand growth:** Global energy demand is rising, particularly in developing regions, straining existing fossil-fuel-based systems.
- **Climate change:** Reducing greenhouse gas emissions requires rapidly shifting to renewable energy sources.
- **Technological advancements:** Innovations in solar panels, wind turbines, and energy storage create opportunities to enhance efficiency and reliability.
- **Energy poverty:** Approximately 800 million people globally still lack access to electricity, highlighting the need for equitable energy distribution.
- **Policy pressures:** International agreements and national policies are setting ambitious targets for renewable energy adoption and carbon neutrality.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- **Advancements in renewable technology:** Innovations in materials (e.g., perovskite solar cells, advanced composites for wind turbines) are increasing efficiency and affordability.
- **Decentralised energy systems:** Off-grid and microgrid technologies enable energy generation in remote areas, reducing dependency on centralised grids.
- **Energy storage breakthroughs:** Improvements in battery technologies (e.g., solid-state batteries, green hydrogen) are addressing the intermittency of renewable energy sources like solar and wind.
- **Integration with IoT and smart grids:** IoT and AI technologies allow energy systems to optimise performance and adapt to real-time demand fluctuations.

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- **Incentives for renewable energy:** Governments and organisations offer subsidies, tax incentives, and grants to promote renewable energy adoption.
- **Corporate sustainability goals:** Companies increasingly adopt renewable energy as part of their environmental, social, and governance (ESG) commitments, creating market demand.

Constraints

- **Intermittency issues:** Solar and wind energy generation depend on weather conditions, requiring efficient energy storage systems to ensure reliability.
- **High initial costs:** While operational costs for renewable systems are low, the initial setup, especially for emerging technologies, can be prohibitively expensive.
- **Land and resource requirements:** Large-scale renewable energy projects like solar and wind farms require significant land and materials, potentially causing environmental and social conflicts.
- **Infrastructure challenges:** Many regions lack the infrastructure (e.g., grid connections, transport networks) to support renewable energy systems.
- **Technological limitations:** Current renewable energy technologies may struggle to meet the energy needs of energy-intensive industries without complementary solutions like carbon capture or nuclear energy.
- **Policy and regulatory barriers:** Lengthy permitting processes, inconsistent policies, and a lack of international standards can hinder deploying renewable energy systems.

Favourable circumstances, initiatives, or legislation

- **Global climate agreements:** Policies like the Paris Agreement drive investment in renewable energy solutions to meet emission reduction targets.
- **Renewable energy subsidies:** Many governments offer financial incentives for renewable energy projects, including tax credits and grants for solar and wind installations.
- **Corporate renewable energy goals:** Companies committed to achieving net-zero carbon emissions invest in renewable energy infrastructure and solutions.
- **Green innovation funds:** Public and private sector funding for green technologies is growing, enabling the development and deployment of advanced energy systems.

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- **Sustainable Development Goals (SDG 7):** The UN's focus on affordable and clean energy creates a supportive environment for innovations that address energy access and sustainability.
- **Community-led energy projects:** Grassroots initiatives in renewable energy generation (e.g., community solar projects) provide models for scaling up sustainable energy solutions.

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WP3 Training Modules on Biomimicry Process Design

Task 3.1/ A1. Developing Self-learning Kit for VET students - LP: ATS / CPs: ALL

LET'S MIMIC CHALLENGES

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Challenge: Name of the challenge

BIOMIMICRY 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** How can we design transport systems that effectively minimize shock and vibration while ensuring the safety and integrity of passengers and sensitive cargo? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **What the design needs to do** • **Vibration and shock absorption:** The design should effectively reduce the impact of vibrations and shocks, whether caused by road irregularities, sudden braking, or other transit conditions. • **Suspension and damping efficiency:** The system should employ advanced suspension or damping mechanisms capable of adjusting to different load types and conditions, reducing vehicle wear and tear and minimising discomfort for passengers or cargo. • **Real-time monitoring and adjustment:** Incorporate smart monitoring systems that continuously assess shock and vibration levels, adjusting suspension settings or damping mechanisms to respond to changes in terrain or road conditions. • **Durable, low-maintenance materials:** Use materials that can withstand high levels of vibration over time without degrading, ensuring that the solution remains effective and reduces the frequency of maintenance. • **Compatibility with diverse transport modes:** To maximise impact, the design must be adaptable to various types of

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transport systems, including trucks, trains, aircraft, and public transit.

Target audience

- **Logistics and freight companies:** Companies transporting sensitive or fragile goods require solutions that minimise the risk of damage during transit, particularly in sectors like pharmaceuticals, electronics, and luxury goods.
- **Public and private transportation providers:** Operators of passenger transport systems—buses, trains, and ride-sharing fleets—aim to improve passenger comfort and reduce long-term maintenance costs.
- **Automotive and aerospace manufacturers:** These industries need efficient shock and vibration mitigation technologies to incorporate into vehicle designs, improving safety, durability, and comfort.
- **Consumer electronics and medical equipment suppliers:** Companies that transport highly sensitive equipment need systems that minimise shock and vibration to prevent costly damage and ensure safe, functional delivery.
- **Urban planners and public safety officials:** Stakeholders in city planning and public transportation are interested in reducing environmental noise and vibrations caused by heavy vehicles and protecting infrastructure from shock-induced damage.

Context

- **Growth in e-commerce and sensitive cargo needs:** With the rise of e-commerce and the need to transport delicate items like electronics, medical equipment, and perishable goods, there is an increasing need for transport systems that minimise vibrations and shocks.
- **Advances in materials science and smart technology:** New materials, smart sensors, and real-time monitoring technologies allow for the integration of innovative shock-absorption solutions into transport systems.
- **Safety and comfort requirements:** Rising passenger expectations and stricter safety regulations are pushing the transportation industry to adopt solutions that prioritise comfort and minimise the risk of injury due to sudden shocks or continuous vibrations.
- **Cost efficiency and maintenance demands:** High maintenance costs caused by component wear due to vibrations highlight the need for cost-effective, durable shock and vibration mitigation solutions.

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- **Environmental and noise concerns:** Vibrations from transport systems contribute to environmental noise and structural damage, particularly in urban settings. This leads to a demand for transport systems that minimize vibrations and reduce associated impacts on nearby communities.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- **Innovation in damping and suspension technology:** Advances in active and semi-active suspension systems, hydraulic dampers, and pneumatic systems offer potential for significant improvement in shock and vibration reduction.
- **Smart monitoring and AI-driven adjustments:** Integration of AI and IoT sensors can enable real-time monitoring and adaptive adjustments, optimising suspension settings based on current road and environmental conditions.
- **Increased demand for secure cargo transport:** Industries dealing in sensitive cargo, such as pharmaceuticals and electronics, provide a strong market for vibration-minimising transport solutions, creating opportunities for adoption and innovation.
- **Government regulations on passenger comfort and safety:** Government standards requiring improved passenger safety and cargo protection push transportation systems to adopt effective shock-absorbing solutions.
- **High-performance materials:** Innovations in materials like composite polymers, carbon fibre, and viscoelastic materials present opportunities to create more resilient, lightweight solutions for shock absorption in transport.

Constraints

- **High development and installation costs:** Advanced suspension and damping technologies, as well as high-performance materials, may be costly to develop and integrate, especially for smaller logistics providers or budget-conscious public transport systems.
- **Weight and space limitations:** Adding or enhancing shock-absorption systems may increase the weight of the transport vehicle, reducing energy efficiency and payload capacity, and may also limit space for cargo or passengers.
- **Complexity of retrofitting existing transport systems:** Retrofitting older vehicles with advanced shock-absorbing systems can be challenging and costly, often requiring

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structural modifications that may not be feasible or cost-effective.

- **Environmental wear and tear:** Constant exposure to rough conditions, such as off-road terrains or extreme climates, can wear down suspension systems over time, impacting long-term durability and effectiveness.
- **Balancing shock absorption and control:** Achieving optimal shock absorption without compromising control, stability, or handling can be challenging, especially in high-speed or high-stakes environments such as racing, aviation, or mountainous transport.

Favourable circumstances, initiatives, or legislation

- **Funding and incentives for innovation in transportation safety:** Governments and transportation authorities increasingly offer grants and incentives for research and development in transportation safety, providing financial support for shock-absorption innovations.
- **Sustainability and green transport movements:** As companies focus on sustainability, they invest in solutions that can reduce fuel consumption, emissions, and maintenance costs—outcomes that shock-minimising systems can support by enhancing vehicle efficiency.
- **Stringent safety and quality standards:** Regulations, particularly in the automotive and aerospace industries, require enhanced shock and vibration protection for passenger safety and cargo security, driving industry interest in advanced solutions.
- **Growth of industry standards for cargo protection:** Expanding industry standards for safe handling of fragile goods in transit aligns with efforts to minimise shock and vibration, further motivating logistics companies to invest in innovative transportation systems.
- **Collaborations with research institutions:** Partnerships with research institutions specialising in material science, engineering, and transport design can foster advancements in shock-absorbing technologies and accelerate the development and implementation of solutions across the industry.

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WP3 Training Modules on Biomimicry Process Design

Task 3.1/ A1. Developing Self-learning Kit for VET students - LP: ATS / CPs: ALL

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Challenge: Name of the challenge

BIOMIMICRY 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** How can we design filtration systems that maximize efficiency, reduce energy consumption, and effectively remove contaminants across various applications? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **What the design needs to do:** • **Effective filtration of targeted contaminants:** The system must be capable of targeting and capturing specific pollutants, such as fine particles, chemicals, bacteria, or heavy metals, depending on its intended application. • **Optimise flow and pressure levels:** The design must efficiently manage fluid (air or water) flow while maintaining low pressure drops, reducing energy demand and enhancing system efficiency. • **Long-term performance and filter regeneration:** The system should maintain high filtration efficiency over time and, if possible, include options for filter regeneration or extended service life to reduce waste and maintenance frequency. • **Smart monitoring and maintenance alerts:** Equip the filtration system with monitoring technology to track filter performance, contaminant load, and maintenance needs, helping users optimise performance and maintain the system effectively. • **Environmental and economic viability:** Use sustainable materials, minimise waste, and manage costs to appeal to a broader market, from individual users to large industries.

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Target audience

- **Industrial and manufacturing companies:** Industries requiring air or water purification, such as pharmaceutical, chemical, and food production, benefit from efficient filtration systems to meet regulatory standards and ensure product quality.
- **Municipal water treatment plants:** Public water systems need effective, scalable filtration solutions to remove contaminants and ensure the delivery of safe, clean water to communities.
- **Healthcare and laboratory facilities:** Medical facilities require filtration systems that capture microbes and hazardous particles, ensuring sterile environments and safe air and water.
- **Commercial and residential users:** For health and environmental reasons, homes and businesses seek affordable, reliable filtration systems to improve water quality and reduce air pollution.
- **Environmental organisations and NGOs:** Environmental groups working in polluted water or air areas may use efficient filtration systems to address contamination challenges, particularly in regions lacking access to clean resources.

Context

- **Increasing demand for clean air and water:** With rising pollution levels and water scarcity in many regions, there is a growing need for effective filtration systems that can provide clean resources.
- **Technological innovations in filtration media:** Advances in nanotechnology, activated carbon, and other filtration media offer new options for highly efficient contaminant capture across different substances and particle sizes.
- **Energy efficiency and sustainability goals:** As industries focus on energy-efficient solutions, filtration systems that minimise energy use while maintaining high performance are being promoted, aligning with global sustainability objectives.
- **Stringent health and safety regulations:** In sectors like healthcare, food production, and public utilities, stringent safety and environmental rules mandate reliable and efficient filtration systems to reduce pollutants and prevent health risks.
- **Industrial and urban expansion:** Rapid urbanisation and industrial growth increase the need for effective filtration in waste management, water treatment, and air purification to manage pollution and protect environmental health.

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1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- **Advances in filtration media and materials:** New materials, such as electrospun fibres, graphene, and ceramic membranes, offer the potential for improved filtration efficiency, allowing for selective filtering of specific particles or chemicals.
- **Smart monitoring and adaptive technologies:** IoT-enabled sensors and adaptive technologies can help filtration systems respond to changes in contaminant levels in real-time, optimizing performance and alerting users to maintenance needs.
- **Government grants and environmental incentives:** Many governments and organisations offer funding, grants, or incentives for technologies that support clean water and air initiatives, creating financial support for innovation in filtration systems.
- **Growing market demand:** Rising awareness of environmental health and safety and increased consumer demand for clean resources present a significant market opportunity for efficient filtration systems across industries and the consumer sector.
- **Research partnerships with academic institutions:** Collaborating with research institutions on filtration technology development can lead to breakthroughs in materials science and performance and cost improvements in filtration systems.

Constraints

- **High initial costs for advanced technologies:** Filtration systems using advanced materials or IoT monitoring may have high upfront costs, limiting access for low-income regions or smaller organisations.
- **Maintenance and lifespan of filtration media:** Some require regular replacement or cleaning, which can add to the system's long-term costs and may be challenging for remote areas or low-resource settings.
- **Energy requirements for specific systems:** Some high-efficiency or specialised filtration systems, such as industrial water filters or HVAC filters in air systems, can have high energy demands, which may limit their efficiency or environmental viability.
- **Waste management of used filters:** Disposal of spent filters, particularly those used in industrial settings that capture hazardous materials, presents an environmental challenge.

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Safe and sustainable disposal or recycling solutions are needed.

- **Complexity of customisation for diverse applications:** Different industries require filtration systems tailored to specific contaminants, flow rates, and environmental conditions, making standardisation difficult and potentially raising production costs.

Favourable circumstances, initiatives, or legislation

- **Environmental protection regulations:** Stricter environmental and public health regulations around air and water quality drive demand for advanced filtration systems, especially in industries where contaminant removal is mandatory.
- **Incentives for green technology and energy efficiency:** Government and private sector incentives encouraging sustainable technology adoption can support the development of energy-efficient filtration solutions.
- **Global health initiatives for clean water and air:** International health and environmental organisations focus on clean water and air accessibility, encouraging investment in filtration technology to meet basic needs in underserved areas.
- **Growing market for green building certifications:** Certifications such as LEED, which emphasise energy efficiency and sustainability, create demand for filtration systems that contribute to cleaner, healthier indoor air and water environments.
- **Increasing collaboration between sectors:** Growing cooperation between industrial, governmental, and academic institutions encourages knowledge-sharing and innovation in filtration, driving the development of efficient, cost-effective, and sustainable solutions.

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WP3 Training Modules on Biomimicry Process Design

Task 3.1/ A1. Developing Self-learning Kit for VET students - LP: ATS / CPs: ALL

LET'S MIMIC CHALLENGES

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The description column provides guidelines with examples for filling in the information for the biomimicry design steps.

Challenge: Eco-Friendly Noise Reduction in Urban Spaces

BIOMIMICRY 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.** **Challenge** Urban environments are plagued by noise pollution, which has a negative impact on public health, stress levels, and overall well-being. The challenge is: How can we create passive, eco-friendly solutions to reduce noise pollution in cities, inspired by natural systems? **Exploratory questions** • How does nature manage and dampen sound in noisy environments? • Which natural materials or structures can effectively absorb or deflect sound waves? **Primary goals** • Reduce noise levels in urban areas by 20-30 decibels. • Develop a solution that is low-maintenance and environmentally friendly. • Ensure scalability and adaptability for various urban landscapes. **1.b Describe what the design needs to do or solve (not what you will make or design), who your target audience is, and what the context of the challenge is.** **The design needs to** • Passively absorb or deflect urban noise without relying on power or complex technology.

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- Integrate seamlessly into public spaces, such as parks, roadsides, or building facades.
- Enhance aesthetic and environmental benefits by promoting biodiversity.

Target audience

- Urban developers, city planners, and environmental policymakers.

Context
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.

1.c Identify the opportunities and/or constraints that might impact achieving a successful outcome.

Opportunities

- Rising awareness of noise pollution's health effects.
- Support from environmental policies focused on sustainable urban living.
- Potential to integrate with existing green infrastructure initiatives.

Constraints

- Limited funding for noise reduction projects compared to other priorities.
- Potential resistance from stakeholders unfamiliar with biomimicry-based solutions.
- Need for customisation in different urban environments due to varying noise sources.

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Challenge: Reducing water consumption in urban landscapes

BIOMIMICRY 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.** 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. **Challenge** How can we design urban landscapes that reduce water usage while maintaining green spaces and aesthetic appeal? **Exploratory questions** • How do desert plants survive with minimal water? • How do animals and plants capture or store water in arid environments? **Primary goals** • Develop water-efficient urban landscaping solutions. • Enhance water conservation without sacrificing green space or visual appeal. **1.b Describe what the design needs to do or solve (not what you will make or design), who your target audience is, and what the context of the challenge is.** **What the design needs to do** • Reduce water consumption in urban landscapes by utilising innovative materials, design, or irrigation techniques inspired by natural processes. • Maintain or improve the visual and ecological quality of green spaces.

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Target audience

- City planners, landscape architects, and urban developers.
- Local government authorities and sustainability-focused organisations.

Context

The solution would be implemented in urban parks, streetscapes, residential developments, and other publicly accessible green spaces in cities facing water scarcity.

1.c Identify the opportunities and/or constraints that might impact achieving a successful outcome.

Opportunities

- Rising focus on sustainable urban design and water conservation.
- Availability of new technologies and natural designs to reduce water use.
- Public support for initiatives to combat climate change and promote sustainability.

Constraints

- Initial costs for implementing new water-efficient technologies.
- Potential resistance to changes in traditional landscaping practices.
- Maintenance challenges for some natural systems in urban environments.

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Challenge: Enhancing Urban Waste Management with Biomimicry

BIOMIMICRY 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.** • How can we improve waste segregation and recycling in urban environments? • How can urban waste management systems be made more efficient and sustainable? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** • The design should improve waste sorting, processing, and recycling to reduce landfill dependency and environmental harm. • The target audience includes city governments, waste management companies, and urban residents. • The challenge is set in cities, which often face waste accumulation problems due to high population densities and limited space for waste management. **1.c Identify the opportunities and/or constraints that might impact achieving a successful outcome.** **Opportunities** • Growing interest in circular economy solutions. • Increased government incentives for sustainable urban development. • Technological advancements in waste processing and recycling. **Constraints** • Lack of infrastructure for waste sorting in some urban areas.

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	• Resistance to changes in waste management habits among residents. • High costs of implementing new waste management systems.

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Challenge: Sustainable Water Management in Urban Areas

BIOMIMICRY 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.** **Challenge** How can we improve water management in urban environments to ensure efficient usage and minimise waste? **Exploratory questions** • How can we collect and store water efficiently in cities? • How can we minimise water wastage during periods of heavy rainfall and drought? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **What the design needs to solve** The solution needs to optimise water usage, ensure effective water storage, and reduce excess runoff during rainfall. The design should address water scarcity, especially in areas facing droughts, while also managing excessive rainwater to prevent flooding. **Target audience** Urban planners, water management authorities, and residents in cities facing water scarcity or flooding challenges. **Context** Urban environments, particularly in cities with rapid population growth, poor drainage systems, or insufficient rainwater harvesting infrastructure. **1.c Identify the opportunities and/or constraints that might impact achieving a successful outcome.**

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Opportunities

- Rising awareness about water conservation and sustainability.
- Technological advancements in water harvesting and recycling.
- Potential policy support for water management initiatives.

Constraints

- Limited space for implementing new water management systems in densely populated areas.
- High initial costs of new infrastructure or retrofitting existing systems.
- Lack of awareness or resistance to adopting new practices in water management.

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Challenge: Reducing Energy Consumption in Industrial Processes

BIOMIMICRY 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.** How can we reduce energy consumption in industrial manufacturing processes without compromising product quality or production speed? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Primary goals** The design should focus on lowering energy use in the industrial sector, particularly in manufacturing. The solution needs to minimise energy waste and improve overall efficiency without increasing production costs or slowing down operations. **Target audience** Industrial manufacturers, factory owners, sustainability experts, and engineers are working on optimising industrial operations. **Context** This challenge particularly applies to energy-intensive industries, including steel, cement, paper, and automotive manufacturing. These industries are key to the global economy, but are responsible for significant carbon emissions and energy consumption. **1.c Identify the opportunities and/or constraints that might impact achieving a successful outcome.** **Opportunities** • Advances in renewable energy and energy-efficient technologies can be integrated into industrial processes. • Increasing regulation and demand for sustainable operations provide incentives to adopt energy-saving solutions.

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- Growing interest in carbon footprint reduction offers funding and support for energy efficiency innovations.

Constraints

- High capital investment required for implementing energy-efficient technologies.
- Potential resistance from industries due to concerns about production disruptions or high initial costs.
- Technological limitations in some processes make energy reduction difficult.

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Challenge: Reducing Water Waste in Agriculture Through Efficient Irrigation Systems

BIOMIMICRY 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.** **Challenge** How can we reduce water waste in agriculture while ensuring crops receive optimal hydration? **Exploratory questions** • How can we reduce irrigation water usage without sacrificing crop yields? • How can we ensure water is distributed efficiently to areas that need it most? **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Context** The design should reduce water usage in agricultural irrigation systems, particularly in regions where water scarcity is a significant issue. **Target audience** Farmers, agricultural companies, and irrigation system developers face challenges with water conservation. **Setting** This solution would be applied in areas with water shortages or regions that rely heavily on irrigation for crop production. **1.c Identify the opportunities and/or constraints that might impact achieving a successful outcome.** **Opportunities**

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	• Increasing demand for sustainable agriculture practices. • Availability of technology to support precision farming. • Potential for government incentives for water-saving innovations in agriculture. **Constraints** • High upfront costs for implementing advanced irrigation systems. • Resistance from farmers to adopt new technologies due to traditional practices. • Difficulty in monitoring water usage in large agricultural fields.

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Challenge: Designing Structures to Withstand Extreme Weather Events

BIOMIMICRY 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.** **Challenge** How can we design buildings or structures that can withstand extreme weather events, such as hurricanes, tornadoes, or high winds, while maintaining energy efficiency and cost-effectiveness? **Exploratory questions** How can buildings resist high wind pressures without structural failure? • How can natural forms or patterns inspire materials or designs for extreme weather resistance? • How can we ensure energy efficiency alongside durability? **1.b Describe what the design needs to do or solve (not what you will make or design), who your target audience is, and what the context of the challenge is.** **Context** The design must focus on creating buildings that are structurally sound during extreme weather while minimising energy consumption for heating or cooling. The solution should prioritize sustainable materials and adaptable designs for various geographic regions. **Target audience** Architects, engineers, urban developers, and policymakers are working in areas prone to extreme weather events. **Setting** This solution would be applicable in hurricane-prone coastal areas, regions facing frequent tornadoes, and urban zones experiencing increasingly extreme weather due to climate change.

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1.c Identify the opportunities and/or constraints that might impact achieving a successful outcome.

Opportunities

- Growing demand for climate-resilient infrastructure.
- Advancements in biomimicry and material science for structural innovation.
- Rising awareness and government funding for disaster-resilient structures.

Constraints

- High initial costs for materials and design implementation.
- Lack of public awareness about the long-term benefits of resilient structures.
- Variability in building codes and regulations across regions.

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Challenge: Enhancing Building Insulation Inspired by Nature

BIOMIMICRY 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.** **Challenge** How can we enhance the energy efficiency of buildings through improved insulation while minimising environmental impact? **Exploratory questions** • How can we create building materials that offer superior insulation without relying on synthetic or non-biodegradable materials? • Can natural mechanisms for heat retention or dissipation be replicated in building design? **1.b Describe what the design needs to do or solve (not what you will make or design), who your target audience is, and what the context of the challenge is.** **Context** The design should enhance thermal regulation in buildings, reducing the need for artificial heating and cooling. **Target audience** Architects, building material manufacturers, and construction companies are seeking sustainable solutions for energy-efficient building design. **Setting** Applicable in urban and rural settings, especially in regions with extreme temperatures where energy consumption for heating or cooling is high. **1.c Identify the opportunities and/or constraints that might impact achieving a successful outcome.**

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	Opportunities • Growing interest in sustainable architecture and green building certifications. • Technological advances in biomimicry and material science. • Government incentives for energy-efficient building solutions. **Constraints** • Limited availability of eco-friendly materials that mimic natural insulation. • Cost-effectiveness and scalability of the solution.

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Challenge: Wastewater treatment system

BIOMIMICRY 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.** **Challenge** How can we improve wastewater treatment processes to increase efficiency while minimizing environmental impact and reducing energy consumption? **Exploratory questions** • How can we design a wastewater treatment system that uses natural processes to filter and purify water? • Can we create a system that reduces the need for synthetic chemicals or high-energy processes in water purification? • What natural organisms or materials can be employed to break down pollutants effectively? **1.b Describe what the design needs to do or solve (not what you will make or design), who your target audience is, and what the context of the challenge is.** **Context** The solution should aim to provide a more sustainable approach to wastewater treatment, especially in urban areas, rural communities, or developing countries where conventional treatment methods may be costly, energy-intensive, or inaccessible. It should integrate natural processes that purify water while reducing environmental pollution. **Target audience** Environmental engineers, wastewater treatment facilities, municipalities, and developers are interested in green infrastructure solutions. **Setting** Applicable in both developed and developing regions, with a focus on areas where traditional wastewater treatment is expensive or

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unsustainable. This technology is particularly useful for small communities, agricultural systems, or eco-villages with limited access to advanced filtration technology.

1.c Identify the opportunities and/or constraints that might impact achieving a successful outcome.

Opportunities

- Rising concerns over water scarcity and pollution.
- Demand for sustainable water management solutions.
- Government and international organisation support for eco-friendly water purification technologies.

Constraints

- Scalability of natural systems in large urban settings.
- Potential costs of implementing new filtration technologies at a large scale.
- Variability in water quality and pollution types depending on location.

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Challenge: Enhancing Urban Air Quality Through Natural Filtration Systems

BIOMIMICRY 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.** **Challenge** How can we improve urban air quality by reducing pollutants, such as particulate matter and gases, in a way that is sustainable and natural? **Exploratory questions** • How can we create air filtration systems inspired by natural processes that effectively remove pollutants from the air? • Can plant systems or natural materials be utilised to enhance air purification in urban environments? • How can we ensure that the solution is scalable for large urban areas and cost-effective for implementation? **1.b Describe what the design needs to do or solve (not what you will make or design), who your target audience is, and what the context of the challenge is.** **Context** 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. **Target Audience** Urban planners, environmental agencies, municipal governments, and companies specializing in air quality improvement. **Setting** This solution would be implemented in cities, especially those with high levels of air pollution, and could be scaled for use in both public spaces and residential areas.

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1.c Identify the opportunities and/or constraints that might impact achieving a successful outcome.

Opportunities

- Increased demand for green technologies to combat air pollution.
- Growing focus on sustainability and environmental health in urban development.
- Potential for public health benefits, such as reduced respiratory diseases and better overall quality of life.

Constraints

- Limited funding or resources for large-scale urban air quality projects.
- The need for fast implementation in high-density urban environments.
- Challenges in maintaining and scaling natural air filtration systems in different urban settings.

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WP3 Training Modules on Biomimicry Process Design

Task 3.1/ A1. Developing Self-learning Kit for VET students - LP: ATS / CPs: ALL

LET'S MIMIC CHALLENGES

A challenge concerns an example of a past, real life problem that was solved through biomimicry. This task aims to identify and document the challenge and the solution that was applied.

The description column provides guidelines with examples for filling in the information for the biomimicry design steps.

Challenge: Creating a strong, reusable adhesive without the use of chemicals or leaving residue.

BIOMIMICRY 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** How can I create a reusable adhesive that sticks to surfaces without leaving residue or relying on chemicals? **Exploratory questions** • How do geckos adhere to surfaces?. • Can I replicate the microstructures responsible for adhesion?. **Primary goal** Develop a non-toxic, reusable adhesive for applications such as robotics or medical devices. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience, and what is the context of the challenge.** **Design needs:** Create a reliable adhesive for smooth and uneven surfaces. **Target audience** • **Industries (healthcare, packaging, etc.):** Benefit from adhesives that improve operational efficiency by offering precise, clean, and residue-free bonding solutions. • **Healthcare professionals:** Access to non-invasive adhesive solutions that protect patient skin, improving medical care and patient comfort. • **Manufacturers:** Gain a sustainable alternative for adhesives that improves durability and reduces production costs.

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- **Environment advocates:** Reduced chemical waste and fewer non-biodegradable adhesives polluting the ecosystem. Reduced reliance on synthetic, non-biodegradable adhesives, minimising environmental waste.
- **Consumers:** Gain access to eco-friendly, reusable adhesives that are safer and leave no residue, reducing single-use waste.

Context

The adhesive will be used in various settings, including healthcare (e.g., bandages) and industrial (e.g., robotic grips).

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- Growing demand for eco-friendly adhesives.
- Increased interest in robotics and medical applications.

Constraints

- Difficulty replicating the gecko's microstructures at scale.
- Cost-effectiveness of manufacturing.

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Challenge: Reducing energy consumption for heating and cooling buildings

BIOMIMICRY 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** How can we naturally regulate indoor temperatures in buildings to reduce energy consumption? **Exploratory questions** • How do termite mounds maintain constant internal temperatures?. • Can this principle be applied to building design?. **Primary goal** Design a passive cooling and ventilation system for sustainable architecture. **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.** **Design needs** Reduce the need for HVAC systems by regulating building temperatures passively. **Target audience** • **Building occupants**: Experience improved comfort with natural ventilation and reduced energy costs for heating and cooling. • **Developers and architects:** Gain a sustainable, cost-effective feature to enhance building value and meet green building standards. • **Urban developers:** Attract eco-conscious clients with sustainable building designs that lower energy costs.

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- **Residents in hot climates:** Experience improved indoor comfort without the financial burden of high energy bills.
- **Green building advocates:** Promote renewable energy usage and advocate for sustainable infrastructure.
- **Environment advocates:** Decreased reliance on energy-intensive HVAC systems, reducing greenhouse gas emissions.

Context

Primarily for buildings in hot climates or regions with limited energy resources.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- Increased focus on green building certifications.
- Advances in computational fluid dynamics for ventilation design.

Constraints

- High initial cost of implementation.
- Structural limitations in retrofitting older buildings..

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Challenge: Improving the efficiency and reducing the noise of wind turbines.

BIOMIMICRY 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** How can we improve the efficiency of wind turbines while reducing noise? **Exploratory questions** • What makes the humpback whale's flippers so agile and efficient in water?. • Can these tubercles enhance wind turbine design?. **Primary goal** Increase wind turbine performance and lifespan while minimising environmental impact. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience and what is the context of the challenge.** **Design needs** Enhance turbine aerodynamics and reduce mechanical stress. **Target audience** • **Energy producers:** Increased efficiency in energy generation, even in low-wind environments, resulting in higher profitability and reduced operational costs. • **Renewable energy companies:** Achieve higher energy yields, even in low-wind conditions, boosting profitability. • **Rural communities:** Gain access to reliable renewable energy sources that reduce dependence on fossil fuels. • **Environmental advocates:** Use improved turbines as a model for sustainable energy solutions, furthering advocacy efforts.

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Enhanced adoption of wind energy reduces dependence on fossil fuels and mitigates climate change.

- **Communities:** Greater access to renewable energy at potentially lower costs due to higher efficiency.

Context

Implementation in wind farms, particularly in noise-sensitive areas.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- Global shift toward renewable energy.
- Increased funding for wind power innovation.

Constraints

- Complexities in manufacturing tubercle-based blades.
- Variability in wind patterns across locations..

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Challenge: Increasing the efficiency of light-emitting devices while reducing energy waste.

BIOMIMICRY 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.** How can we make LEDs more energy-efficient and sustainable? **Exploratory questions** • How do fireflies achieve such high light efficiency?. • Can this mechanism be integrated into LED design?. **Primaryoal** Reduce energy consumption in lighting systems globally. **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.** **Design needs** Enhance light output and reduce heat loss. **Target audience** • **Manufacturers:** More energy-efficient LED lights. Maximized light output with minimized energy consumption, thus reducing overall operational costs and aligning with the growing demand for energy-saving solutions. • **Urban planners:** Enhanced urban lighting with minimal energy consumption, supporting sustainable city initiatives. • **Urban residents:** Enhanced street lighting improves safety while lowering municipal energy consumption costs. • **Households:** Lower electricity bills and better lighting quality with brighter and more energy-efficient LEDs. • **Energy conservationists:** Push for widespread adoption of energy-efficient lighting to combat climate change.

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- **Environment advocates:** Reduced energy demand leads to lower carbon emissions and less strain on power grids.

Context

Urban and rural lighting systems, including streetlights and those used in households.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- Growing adoption of LED lighting.
- Supportive policies for energy-efficient technologies.

Constraints

- Initial R&D costs.
- Compatibility with existing LED production methods..

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Challenge: Reducing glare and improving visibility in optical devices and solar panels.

BIOMIMICRY 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** How can we reduce glare and improve the efficiency of optical devices and solar panels? **Exploratory questions** • How do moth eyes minimise light reflection? • Can this principle be applied to glass or plastic surfaces? **Primary goal** Increase visibility and efficiency in optical devices and energy systems. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience and what is the context of the challenge.** **Design needs** Reduce glare in devices and enhance light absorption in solar panels. **Target audience** • **Solar energy providers:** Increased panel efficiency leads to more energy production and profitability. • **Electronics manufacturers:** Develop products with enhanced screen clarity, improving user satisfaction. • **Eco-conscious consumers:** Access to products that maximise energy use and minimise light waste. • **Consumers**: Enhanced screen visibility for electronics, improved solar panel efficiency, and better user experience with anti-glare products. • **Environment advocates:** More efficient solar panels contribute to increased renewable energy adoption and reduced carbon emissions.

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Context

Devices like smartphones, tablets, and outdoor solar installations.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- Demand for improved device screens and renewable energy.

Constraints

Precision is required for nanoscale manufacturing.

- Durability of coatings in harsh conditions..

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Challenge: Reducing noise and improving speed efficiency in high-speed trains.

BIOMIMICRY 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** How can we design quieter, more aerodynamic high-speed trains? **Exploratory questions** • How does the kingfisher's beak reduce water splash? • Can this mechanism reduce train noise? **Primary goal** Minimise noise pollution and improve train speed efficiency. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience and what is the context of the challenge.** **Design needs** Ensure high-speed trains operate efficiently and quietly. **Target audience** • **Train manufacturers:** Trains with more efficient aerodynamics, reducing drag and fuel consumption, which leads to lower operating costs and higher energy efficiency. • **Urban commuters:** Faster, quieter, and more comfortable travel at reduced costs due to improved energy efficiency. • **Transportation providers:** Reduced operational costs through energy efficiency and compliance with noise pollution regulations. • **Train operators:** Lower operating costs and reduced noise complaints improve overall service quality. • **Environmentalists**: Use quieter, more energy-efficient transport options to advocate for reduced carbon footprints in

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urban areas. Lower emissions and noise pollution contribute to cleaner, more sustainable urban environments.

- **Passengers:** Enjoy quieter, more comfortable travel with reduced energy costs passed down in ticket pricing.

Context

High-speed rail networks in densely populated regions.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- Rising demand for eco-friendly transportation.

Constraints

- High cost of redesigning train exteriors.
- Resistance to upgrading existing infrastructure..

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Challenge: Developing lightweight yet strong and elastic materials for protective and medical applications.

BIOMIMICRY 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** How can we create strong, lightweight, and elastic materials for industrial and medical use? **Exploratory questions** • What makes spider silk so strong and versatile? • Can we replicate its properties synthetically? **Primary goal** Design fibres for protective gear and medical sutures. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience and what is the context of the challenge.** **Design needs** Provide durable, lightweight materials for extreme conditions. **Target audience** • **Healthcare sector:** Develop biocompatible, strong, and flexible materials for medical sutures and implants, improving treatment outcomes. • **Construction industry:** Utilize lightweight yet durable materials for infrastructure projects, reducing transportation and production costs. • **Environmental advocates:** Promote biodegradable fibres to reduce dependency on synthetic materials and decrease waste. **Context** Applications in hospitals and protective clothing.

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1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

Expanding markets for advanced textiles.

Constraints

Ethical concerns about mass-producing spider silk synthetically.

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Challenge: Enhancing the aerodynamics and fuel efficiency of vehicles.

BIOMIMICRY 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** How can we improve car aerodynamics and fuel efficiency? **Exploratory questions** • How does the boxfish maintain stability and efficiency in water? • Can its shape reduce drag in vehicles? **Primary goal** Enhance car designs to improve fuel economy and stability. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience and what is the context of the challenge.** **Design needs** Improve aerodynamics and energy efficiency in cars. **Target audience:** • **Automotive industry:** Produce cars with improved fuel efficiency and a unique aesthetic appeal, catering to green markets. Competitive advantage through innovation in car design, aligning with consumer demand for green technologies. • **Drivers and car owners:** Experience fuel savings due to improved aerodynamics and enjoy vehicles that are both eco-friendly and aesthetically appealing. • **Eco-Friendly car buyers:** Save on fuel costs while reducing their carbon footprint. • **Climate change advocates:** Reduced fuel consumption and emissions support global climate goals. Use aerodynamically

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efficient vehicles as examples of environmentally conscious engineering.

Context

Fuel-efficient vehicles in urban and highway settings.

1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- Increased demand for low-emission vehicles.

Constraints

- Compatibility with existing car manufacturing processes..

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Challenge: Collecting water in arid environments where traditional methods are ineffective.

BIOMIMICRY 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** How can we harvest water in arid regions effectively? **Exploratory questions** How does the Namib Desert beetle collect water? **Primary goal** Develop water-harvesting solutions for desert communities. **1.b Describe what the design needs to do or solve (not what you will make or design), who is your target audience and what is the context of the challenge.** **Design needs** Increase water access in regions with limited rainfall. **Target audience** • **Agricultural workers**: Support irrigation efforts in arid regions, leading to increased crop yields and food security. • **Global aid organizations:** Implement water harvesting systems in vulnerable regions to address water scarcity and related challenges. • **Communities in arid regions:** Gain access to a reliable, low-cost water source, improving quality of life and reducing water scarcity issues. • **Environment advocates:** Passive water collection methods reduce the ecological footprint compared to energy-intensive desalination plants. **Context** Water-scarce regions like deserts.

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1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.

Opportunities

- Increasing focus on water conservation.

Constraints

- Challenges in scaling up the technology for widespread use..

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Challenge: Creating building materials that respond adaptively to environmental moisture.

BIOMIMICRY 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** How can we create smart materials that adapt to environmental moisture? **Exploratory questions** How do pinecones respond to changes in humidity? **Primary goal** Develop materials for passive building ventilation. **1.b Describe what the design needs to do or solve (not what you will make or design), who your target audience is, and what the context of the challenge is.** **Design needs** Optimise building ventilation to reduce energy consumption. **Target audience** • **Construction industry**: Access to innovative materials that align with green building certifications and sustainability trends. • **Architects**: Access innovative building solutions that combine aesthetic appeal with functional benefits. • **Green construction companies:** Meet sustainability goals by incorporating natural materials into projects, appealing to eco-conscious clients. • **Homeowners**: Improved indoor air quality and natural climate control with reduced energy bills. • **Environment advocates:** Reduction in energy consumption and reliance on synthetic materials, contributing to greener construction practices. **Context**

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	Urban buildings in humid or variable climates. **1.c Identify the opportunities and/ or constraints that might impact achieving a successful outcome.** **Opportunities** • Interest in energy-efficient buildings. **Constraints** • Costs of implementing these materials in large-scale projects..

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Challenge: Energy-efficient cooling inspired by beetles

BIOMIMICRY DESIGN	Description
Step 1 – Define the challenge	**1.a Define the challenge as a question.** **Challenge** How can we design energy-efficient cooling systems by mimicking the water-harvesting and thermoregulatory strategies of beetles? **Exploratory questions** • How do beetles in arid environments manage to cool themselves or collect moisture to survive?. • What physical features of beetles facilitate heat regulation or water collection?. • **C**an these natural mechanisms be replicated in architectural or product design? **.** **Primary goal** Develop a passive or low-energy cooling system inspired by beetles that can reduce energy consumption in buildings, electronics, or clothing. **1.b Describe what the design needs to do or solve, who is your target audience, and the context.** **Design needs** • Regulate temperature passively or with minimal energy input. • Adapt to various climates or environments, especially hot and dry ones. • Be scalable and integratable in architecture, electronics, or textiles. **Target audience** • Architects and urban developers.

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- Manufacturers of wearable technology or electronics.
- Engineers designing climate-resilient housing or shelters.
- Consumers in regions with limited access to air conditioning.
- Sustainability advocates and green tech startups.

Context

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 like the Namib Desert beetle, which captures moisture and regulates body temperature, offers a pathway to sustainable cooling.

1.c Identify the opportunities and/or constraints.

Opportunities

- Growing demand for sustainable and energy-efficient cooling.
- Advances in materials science (e.g., hydrophobic coatings, phase change materials).
- Public and policy support for green building and climate adaptation.

Constraints / Risks

- Technical complexity in replicating microstructures on a large scale.
- Durability and maintenance of passive systems.
- Initial investment and cost of bioinspired material development.
- Varying effectiveness across different environmental conditions..

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Challenge: Energy-efficient cooling inspired by beetles

BIOMIMICRY DESIGN	Description
Step 1 – Define the challenge	**1.a Define the challenge as a question.** **Challenge** How can we develop an efficient, quiet, and manoeuvrable underwater propulsion system inspired by natural swimmers? **Exploratory questions** • How do manta rays and other marine animals move through water so efficiently?. • What are the key physical features that contribute to low-resistance propulsion?. • **C**an natural swimming mechanisms replace or augment traditional propellers? **.** **Primary goals** Design a sustainable underwater propulsion system that minimises noise, maximises energy efficiency, and improves manoeuvrability. **1.b Describe what the design needs to do or solve, who your target audience is, and the context.** **Design needs** • Provide smooth, energy-efficient propulsion in underwater environments. • Minimise noise to avoid disrupting marine life or detection. • Allow precise manoeuvring in tight or complex spaces. **Target audience** • Designers of underwater drones (ROVs and AUVs). • Marine engineers and naval architects. • Environmental monitoring agencies.

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- Research and exploration teams.
- Recreational and sport diving tech developers.

Context

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. This presents an opportunity to rethink underwater movement using biomimicry.

1.c Identify the opportunities and/or constraints.

Opportunities

- Advances in soft robotics and flexible materials.
- Growing demand for stealthy, energy-saving marine systems.
- Environmental incentives for reducing acoustic pollution.

Constraints

- Technical complexity of biomimetic movement replication.
- Durability and cost of soft-material actuators.
- Limited control algorithms for fin-based propulsion systems..

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Challenge: Self-healing building materials

BIOMIMICRY DESIGN	Description
Step 1 – Define the challenge	**1.a Define the challenge as a question.** **Challenge** How can we create building materials that autonomously repair damage, extend their lifespan, and reduce maintenance needs, inspired by biological self-repair mechanisms? **Exploratory questions** • How do biological organisms heal themselves after injury?. • What triggers natural self-healing responses?. • Can these principles be replicated in concrete or structural materials?. **Primary goals** To design construction materials—especially concrete—that can autonomously heal cracks or other damage without human intervention, improving durability and sustainability. **1.b Describe what the design needs to do or solve, who is your target audience, and the context.** **Design needs** • Detect and repair microcracks automatically. • Maintain or restore structural integrity over time. • Reduce maintenance costs and resource usage. **Target Audience:** • Construction and civil engineering firms. • Municipal infrastructure planners. • Developers in earthquake or flood-prone zones. • Governments focused on sustainability and climate resilience.

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Context

Infrastructure deteriorates over time due to weather, mechanical stress, and aging. 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 revolutionize long-term resilience in urban environments.

1.c Identify the opportunities and/or constraints.

Opportunities

- Reduction in carbon footprint by extending building lifespans.
- Integration into green infrastructure projects.
- New markets for sustainable construction products.

Constraints

- Cost and scalability of biomimetic additives.
- Long-term performance under varied environmental conditions.
- Regulatory and certification hurdles..

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WP3 Training Modules on Biomimicry Process Design

Task 3.1/ A1. Developing Self-learning Kit for VET students - LP: ATS / CPs: ALL

LET'S MIMIC CHALLENGES

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Challenge: Bio-inspired anti-fouling surfaces

BIOMIMICRY DESIGN	Description
Step 1 – Define the challenge	**1.a Define the challenge as a question.** **Challenge** How can we prevent biofouling on surfaces, such as ships, pipes, or medical tools, without using toxic coatings, drawing inspiration from nature? **Exploratory questions** • How do marine animals like sharks and dolphins keep their skin free of barnacles and algae?. • Are there passive, non-toxic strategies in nature for surface cleanliness?. • Can we replicate such structures on industrial or medical materials?. **Primary goals** To develop **eco-friendly surfaces** that resist biological buildup (biofouling) by mimicking textures or properties found in nature. **1.b Describe what the design needs to do or solve, who your target audience is, and the context.** **Design needs** • Prevent the settlement of algae, barnacles, or bacteria. • Eliminate or minimise the use of toxic coatings or cleaning chemicals. • Be adaptable to ships, offshore structures, medical devices, or water systems. **Target audience** • Maritime industry (navy, shipping, offshore energy). • Water treatment and piping infrastructure.

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- Biomedical device manufacturers.
- Sustainability-oriented product designers.

Context

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.

1.c Identify the opportunities and/or constraints.

Opportunities

- Regulations phasing out toxic anti-fouling paints.
- Growing demand for sustainable marine coatings.
- Advances in nano/microfabrication.

Constraints

- Manufacturing cost of complex surface textures.
- Durability and maintenance of surface features.
- Need for standardisation in marine coatings..

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Challenge: Bio-Inspired Urban Air Purification

BIOMIMICRY DESIGN	Description
Step 1 – Define the challenge	**1.a Define the challenge as a question.** How can we develop a passive, sustainable system for purifying polluted urban air that mimics natural filtration mechanisms, such as those found in forests? **Exploratory questions** • How do trees and forests naturally clean the air? • What structural or chemical features enable plants to capture or break down air pollutants? • Can we replicate forest-like purification systems in urban architecture or infrastructure? **Primary goals** Create a **bio-inspired air filtration system** for urban areas that mimics natural forest mechanisms to improve air quality without relying on energy-intensive technologies. **1.b Describe what the design needs to do or solve, who your target audience is, and the context.** **Design needs** • Filter fine dust (PM2.5/PM10), NOx, CO2, and other pollutants. • Be scalable to building facades, street furniture, or public infrastructure. • Work passively or with minimal energy input. **Target audience** • Urban planners and architects. • Environmental engineers. • Public health agencies and smart city developers. **Context** Air pollution is a growing concern in densely populated cities. Forests

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provide a proven model for passive, chemical-free air purification. By translating these natural principles into the built environment, we can enhance livability and sustainability.

1.c Identify the opportunities and/or constraints.

Opportunities

- Integration into green architecture and climate-resilient cities.
- Public and policy support for clean air initiatives.
- Innovations in green walls and bio-reactive materials.

Constraints

- Space limitations in urban environments.
- Maintenance of living systems (e.g., irrigation for vertical gardens).
- Cost of installation and retrofitting..

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Challenge: Bio-inspired noise-reducing structures

BIOMIMICRY DESIGN	Description
Step 1 – Define the challenge	**1.a Define the challenge as a question.** How can we design passive, sustainable structures that reduce environmental and indoor noise levels by mimicking nature's silent movement and sound absorption strategies? **Exploratory questions** • How do certain animals creep or minimize sound in noisy environments? • How does the structure of feathers, fur, or foliage influence acoustic properties? • Can these principles be adapted into architectural or interior solutions? **Primary goal** Create bio-inspired acoustic structures or panels that absorb or diffuse sound efficiently without relying on electronic systems, thereby improving the quality of life in noisy environments. **1.b Describe what the design needs to do or solve, who your target audience is, and the context.** **Design needs** • Reduce or absorb noise (e.g. traffic, machinery, speech). • Be adaptable to indoor and outdoor environments. • Offer scalable, energy-efficient solutions without the use of power-consuming tech. **Target audience** • Urban developers and architects. • Public institutions (schools, hospitals, libraries). • Transportation authorities.

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- Workplace designers and co-working spaces.

Context

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.

1.c Identify the opportunities and/or constraints.

Opportunities

- Urban densification drives demand for acoustic comfort.
- Green building certifications support non-electric, sustainable noise reduction.
- Advances in 3D printing and smart materials make biomimetic forms more feasible.

Constraints

- Balancing aesthetic design with acoustic performance.
- Durability and fire-resistance of soft/fibrous structures.
- Costs of complex surface fabrication at scale.

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Challenge: Bio-Inspired Anti-Icing Surfaces

BIOMIMICRY DESIGN	Description
Step 1 – Define the challenge	**1.a Define the challenge as a question.** How can we design surfaces that prevent or delay the formation of ice by mimicking natural anti-icing mechanisms found in organisms like lotus leaves or penguins? **Exploratory questions** • How do penguins and lotus leaves stay free from ice in freezing conditions? • Can natural superhydrophobic or textured surfaces be translated into materials for aviation, infrastructure, or textiles? • What are the micro/ nano surface features responsible for ice repellence in nature? **Primary goal** Create passive, non-toxic, and energy-efficient **anti-icing surfaces** that reduce ice buildup for applications in transportation, infrastructure, and public safety. **1.b Describe what the design needs to do or solve, who your target audience is, and the context.** **Design needs** • Delay or prevent ice nucleation and adhesion. • Apply to various materials (metal, plastic, fabric). • Avoid reliance on electricity, chemicals, or active heating. **Target audience** • Aviation and aerospace engineers. • Wind turbine manufacturers and maintenance providers. • Public safety and infrastructure designers.

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- Clothing and sports equipment developers for cold climates.

Context

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.

1.c Identify the opportunities and/or constraints.

Opportunities

- Growing demand in aviation, renewable energy, and wearable tech.
- Regulatory push for reducing toxic de-icing chemicals.
- Advancements in bio-inspired coatings and 3D surface engineering.

Constraints

- Durability under mechanical abrasion.
- Manufacturing scalability for textured surfaces.
- Surface performance in extreme or changing environments..

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Challenge: Bio-inspired water-repellent textiles

BIOMIMICRY DESIGN	Description
Step 1 – Define the challenge	**1.a Define the challenge as a question.** How can we create water-repellent textiles that mimic nature's ability to shed water, without relying on harmful chemicals or compromising fabric breathability and flexibility? **Exploratory questions** • How do lotus leaves and butterfly wings stay dry and clean?. • What microstructures prevent water from sticking to natural surfaces?. • Can these be sustainably replicated on fibres and fabrics?. **Main Goal:** Design **non-toxic, durable, and breathable water-repellent textiles** by mimicking structures and functions found in nature. **1.b Describe what the design needs to do or solve, who your target audience is, and the context.** **Design needs** • Repel water passively, even under light pressure or exposure. • Maintain breathability and softness. • Avoid the use of perfluorinated chemicals (e.g., PFAS). **Target audience** • Outdoor clothing and gear manufacturers. • Textile engineers and fashion designers. • Medical and emergency response textile producers. **Context** Conventional water-repellent coatings (e.g., DWR) often contain harmful chemicals that degrade over time. Nature, however, offers elegant solutions using **micro- and nano-scale structures** that passively resist moisture without pollution or discomfort. **1.c Identify the opportunities and/or constraints.** **Opportunities**

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	• Strong demand for sustainable fashion and technical clothing. • Existing advances in nano-texturing and hydrophobic fiber treatment. • Regulatory pressure to replace PFAS-based coatings. **Constraints** • Maintaining long-term durability of surface structures. • Ensuring manufacturability at commercial scale. • Balancing water repellency with air permeability and skin comfort..

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Challenge: Enhancing Wind Turbine Efficiency with Biomimicry

BIOMIMICRY DESIGN	Description
Step 1 – Define the challenge	**1.a Define the challenge as a question.** How can we enhance the aerodynamic performance and energy efficiency of wind turbines by drawing inspiration from nature's solutions to fluid movement, such as the fins of humpback whales? **Exploratory questions** • How do whales manoeuvre with power and efficiency in turbulent water?. • What is the function of tubercles on whale fins?. • Can we translate these patterns into wind energy applications?. **Primary goal** Increase wind turbine efficiency and reliability by mimicking **biological adaptations** that enhance lift and reduce drag in unsteady flow environments. **1.b Describe what the design needs to do or solve, who your target audience is, and the context.** **Design needs** • Maximise aerodynamic lift and torque. • Operate more efficiently in low-wind and turbulent conditions. • Reduce mechanical noise and vibration. **Target audience** • Renewable energy developers. • Wind turbine blade manufacturers. • Engineers focused on sustainable energy innovation. **Context** Standard turbine blade designs struggle in **variable wind** conditions. Nature, however, offers highly refined adaptations for moving

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efficiently through fluids, such as the **tubercle pectoral fins of humpback whales**, which allow for greater lift and manoeuvrability.

1.c Identify the opportunities and/or constraints.

Opportunities

- Increased turbine efficiency can expand adoption in low-wind zones.
- Lower mechanical stress leads to longer blade lifespan.
- Nature-inspired designs can reduce bird collisions and noise.

Constraints

- Engineering and cost challenges in producing complex blade surfaces.
- Retrofitting existing turbines.
- Weather and erosion resistance of biomimetic features..

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Challenge: Reducing Microplastic Pollution Using Biomimicry

BIOMIMICRY DESIGN	Description
Step 1 – Define the challenge	**1.a Define the challenge as a question.** How can we remove microplastics from water systems efficiently and sustainably by mimicking biological organisms and filtration processes found in nature? **Exploratory quesions** • How do filter feeders like mussels or sponges separate particles from water?. • What adhesive or binding strategies exist in aquatic environments?. • Can nature's filtration and binding strategies be integrated into water infrastructure?. **Main Goal:** Develop **passive, scalable, and eco-friendly systems** to capture and remove microplastic particles from freshwater and marine ecosystems. **1.b Describe what the design needs to do or solve, who your target audience is, and the context.** **Design needs** • Capture microplastic particles (sizes <5 mm). • Avoid introducing new pollutants or requiring high energy. • Be adaptable to urban water treatment or coastal defence systems. **Target audience** • Municipal water treatment plants. • Environmental NGOs and marine conservation programs. • Designers of smart stormwater and wastewater systems. **Context**

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Microplastics are pervasive and pose risks to marine ecosystems, wildlife, and human health. While chemical and mechanical filters exist, **nature already offers highly effective filtration and particle-binding systems**, such as the **filter-feeding mechanisms of mussels and bivalves**.

1.c Identify the opportunities and/or constraints.

Opportunities

- Growing interest in regenerative and nature-based solutions.
- New biodegradable materials for filters and adhesives.
- Increased funding for ocean and river cleanup initiatives.

Constraints

- Scaling filtration systems across large volumes.
- Maintenance of bioinspired filters (clogging, cleaning).
- Avoiding unintended trapping of beneficial organisms..

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