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# Biomimicry Design for Sustainability Skills in VET

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**KA220-VET - Cooperation Partnerships in Vocational Education and Training**

## D2.1 Biomimicry Process Design for Sustainability Skills in VET

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# Executive summary

Biomimicry, or “innovation inspired by nature”, is based on the idea that nature has already solved the problems humans face today, such as energy, transportation, food production, waste management, and cooperation (Benyus, 2014). It follows the fundamental principles of nature, such as generating renewable energy, using energy efficiently, recycling, and producing eco-friendly materials. Mimicking nature’s principles and designs is essential to creating a sustainable future for our planet. Furthermore, the 21st-century design of a sustainable future combines different disciplines through collaboration and cooperation methods.

Biomimicry also aligns with the objectives of STEM education by creating opportunities for teachers to teach STEM subjects and environmental sciences, and to develop 21st-century skills. Thus, biomimicry offers a way to learn from the natural world to solve human problems and aims to educate nature lovers and environmentally conscious students (Biomimicry Institute, 2017, p. 3). As the global community faces complex environmental and societal challenges, designers and engineers look to the natural world for inspiration to create efficient, sustainable, and resilient solutions. Integrating biomimicry into educational curricula fosters creativity and problem-solving skills and instils a deep respect for nature and its processes.

A large number of VET graduates are working in various economic sectors. Many employment sectors are regulated by standards that govern their operations, and many jobs have defined skill standards. Individuals typically undertake VET to obtain the skills or qualifications needed for regulated occupations or jobs for which standards of competence are established. Unfortunately, many existing regulations and standards date from an era before sustainability was fully understood and have not yet been updated in depth to meet the requirements for a transition to a green economy. They may even help maintain a “business-as-usual” mode of operations, work processes and methods when this is not sustainable, using raw materials and creating waste and emissions to a degree that causes unnecessary environmental harm.

Implementing education for sustainable development (ESD) in VET can serve as an enabler of transformation in TVET institutions by expanding the sustainability scope of an institutional

vision and increasing opportunities to build the capacities of the community and its stakeholders. In effect, ESD provides an enhanced tool to equip youth and adults with the skills needed in the changing world of work, including the knowledge and competency requirements to transition to green economies and societies.

In this context, blending Biomimicry Process Design and Project-Based Learning (PBL) emerges as an effective pedagogical strategy that aligns perfectly with the principles of biomimicry. PBL engages students in real-world projects that require critical thinking, collaboration, and hands-on learning. By working on projects that address genuine challenges, students develop a deeper understanding of the subject matter and gain practical skills directly applicable to their future careers.

On the other hand, Vocational Education and Training (VET) systems prepare individuals with the necessary knowledge, skills, and competencies to participate in the green economy and actively adopt sustainable practices. This includes both foundational or field-related knowledge and transversal, or soft, skills that help an individual excel independently of the subject area. Among those skills are green competencies, which are of continuously increasing importance in the face of 21$^{st}$ industry and societal challenges related to climate change and the UN Sustainable Development Goals (UN 2024). UNEP (2011) states that a green economy seeks to improve human well-being and promote social equity while minimising environmental risks and ecological scarcities. Achieving such a society is crucial to transitioning toward a sustainable future.

Aligning with emerging needs, project LET'S MIMIC aims to build green, specifically biomimicry, skills among VET students to prepare empowered young professionals with the knowledge and competencies required in the professional world. Biomimicry is an innovative design approach that aims to introduce solutions to real-world challenges inspired by natural processes and respecting the balance of ecosystems.

This report presents the results of needs and current practices analysis on building biomimicry skills in VET. This work has been implemented in Greece, Romania, Turkey, France, Spain, and Portugal to ensure the European relevance of the project activities design. The work continues with the presentation of the LET'S MIMIC methodological learning design through which students develop innovation skills inspired by natural models and processes.

# PART A – Learning Outcomes Matrix for Sustainability Skills in VET

# 1. Introduction to needs analysis on biomimicry skills building

Part A of this report presents a needs analysis on building biomimicry and problem-solving skills through innovative project-based learning. The study is based on desk research of current practices on building general sustainability and more specific biomimicry skills in countries represented in the consortium through project partners, namely Greece, Romania, Türkiye, France, Spain, and Portugal. In addition, it analyses results from questionnaire-based research conducted by all project partners on student needs and expectations related to the same subject. The outcomes of needs analysis are summarised in a Learning Outcomes Matrix for Sustainability Skills in VET learners. This matrix aims to integrate sustainability-focused competencies into VET initiatives, fostering a generation equipped to contribute to sustainable development.

# 2. Preliminary analysis

## 2.1 Aim of the preliminary analysis

The preliminary analysis included desk research and two online questionnaires (one for VET learners and one for VET teachers).

The desk research aimed at examining the current situation in VET in Greece, Romania, Türkiye, France, Spain, and Portugal regarding **sustainability skills**, how sustainability skills are being developed and integrated into curricula, what instruments are being used, what associated national strategies exist, and what the **level of biomimicry knowledge** and its usage are, as well as the **usage of Project-Based Learning (PBL)**.

The extended questionnaire for VET learners aimed to identify their knowledge of sustainability, the environment, and biomimicry, as well as **their interest in these topics**.

The extended questionnaire for VET teachers aimed to determine the place given to **sustainability skills in current curricula**, the **methodologies they apply to train sustainability** skills, the tools and sources they use, their **knowledge and implementation of the biomimicry** approach, and whether and how they apply **PBL methodology**.

## 2.2 Methodology of the preliminary analysis

All partners conducted preliminary desk-based research on current practices in building sustainability and, more specifically, on biomimicry skills. The study further focused on how PBL is currently deployed in VET. As stated above, it was conducted in Greece, Romania, Türkiye, France, Spain, and Portugal. It focused on the following themes:

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| **Sustainability skills** | How are sustainability competencies being developed, and how are they being integrated into VET curricula in each country? What instruments are used? |

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| | What is the national strategy for the development of sustainability skills in VET? |
| **Biomimicry** | Is biomimicry applied in VET? Specifically:<br>● How is biomimicry integrated into VET curricula?<br>● What are examples of training courses that include biomimicry? |
| **PBL** | Is PBL applied in VET learning? What are some concrete examples of how PBL is implemented in VET courses? |

*Table 1. Desk research questions.*

Upon completing the desk analysis, project partners administered two online questionnaires to **201 VET students** and **126 VET teachers**.

The questionnaire for students included the questions detailed in the following table:

| | |
|---|---|
| **Select your country** | Greece/Romania/Türkiye/France/Spain/Portugal |
| **Background Information** | What educational program are you enrolled in? |
| | Have you previously studied environmental sustainability, biomimicry, or related subjects such as environmentally friendly solutions, sustainable product design, sustainable engineering, sustainable buildings, sustainable agriculture, etc.? |
| | If the answer to the above question is "yes", please provide a short description. |

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| **Understanding of Biomimicry** | Have you been exposed to the concept of biomimicry before? |
| | If the answer to the above question is "yes", please provide a short description. |
| | Can you give an example of an environmental solution based on biomimicry? For example, aeroplane wings are inspired by birds; a cyclical economy is inspired by the cycle of life in nature; the fabric of Olympic athlete swimsuits is inspired by sharkskin; mussels inspire underwater adhesive; non-slip shoe soles are inspired by snakeskin; termite mounds inspire self-cooling buildings; and forests inspire chemical-free water filtration systems. |
| | How do you think biomimicry can contribute to sustainable design? |
| **Skills Assessment** | Rate your skill level in the following areas on a scale from 1 (no experience) to 5 (expert):<br>● Creativity and innovation.<br>● Problem-solving.<br>● Technical drawing (manual or CAD).<br>● Scientific research.<br>● Team collaboration. |
| | Have you worked on any projects where you applied biomimicry principles? If yes, please describe the project briefly. |

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| **Interest and Motivation** | Why are you interested in biomimicry or environmental design? |
| | What areas of biomimicry or environmental design are you most interested in exploring further?<br>● Architecture.<br>● Product design.<br>● Material science.<br>● Robotics.<br>● Sustainable buildings.<br>● Sustainable cities.<br>● Clean water.<br>● Medicine.<br>● Environmental preservation.<br>● Protection from natural disasters.<br>● Others. |
| **Practical Application** | Imagine you are tasked with designing a new product for collecting water in dry areas. What are the first steps to your solution? |
| **Feedback** | Do you think learning about biomimicry can enhance your professional skills? |
| | What resources or tools would help you better understand and apply biomimicry in your designs? |

*Table 2. Questionnaire for VET students.*

The questionnaire for teachers included the questions detailed in the following table:

| | |
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| **Select your country** | Greece/Romania/Türkiye/France/Spain/Portugal |
| **Background Information** | What subjects do you teach? |
| | How many years of teaching experience do you have? |
| | Have you previously taught or used concepts related to environmental sustainability or biomimicry in your courses? If the answer to the above question is "yes", please describe briefly how. |
| **Understanding and Application of Biomimicry and PBL** | Define biomimicry in your own words. |
| | Please mention any environmental sustainability or biomimicry examples you have discussed with your students. |
| | What role do you believe biomimicry plays in modern design and environmental education? |
| | Do you apply PBL as a teaching method? If your answer is "Yes", please indicate some examples and the frequency of using this method. |
| **Teaching Skills and Curriculum Integration** | Rate your confidence level in teaching the following aspects of biomimicry on a scale from 1 (not confident) to 5 (very confident):<br>● Understanding ecological principles.<br>● Applying biomimicry in practical design projects. |

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| | • Integrating biomimicry with other subjects (e.g., mathematics, science).<br>• Encouraging innovative thinking through biomimicry.<br>• Applying PBL. |
| | Have you faced any challenges integrating environmental sustainability or biomimicry into your curriculum? If the answer to the above question is "yes", please comment briefly. |
| **Professional Development and Resources** | What types of resources would assist you in teaching environmental sustainability or biomimicry more effectively? (Select all that apply):<br>• Textbooks and academic articles.<br>• Online courses or workshops.<br>• Guest lectures from industry professionals.<br>• Hands-on project materials.<br>• Cases or examples of environmental sustainability or biomimicry solutions.<br>• Software tools like digital presentations, games, simulations, etc.<br>• Audio-visual material, such as images, videos, or others.<br>• Exchange of knowledge with other educators.<br>• Other (Specify). |
| | Would you be interested in attending a professional development program focused on biomimicry? |

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| | What topics in biomimicry would you like to learn more about for teaching purposes? |
| **Feedback and Suggestions** | How do you think biomimicry could be integrated more effectively into learning? |
| | Do you have additional comments or suggestions regarding teaching biomimicry in vocational education? |

*Table 3. Questionnaire for VET teachers.*

The two questionnaires were translated and delivered in national languages. All answers were collected and translated into English to elaborate on the results. The main findings of the desk research and the questionnaires are outlined in the next paragraph.

# 3. Analysis of practices on building sustainability, biomimicry, and PBL skills

The results presented below are related to desk research and the online questionnaires, which were sent to the following countries: Greece, Romania, Türkiye, France, Spain, and Portugal.

## 3.1 Current practices on building sustainability skills

### 3.1.1 In Greece

**How are sustainability competencies being developed, and how are they being integrated into VET curricula in each country? What instruments are used?**

Developing and integrating sustainability competencies into vocational education and training (VET) curricula is becoming increasingly important in Greece. Various instruments and strategies are being employed to achieve this goal.

Firstly, Greece, like other European Union (EU) member states, is guided by EU policies and frameworks that emphasise educational sustainability. These policies provide the overarching framework for integrating sustainability competencies into VET curricula. For instance, the European Green Deal (2024) emphasises the importance of sustainable development across all sectors, including education.

In Greece, several strategic initiatives, policy frameworks, and practical instruments guide the development of sustainability competencies and their integration into VET curricula. These efforts ensure the workforce has the necessary skills to support the United Nations Sustainable Development Goals (2024) and transition towards a green economy.

Strategic frameworks include the National Skills Strategy, Greece. Announced in the context of the European Year of Skills 2023, the strategy aims to align VET with labour market needs, emphasising sustainability skills. This strategy involves integrating sustainability competencies into VET curricula through systematic skills anticipation and foresight activities. The strategy is supported by Law 4763/2020, which reforms VET governance, promoting innovative teaching methods and establishing model vocational schools and experimental training institutes focused on sustainability and excellence in education.

Competence frameworks help guide curriculum development and reskilling for sustainability. VET programs are being updated to include competence frameworks that emphasise environmental awareness, sustainable practices, and green technologies. These frameworks guide curricula development that incorporates sustainability at various educational levels.

Several updates have been made to the VET specialisations curricula in this context. They include new occupational profiles, guided by the Mechanism for the Identification of Labour Market Needs, tailored to meet the demands of the green economy and incorporating sustainability-related competencies (CEDEFOP). In addition, VET curricula are being updated to include green skills modules, such as renewable energy technologies, sustainable agriculture, waste management, and environmental conservation. These modules ensure students acquire practical and theoretical knowledge relevant to sustainable development. Educational innovation includes using digital platforms and online learning to enhance VET delivery through digital content and resources on various sustainability and environmental management aspects.

VET practices are also updated through collaboration with the industry. Partnerships with local businesses and industry stakeholders are crucial in integrating sustainability into VET. These collaborations provide real-world training opportunities, internships, and apprenticeships focusing on sustainable practices and technologies.

Teacher training and professional development are essential to effectively integrating sustainability competencies into VET curricula. Educators need workshops, seminars, and courses focused on sustainability education to equip them with the knowledge and tools to teach sustainability effectively. Educator skills are updated through continuous professional development programs for VET teachers and trainers, including training on sustainability competencies and innovative teaching methods. These programs ensure educators are well-equipped to teach and integrate sustainability into their curricula. Furthermore, the Ministry of Education provides technical and pedagogical support to VET institutions, helping them implement sustainability-focused curricula and teaching practices effectively.

Moreover, VET institutions can serve as sustainability models by implementing environmentally friendly practices. This could include energy-efficiency measures, waste-reduction strategies, and the promotion of sustainable transportation options. Collaboration

with businesses, NGOs, and other stakeholders can also enrich VET curricula with real-world examples and practical experiences related to sustainability. Industry partnerships, for instance, can provide students with internship opportunities focused on sustainable practices.

Incorporating project-based learning and experiential education methodologies into VET curricula allows students to engage directly with sustainability challenges and solutions. For example, hands-on projects related to renewable energy, waste management, or sustainable agriculture can deepen students' understanding of sustainability principles. Finally, digital tools and e-learning platforms can be utilised to deliver sustainability-focused content to VET students. Online modules, interactive simulations, and virtual labs can enhance learning experiences and reach a wider audience.

In terms of instruments used, the Mechanism for the Identification of Labour Market Needs provides data and insights on labour market trends and skill needs, helping to align VET programs with sustainability competencies (CEDEFOP, 2023). In addition, the National Qualifications Framework (NQF) supports the classification and certification of qualifications, ensuring that sustainability competencies are recognised and standardised across VET programs.

In summary, Greece is actively developing and integrating sustainability competencies into VET curricula through strategic policy initiatives, curriculum updates, educational tools, and industry collaborations. These efforts are supported by robust instruments and frameworks designed to prepare the workforce for sustainable development challenges.

**What is the national strategy for the development of sustainability skills in VET?**

Greece's Ministry of Education, Research, and Religious Affairs oversees education policies and reforms. While there may not be a national strategy exclusively focused on sustainability skills in VET, sustainability principles will likely be integrated into broader education initiatives. This integration may occur through curriculum revisions, teacher training programs, stakeholder partnerships, and the implementation of sustainable practices within educational institutions.

Like many other countries, Greece aligns its education strategies with broader European Union (EU) policies and frameworks, emphasising sustainability across all educational levels. The European Union has several initiatives and strategies related to sustainability in

education, which member states like Greece are expected to incorporate into their national agendas. One such initiative is the European Green Deal, a comprehensive plan to sustain the EU's economy. It covers various sectors, including education, focusing on integrating sustainability principles into all aspects of policy and practice.

Another significant initiative is the European Skills Agenda, which aims to ensure people develop the skills they need for green and digital transitions and recovery from the COVID-19 pandemic. It emphasises upskilling and reskilling, including vocational education, to meet the demands of a sustainable economy. Additionally, the EU is working towards creating a European Education Area by 2025. This initiative includes promoting shared values, fostering inclusive education, and enhancing digital and green skills among learners. It provides a framework within which member states can develop their national education strategies.

Greece has implemented a comprehensive national strategy to develop sustainability skills, aligning with broader European goals and the SDGs. This strategy is part of the National Skills Strategy, announced during the European Year of Skills in 2023, which focuses on anticipating and addressing labour market needs through improved education and training programs. Key aspects of this strategy include skills anticipation and foresight, guided by the Mechanism for the Identification of Labour Market Needs, help design relevant vocational education and training (VET) programs and inform the development of new curricula and occupational profiles to match market needs.

Furthermore, Greece's approach to skills development is closely tied to its commitment to the SDGs. The country's Sustainable Development Report (2023) tracks progress on various indicators, ensuring that educational initiatives contribute to sustainable development, including clean energy, responsible consumption, and climate action.

On the other hand, under Law 4763/2020, recent reforms in VET governance emphasise innovative teaching methods and the establishment of model vocational schools. These reforms aim to enhance VET's attractiveness and responsiveness to labour market demands, thus fostering skills that support sustainability and green economy transitions.

The national strategy in Greece involves stakeholder engagement, namely the active participation of social partners, including employers, trade unions, and educational institutions. This ensures that the skills developed are relevant and in demand. This

collaborative approach helps continuously update and improve VET programs to meet the evolving needs of the economy.

Finally, lifelong learning and continuous upskilling ensure that the workforce remains adaptable and capable of meeting new challenges, particularly sustainability and digital transformation.

The above demonstrates that Greece's national strategy for developing sustainability skills is a multifaceted approach that integrates policy, education, and stakeholder collaboration to build a skilled workforce capable of supporting sustainable development goals (CEDEFOP, 2020) (Sustainable Development Report 2023).

### 3.1.2 In Romania

**How are sustainability competencies being developed, and how are they being integrated into VET curricula in each country? What instruments are used?**

In Romania, VET covers both high school and post-secondary education and is integral to the pre-university education system. It is generally the responsibility of the National Ministry of Education (NME) and the National Centre for the Development of Professional and Technical Education.

However, VET finds itself at a crossroads in educational, social, economic and labour policies. Consequently, the actors in these sectors are connected in different ways to the decision-making process and establishment of the curricula. The institutional framework of VET in Romania is highly fragmented, and several organisations perform essential functions. The vital functions specific to the VET system are precisely fulfilled, in addition to the NME, by four different organisations. Five units within the NME perform various tasks within the general education system, the most important being found in the VET field. Overall, the multiple functions of the VET system are fulfilled by staff from nine different organisations at the central level.

In terms of the curricula, three major profiles for vocational and technical education (VET) are defined within the National Methodology of Organization and Functioning of Vocational Education (NMOFVE): technical, natural resources and Environmental Protection and services, with a total of 17 basic levels of qualifications and the curriculum corresponding to

qualifications in VET is drawn up based on the Professional Training Standards for level 3 and 4 professional qualifications of the National Qualifications Framework (PTS) and the National Strategy for Sustainable Development in Romania, 2030, which focus on Education for Sustainable Development (ESD), as an integral part of the school curricula.

The VTS is the most critical regulatory document in designing professional and technical education curricula. It was developed based on the occupational standards in force. These standards form the basis of the certification evaluation and are aligned with the eight areas of critical competencies defined by the European Framework of Reference for Key Competencies for Lifelong Learning. The standards are formulated in terms of specific knowledge, skills, and attitudes, integrated into the units of general and specialised technical competencies, and formed/deepened in professional training contexts.

In Romania, Education for Sustainable Development (ESD) aims to foster environmental awareness, shift attitudes, and mitigate the impact of human activities. Through ESD programs, students acquire essential knowledge and skills to promote sustainable development, focusing on several key areas. One important aspect is holistic development, which emphasises the balanced growth of individuals across cognitive, emotional, physical, spiritual, and social dimensions. This approach prepares students to navigate an ever-evolving world by ensuring they are well-rounded and resilient in the face of challenges. Additionally, ESD promotes a balanced approach to skill development, helping students identify their learning needs and establish educational priorities that allow for flexible learning pathways.

The spirit of reflection is another critical element, as it encourages students to engage in self-evaluation and critical thinking. This fosters a deeper understanding of themselves and their environment, laying a foundation for personal progress. Furthermore, ESD instils a mindset of overcoming self-limitation, motivating students to explore diverse educational, social, and professional avenues while making informed decisions and pushing their limits. ESD also incorporates prospective approaches that encourage a proactive attitude toward anticipating future challenges and developing innovative solutions. Coupled with resilience, which teaches students to persevere through difficulties, these aspects empower learners to face obstacles with autonomy and self-determination.

In terms of social dynamics, ESD emphasises inclusion and collaboration. It focuses on respectful communication, understanding diverse backgrounds, and ensuring everyone can develop and reach their potential. The curriculum also stresses the importance of sustainability and environmental care, teaching students responsible management of natural resources and contributing to sustainable practices. Moreover, ESD promotes active citizenship, encouraging students to participate in community decision-making and fostering a spirit of solidarity and cooperation for a better future. Finally, it emphasises ethics and accountability, promoting integrity and responsible behaviour in all aspects of life. These components equip students with the skills and attitudes necessary for sustainable living and active community participation.

Topics such as climate change, the environment, and sustainable development are addressed across the curriculum core, targeting specific VET profiles such as ecological technician and environmental quality protection, agro-mountain technician, hydrometeorologist, veterinarian, etc., within some study subjects such as energy and life, chemistry and life, substances in nature, human health and the environment, etc.

Therefore, the issue of interest regarding education for sustainable development and green skill acquisition is addressed in the different components of the school curriculum by discipline: specific skills, learning activities, contents, etc.

**What is the national strategy for the development of sustainability skills in VET?**

It's important to note that Romania lacks a national strategy explicitly targeting skills development in the VET sector. However, there are VET-related references within the National Pre-University Education Law (2023), the National Recovery and Resilience Plan, the Professional Training Standards for level 3 and 4 professional qualifications of the National Qualifications Framework (PTS), and the National Strategy for Sustainable Development in Romania, 2030. These references all aim to enhance education quality and equity, aligning with the ambitious vision outlined in the “Educated Romania” report.

Regarding the green competencies specifically identified for VET, no strict legislation applies only to VET. Initiatives are related to the entire education system. Education for Sustainable Development (ESD) is an integral part of the curriculum in Romania. It aims to develop skills that help students reflect on their actions, considering their impacts in the present and future,

their social implications, cultural, economic, and environmental impact. Subjects regarding ESD, including VET, are integrated, starting with preschool and post-secondary education and at the university level.

### 3.1.3 In Turkey

**How are sustainability competencies being developed, and how are they being integrated into VET curricula in each country? What instruments are used?**

In Turkey, various strategic initiatives and curriculum updates support the integration of sustainability competencies into Vocational Education and Training (VET) curricula, aiming to enhance environmental awareness and skills among learners.

One of the key strategies is curriculum modernisation, which has seen significant updates to incorporate sustainability competencies across existing programs. This modernisation includes integrating green skills into the curricula and developing new educational offerings that address environmental and sustainability challenges. Furthermore, the emphasis on competence-based education ensures that learning outcomes are clearly defined, allowing students to acquire essential skills relevant to sustainability, thereby enhancing their professional and personal development. Integrating sustainability into VET curricula is also facilitated by projects such as the "Green Skills at Vocational Education" initiative. This project aims to improve the quality and awareness of green skills education, particularly in sectors like construction and electrical work, by identifying best practices and incorporating them into educational frameworks. Additionally, the European Social Fund (ESF) plays a vital role in supporting these initiatives by helping to create qualification structures and professional standards that embed sustainability as a core component of VET programs.

To ensure effective teaching of sustainability competencies, Turkey invests in the continuous professional development of VET teachers and trainers through targeted training programs and workshops. These programs focus on integrating green skills into the teaching process, thereby equipping educators with the necessary tools to foster sustainability awareness among students. Various instruments are utilised to enhance the educational experience. Modular education programs are designed to be flexible, allowing for the responsive integration of sustainability topics according to the evolving demands of the labour market.

Additionally, specific training programs to enhance digital and green skills are developed with industry stakeholders to ensure relevance and currency.

Finally, mechanisms for validating prior learning are established to recognise and certify existing competencies related to sustainability. This approach promotes inclusivity within the VET system and supports lifelong learning, ultimately aligning Turkey's VET education with the needs of a sustainable and green economy. These combined efforts illustrate Turkey's commitment to embedding sustainability competencies within its vocational education framework.

**What is the national strategy for the development of sustainability skills in VET?**

Turkey's national strategy for developing sustainability skills in vocational education and training (VET) focuses on integrating green skills into the curriculum, driven by initiatives such as the "Green Skills at Vocational Education" project. This project aims to increase the awareness of VET trainers, policymakers, and students about green skills and to enhance the quality of VET education in this area. The initiative also seeks to expand green job opportunities, contributing to a greener economy and improved employment prospects for VET graduates (CEIPES ETS) (CEDEFOP).

Furthermore, Turkey is aligning its VET curriculum with the broader EU 2020 Strategy, which emphasises environmental protection and sustainable development. The strategy includes conducting interviews and questionnaires with VET trainers and policymakers to identify best practices and incorporate them into the curricula of specific trades, such as electricians and construction. The goal is to ensure that graduates are well-prepared for the demands of a green economy (CEDEFOP).

These efforts are part of a broader national agenda to modernise VET in line with the needs of the economy and society, fostering a connection between education, the labour market, and sustainability objectives (CEDEFOP).

### 3.1.4 In France

**How are sustainability competencies being developed, and how are they being integrated into VET curricula in each country? What instruments are used?**

In France, integrating sustainability competencies into Vocational Education and Training (VET) curricula is implemented through a comprehensive and multifaceted approach. A primary strategy is curriculum integration, where sustainability concepts are embedded across various subjects within VET programs. Specific modules focusing on environmental education, sustainable development, and eco-friendly practices ensure that students receive a well-rounded education in sustainability, fostering a holistic understanding of the subject.

The Ministry of National Education has also developed competence frameworks that outline specific sustainability-related skills and knowledge. These frameworks guide educators in designing and delivering courses that align with national sustainability objectives, as detailed in the Eurydice report "Learning for Sustainability in Europe," which analyses the inclusion of sustainability competencies within European curricula based on the European GreenComp framework. Professional certifications are crucial in equipping students with specialised skills for careers in sustainable industries. VET programs offer certifications in green building practices, renewable energy technologies, and sustainable agriculture, ensuring graduates have the expertise to thrive in these fields.

PBL is another effective method for teaching sustainability skills. Students develop the critical thinking and practical skills necessary to address environmental challenges through real-world projects that require sustainable practices.

Collaboration with industries, non-governmental organisations (NGOs), and local communities enhances students' practical experience. These partnerships help bridge the gap between theoretical knowledge and its application in real-world scenarios. At the European level, initiatives such as GRETA (Greening Responses to Excellence through Thematic Actions) further support the greening of VET by identifying the specific skills needed for the green transition, updating curricula, and fostering environmental awareness among learners. France's strategic efforts in VET aim to equip students with the knowledge, skills, and mindsets essential for contributing to an environmentally sustainable future.

**What is the national strategy for the development of sustainability skills in VET?**

In France, the national strategy for developing sustainability skills in Vocational Education and Training (VET) is shaped by several key policies and initiatives, primarily the National Strategy for Ecological Transition towards Sustainable Development (SNTEDD). Launched by the French

government, this strategy spans from 2015 to 2020 and establishes a framework for coordinated actions across various sectors to facilitate ecological transition. A core objective of the SNTEDD is to integrate ecological principles into all educational levels, including VET, emphasising the role of education in cultivating a culture of environmental sustainability.

The Law on Energy Transition for Green Growth (2015) further supports the integration of sustainability skills by encouraging educational institutions to incorporate concepts related to green growth and energy transition into their programs. This law aligns educational efforts with national goals to reduce carbon emissions and promote renewable energy. Additionally, the Education for Sustainable Development (ESD) policy framework outlines specific objectives for integrating sustainable development principles into education, including clear guidelines for VET institutions to ensure sustainability is a fundamental aspect of vocational training.

Recent national curriculum reforms have also strengthened the focus on sustainability by updating course content, introducing new sustainability-related subjects, and promoting interdisciplinary teaching methods. The French government provides resources and training for VET teachers to empower educators, facilitating professional development programs and workshops that enhance their understanding of sustainability practices and pedagogical strategies.

France's national strategy aims to cultivate a workforce well-versed in sustainability, enabling contributions to the country's ecological transition and sustainable development goals. This is accomplished through comprehensive curriculum integration, supportive policies, and collaborative engagement with stakeholders across various sectors.

### 3.1.5 In Spain

**How are sustainability competencies being developed, and how are they being integrated into VET curricula in each country? What instruments are used?**

Spain has enacted several policies and legislative frameworks to embed sustainability as a fundamental aspect of VET curricula. These efforts align with the European Union's sustainability targets and the United Nations' Sustainable Development Goals (SDGs). One of the critical pieces of legislation is the Organic Law for the Improvement of Educational Quality (LOMCE), which emphasises the importance of environmental education and sustainable

development within school curricula, extending its influence on VET programs. Complementing this is the Spanish Strategy for Sustainable Development (EEDS), which articulates the nation's commitment to sustainability and integrates these principles into educational policies.

The integration of sustainability in VET curricula is reflected in the design of educational programs, which are increasingly focused on competency-based learning. This approach emphasises sustainability-related competencies, such as environmental awareness, resource management, and sustainable practices. Additionally, sustainability is often treated as a cross-curricular theme, ensuring that all VET courses incorporate sustainable development, irrespective of their specific focus. Many VET programs offer dedicated courses or modules on sustainability, covering topics such as environmental science, renewable energy technologies, and sustainable agriculture. Furthermore, training in green skills, including energy efficiency, waste management, and sustainable construction practices, is commonly included in VET curricula.

Integrating sustainability competencies into Spain's VET curricula is comprehensive, involving policy support, curriculum design, teacher training, partnerships, practical training, and thorough assessment. This holistic approach ensures that VET students acquire the knowledge and skills necessary to contribute effectively to sustainable development in their future careers.

**What is the national strategy for the development of sustainability skills in VET?**

Spain's national strategy for developing sustainability skills in Vocational Education and Training (VET) is designed to align with broader European and global sustainability goals, such as the United Nations Sustainable Development Goals and the European Green Deal. This multifaceted strategy encompasses policy initiatives, curriculum integration, partnerships, and ongoing evaluation.

The Spanish Strategy for Sustainable Development (EEDS) is central to this strategy, which outlines Spain’s commitment to sustainability across multiple sectors, including education. This strategy provides a comprehensive framework for embedding sustainable practices within VET programs. The National Plan for Professional Training also includes specific provisions for incorporating green skills and sustainability competencies into the VET system.

Furthermore, the Organic Law for the Improvement of Educational Quality (LOMCE) plays a crucial role by mandating the inclusion of environmental education and sustainable development in educational curricula, thereby significantly impacting VET programs. These initiatives create a cohesive approach to enhancing sustainability education in Spain's vocational training landscape.

### 3.1.6 In Portugal

**How are sustainability competencies being developed, and how are they being integrated into VET curricula in each country? What instruments are used?**

The National Qualifications Framework (NQF) in Portugal delineates eight qualification levels grounded in the domains of "knowledge, skills, and attitudes," aligning with the European Qualifications Framework (EQF) to facilitate the comparison of national qualifications across EU member states. Although the EQF does not explicitly categorise green competencies, it underscores the importance of sustainability-related skills and knowledge across various educational contexts. Each level is characterised by descriptors that outline expected learning outcomes, including environmental awareness and understanding, as well as encompassing knowledge of ecological issues, the dynamics of ecological systems, and the implications of human activities on the environment.

Additionally, resource management skills focus on the efficient use of natural resources, waste management, energy conservation, and sustainable consumption practices. The framework also emphasises sustainable development, encompassing understanding its economic, social, and environmental dimensions and applying these principles in decision-making and problem-solving. Furthermore, green technologies and practices integrate knowledge related to environmentally friendly technologies, renewable energy systems, eco-efficient processes, and green building practices. Overall, the NQF serves as the primary instrument for defining competencies in education, ensuring that sustainability principles are effectively incorporated into Portugal's educational framework.

**What is the national strategy for the development of sustainability skills in VET?**

Although Portugal does not have a national strategy specifically focused on skills development for the VET sector, it has a National Strategy for Development Education, in force between 2018 and 2022, that aimed at all levels of education. The document aligns with the United

Nations' Sustainable Development Goals to strengthen the integration of development education and the training of educational actors across levels of education, teaching, and training, from preschool to higher education (Caeiro, 2022).

At the same time, the National Strategy for Citizenship Education (ENEC) has been running since 2017 in the country for public and private schools that are part of the "Project for Autonomy and Curricular Flexibility", to contribute to the formation of the individuals as participative citizens, initiating the journey of exercising citizenship throughout their lives. The strategy also sets out the "profile of pupils leaving compulsory education" and a document with "essential skills", which lists the knowledge, skills, and attitudes to be developed by all students, leading to the development of competencies as part of a process of promoting autonomy and curricular flexibility. The areas of competencies presented do not correspond to specific curricular areas but rather imply the development of multiple literacies, which are the basis for learning. The competencies presented include well-being, health and the environment, aesthetic and artistic sensitivity, personal growth and autonomy, interpersonal relationships, scientific, technical and technological knowledge, reasoning, and problem-solving.

## 3.2 Current practices in building biomimicry skills

### 3.2.1 In Greece

**Is biomimicry applied in VET? How is biomimicry integrated into VET curricula? What are some examples of training that includes biomimicry?**

The concept of biomimicry has gained attention worldwide as a source of innovation and sustainable solutions across various disciplines. Biomimicry is applied in VET in Greece, though its integration is still emerging and not yet widespread. The Greek VET system, regulated by the Ministry of Education, underwent significant reforms with the introduction of Law 4763/2020, which aims to modernise VET and align it with labour market needs by promoting innovative teaching methods and excellence through model vocational schools (EPAL) and experimental vocational training institutes (IEK). Biomimicry's principles have started to influence various educational programs, including VET. Integrating biomimicry principles into learning enhances STEM education and creative problem-solving through nature-inspired

solutions. Efforts are part of a broader effort to revolutionise education by applying biomimicry principles to foster sustainable thinking and innovation among students.

Incorporating biomimicry into VET curricula in Greece could involve several approaches. One approach is the integration of interdisciplinary modules. Biomimicry principles could be embedded into existing VET courses across engineering, design, architecture, and sustainability disciplines. For example, lessons on how animals and plants inspire engineering design or sustainable manufacturing processes could be included in relevant courses.

Another approach is offering specialised training courses. VET institutions could offer specialised courses or workshops focused specifically on biomimicry. These courses could cover topics such as biomimetic design, bio-inspired innovation, and sustainable technologies inspired by nature.

Additionally, project-based learning could be a key method for incorporating biomimicry into VET curricula. Students could engage in hands-on learning experiences where they apply biomimicry principles to solve real-world problems. For instance, students in construction trades could explore how termite mound structures inspire energy-efficient building designs, while those in agriculture could study natural ecosystems for sustainable farming practices.

**Is biomimicry applied in industry? What are examples, cases, or good practices?**

While comprehensive data on the extent of biomimicry applications in Greek industries might not be available, biomimicry principles are increasingly recognised and utilised across sectors, including agriculture, product design, and technology, as they are in many parts of the world.

The Biomimicry Greece Research Centre (2024) is an organisation that aims to mimic nature models and systems. The centre seeks to mimic natural models and systems to solve complex human problems through innovative solutions inspired by nature. Their projects span multiple disciplines, including health, architecture, and sustainable design. Biomimicry for Humanity (2024), a sister organisation, focuses on inspiring leaders to integrate nature's strategies into human design for a more sustainable world. The organisation emphasises ethical geopolitics and responsible design practices, aligning with global sustainability goals. These organisations are working towards embedding biomimicry principles into Greek industry, fostering innovation that aligns with environmental sustainability and efficiency.

With its diverse ecosystems and rich biodiversity, Greek agriculture has significant opportunities for applying biomimicry principles. For instance, farmers could draw inspiration from natural systems like forests and wetlands to design agroecological farming practices that enhance soil fertility, water conservation, and biodiversity conservation.

Mimicking the structure and function of plant roots or animal behaviours could lead to more resilient and sustainable agricultural systems. Greek industries involved in product design and manufacturing could leverage biomimicry to develop innovative and sustainable products. For example, companies could study the microstructure of lotus leaves to create self-cleaning surfaces or explore the aerodynamics of bird feathers to design more efficient wind turbines. By emulating nature's strategies for efficiency, durability, and resource optimisation, Greek industries can develop products with minimal environmental impact and enhanced performance.

Biomimicry can also inspire technological innovations across various sectors in Greece. In the field of renewable energy, for instance, researchers could look to natural systems such as photosynthesis or the flight patterns of birds to improve the efficiency of solar panels and wind energy systems. In the construction industry, biomimetic approaches to building design could lead to more energy-efficient structures that are resilient to environmental stresses and adaptable to changing climatic conditions.

**What are some government policies or initiatives related to biomimicry?**

The Greek government has taken several steps to promote biomimicry through policies and initiatives, reflecting a commitment to sustainability and innovation.

One relevant area where biomimicry could intersect with government policies is research and innovation funding. The Greek government may offer funding for research and innovation projects exploring biomimicry applications. Grants, subsidies, or incentives could be available for businesses, research institutions, and startups engaged in biomimetic research and development. Environmental protection and biodiversity conservation policies may also encourage the adoption of biomimicry principles in industries such as agriculture, architecture, and manufacturing. By promoting sustainable practices that mimic natural ecosystems, the government can support efforts to mitigate environmental degradation and preserve biodiversity.

Specifically, the National Strategy for Research and Innovation (NSRI, 2024) emphasises sustainable development and green technologies. Biomimicry is highlighted as a strategic area, promoting the use of nature-inspired solutions to address environmental challenges and enhance economic growth. Furthermore, the National Energy and Climate Plan (NECP, 2024) sets ambitious targets to reduce greenhouse gas emissions, increase renewable energy use, and improve energy efficiency. It encourages the adoption of innovative technologies, including biomimicry, to achieve these goals. The plan supports research and development (R&D) in sustainable practices and nature-based solutions.

On the other hand, government initiatives in education and skills development may include incorporating biomimicry concepts into educational curricula at various levels. By integrating biomimicry into school and university programs, the government fosters a culture of innovation and sustainability among future generations of professionals. This includes integrating biomimicry concepts into STEM curricula, supporting research projects, and fostering partnerships between educational institutions and industries.

Furthermore, the government facilitates collaboration between industry stakeholders, research institutions, and academia to promote biomimicry research, knowledge exchange, and technology transfer. Public-private partnerships or innovation clusters focused on sustainable innovation could support the development and commercialisation of biomimetic technologies and products.

### 3.2.2 In Romania

**Is biomimicry applied in VET? How is biomimicry integrated into VET curricula? What are some examples of training that includes biomimicry?**

In Romania, the concept of biomimicry is not yet part of any curriculum, not even for VET. However, subjects that reflect the importance of nature, how students can learn from it, and concepts relevant to biomimicry are incorporated into the curriculum.

In addition, in Romania, a national program named "Green Week" was established for the academic year 2022-2023, which focuses on subjects that apply notions that can be associated with the biomimicry concept, such as biodiversity, green energy, forests and terrestrial life, water and life below water, etc. The program is organised by the provisions of the report "Education on climate change and the environment in sustainable schools", developed by the

working group at the level of the Presidential Administration of the National Strategy on Education for the Environment and Climate Change 2023 - 2030 and of the National Strategy for the Sustainable Development of Romania 2030.

The "Green Week" program lasts five consecutive working days during the school year. It is carried out in accordance with a plan, at the decision of each educational unit, in accordance with the provisions of the Minister of Education's order on the structure of the school year, valid for the respective school year.

**Is biomimicry applied in industry? What are some examples, cases, or good practices?**

Romanian companies have not explored and developed biomimicry as a standalone concept, and there are no known reports of its use.

However, subjects such as energy efficiency and sustainable materials, greenhouses, intelligent houses, bio-inspired constructions and urban biodiversity, Experimental Bionic Architecture, and nature-inspired furniture are increasingly analysed and applied by the business environment that targets construction.

In Romania, several innovative projects focusing on sustainability and energy efficiency highlight the country's commitment to reducing environmental impact while drawing inspiration from nature's ingenious solutions. One notable project is the Green House in Timișoara, which utilises advanced systems for capturing and storing solar energy, natural lighting and ventilation, adapting seamlessly to its environment. Similarly, the Intelligent Building in Bucharest takes inspiration from organic plant structures, harmoniously blending into the urban landscape while optimising energy efficiency and resource usage.

Another significant development is the Sol Residence complex, recognised as the first prosumer street in Romania and Central and Eastern Europe, which also introduced the Zero Energy Module in 2022, designed to meet sustainability standards through 2050. Additionally, Ubikubi, a Romanian design company, creates nature-inspired furniture and decor, including the "Slash" lamp, which mimics the organic shapes found in rocks and wood. Lastly, the luxury brand Malvensky produces jewellery inspired by natural elements, featuring designs that reflect the shapes of flowers, leaves, and other organic forms. These projects represent a growing trend towards integrating sustainability into design and architecture in Romania.

**What are government policies or initiatives related to biomimicry?**

No national initiatives or measures specifically focused on biomimicry are available to date.

However, the National Strategy for Research, Innovation and Intelligent Specialisation, 2022 – 2027, also targets the bioeconomy and biodiversity sectors, focusing on measures that encourage sustainable production, a circular bioeconomy, increased agriculture's contribution to climate neutrality and resilience, and innovative governance models that promote sustainability and resilience.

### 3.2.3 In Turkey

**Is biomimicry applied in VET? How is biomimicry integrated into VET curricula? What are some examples of training that includes biomimicry?**

Biomimicry is being applied in VET institutions in Turkey. It is integrated into VET curricula primarily through STEM (Science, Technology, Engineering, and Mathematics) education initiatives, focusing on the intersection of natural sciences and engineering practices. Biomimicry is incorporated into VET curricula as part of broader STEM education activities. These activities often emphasise the relationship between structure and function in natural organisms and how these principles can inspire engineering and design solutions. For example, students are engaged in projects that mimic biological structures to solve human problems, helping them understand and apply biomimicry principles in practical contexts (Home) (MDPI).

Training courses incorporating biomimicry enhance vocational education and training (VET) curricula by providing practical, hands-on experiences linking theory to real-world applications. One notable example is an elective Environmental Education course for 8th-grade students, in which they design eco-friendly vehicles inspired by the movement and anatomy of insects such as grasshoppers and beetles. This course engages students over multiple class periods, utilising the engineering design process to address environmental challenges such as air pollution through biomimicry. Additionally, interdisciplinary STEM workshops conducted at high schools and universities immerse students in hands-on activities that explore both top-down and bottom-up approaches to biomimicry. These workshops help students develop technical vocabulary and enhance their interdisciplinary understanding and design skills. These initiatives foster creativity, innovation, and heightened sustainability

awareness among students, effectively integrating biomimicry into their educational experiences.

These examples highlight how biomimicry enriches the VET curriculum by providing students with practical, hands-on experiences that bridge theoretical knowledge with real-world applications. The incorporation of biomimicry not only fosters creativity and innovation but also promotes sustainability and environmental consciousness among students.

**Is biomimicry applied in industry? What are examples, cases, or good practices?**

Biomimicry is becoming more prominent across various industries in Turkey, particularly in architecture, engineering, and design. In architecture, natural forms and processes influence the design of energy-efficient systems. For instance, the Istanbul Airport incorporates ventilation and lighting systems inspired by natural airflow and sunlight, enhancing energy efficiency. In materials science, companies are researching bio-inspired innovations, such as self-cleaning surfaces modelled after lotus leaves, for use in construction and textiles.

In the energy sector, Kadir Has University has been exploring energy-efficient systems inspired by natural ecosystems, including wind turbines that mimic bird wing structures to improve efficiency and reduce noise. Istanbul's Water management projects also apply biomimicry by mimicking natural filtration systems like wetlands to promote sustainability. In agriculture, Turkish farmers are adopting permaculture techniques that draw on natural ecosystems to boost biodiversity and sustainability. Additionally, biomimicry influences product design, with ergonomic tools and waste-minimizing packaging being developed to reflect nature’s efficiency. These initiatives showcase Turkey’s growing focus on sustainable and innovative practices through biomimicry.

**What are government policies or initiatives related to biomimicry?**

The Turkish government increasingly recognises biomimicry's potential to promote sustainability and innovation, though policies labelled explicitly as "biomimicry" are not yet widespread. Initiatives under the National Science and Technology Policy, supported by the Ministry of Industry and Technology, encourage research and development of sustainable technologies aligned with biomimetic principles. These programs offer funding for nature-inspired innovations in materials and processes. Government-backed sustainability and green economy initiatives also incorporate biomimetic strategies to improve energy efficiency and

resource management. Universities like Kadir Has and Middle East Technical University play a crucial role in advancing biomimetic research, often collaborating with government bodies to promote education and innovation in this field.

Support for startups and SMEs also reflects the government's commitment to fostering eco-friendly and biomimetic solutions, offering grants and assistance to businesses focused on sustainability. Furthermore, Turkey's participation in EU environmental initiatives helps to integrate biomimetic practices into national policies. Public awareness campaigns add another layer of support by promoting the value of nature-inspired solutions, urging industries to explore biomimicry as a tool for sustainable growth. Collectively, these efforts demonstrate the Turkish government's growing interest in biomimicry as a driving force for innovation and sustainability across sectors.

### 3.2.4 In France

**Is biomimicry applied in VET? How is biomimicry integrated into VET curricula? What are some examples of training that includes biomimicry?**

Biomimicry is increasingly becoming a vital component of VET curricula in France, especially in programs centred around environmental science, engineering, and design. This integration takes various forms, beginning with the inclusion of dedicated course modules on biomimicry. These modules introduce students to the fundamental concepts, principles, and applications of biomimicry across different fields. Furthermore, interdisciplinary projects often feature biomimicry as a central theme, allowing students from diverse specialisations to collaborate on solving real-world problems using nature-inspired solutions. This collaborative approach deepens their understanding of how biomimicry can be practically applied.

In addition to coursework and projects, VET institutions regularly organise workshops and seminars focusing on biomimicry, inviting industry experts to share their insights and experiences. These events provide hands-on learning opportunities and enrich students' comprehension of biomimicry in action. Examples of training courses incorporating biomimicry include sustainable design courses in industrial design and architecture, where students learn to create efficient and eco-friendly designs inspired by natural processes. Similarly, in environmental engineering programs, students explore innovative solutions to environmental challenges, such as utilising wetland-based natural filtration systems for water

treatment. Agricultural studies also leverage biomimicry principles to enhance crop yields and develop pest control methods by emulating natural processes. Through these diverse educational approaches, students gain valuable skills and insights into sustainable practices that can significantly impact their future careers.

**Is biomimicry applied in industry? What are examples, cases, or good practices?**

In France, incorporating biomimicry into various industries drives the development of more efficient and sustainable products and practices. In product design, companies increasingly leverage biomimetic principles to enhance their offerings. A notable example is the company Festo, which utilises biomimicry to design robotic systems that replicate animal movement. This approach leads to more efficient machines and makes them more versatile in various applications.

The agricultural sector also embraces biomimicry, applying its principles to cultivate sustainable farming practices. For instance, some farms implement crop rotation and polyculture techniques that draw inspiration from natural ecosystems. These methods improve soil health and promote biodiversity, resulting in more resilient agricultural systems.

In architecture and urban planning, biomimicry is harnessed to create energy-efficient buildings that utilise natural ventilation and cooling systems. A prime example is the Cité du Vin in Bordeaux, designed with biomimetic principles to optimise natural light and temperature control. This innovative approach enhances the building's sustainability and creates a more comfortable environment for its occupants. Through these diverse applications, biomimicry is a valuable tool in advancing sustainability across multiple sectors in France.

**What are government policies or initiatives related to biomimicry?**

Various national research programs, sustainability initiatives, and educational policies support the advancement of biomimicry. The French government actively funds research programs focusing on biomimicry, primarily through agencies such as the National Centre for Scientific Research (CNRS) and the French Environment and Energy Management Agency (ADEME). These initiatives are designed to support projects exploring the potential applications of biomimicry across diverse industries, encouraging innovation and sustainable practices.

Furthermore, biomimicry is highlighted as a critical component of broader sustainability initiatives, including the National Strategy for Ecological Transition. This strategy promotes the adoption of innovative technologies inspired by nature, aiming to drive ecological progress and foster sustainable development within the country.

On the educational front, the Ministry of National Education plays a pivotal role in integrating biomimicry into curricula. It provides guidelines and funding for pilot programs incorporating biomimetic concepts and training for teachers to enhance their ability to teach these principles. Through these concerted efforts, France is positioning biomimicry as a fundamental aspect of its commitment to sustainability and innovation, fostering a culture that values nature-inspired solutions across multiple sectors.

### 3.2.5 In Spain

**Is biomimicry applied in VET? How is biomimicry integrated into VET curricula? What are some examples of training that includes biomimicry?**

Biomimicry principles are increasingly woven into VET curricula, enriching the educational experience and fostering a deeper understanding of sustainable design. One critical approach is integrating biomimicry into existing science and technology modules. In these courses, students explore natural systems and their functionalities, learning how these principles can be applied to develop innovative and sustainable solutions to various challenges.

Additionally, some VET programs offer specialised modules that focus entirely on biomimicry. These courses delve into the concepts, applications, and methodologies associated with biomimetic design, allowing students to explore the subject in depth. By providing dedicated space for biomimicry, educational institutions equip learners with the skills and knowledge to think critically and creatively about how nature can inspire solutions in their fields.

A cross-disciplinary approach is often employed in teaching biomimicry, where students engage in interdisciplinary projects that draw on knowledge from biology, engineering, design, and environmental science. This collaborative environment encourages students from diverse vocational backgrounds to work together, fostering teamwork and broadening their problem-solving perspectives.

Furthermore, VET curricula frequently include case studies of successful biomimicry applications, showcasing real-world examples such as the design of Velcro, inspired by the hooks of burrs, or energy-efficient building designs that mimic natural ventilation systems. By studying these case studies, students gain valuable insights into how biomimicry can lead to innovative products and solutions, reinforcing the relevance and applicability of their learning principles. Through these varied approaches, integrating biomimicry into VET education enhances student engagement and prepares them to contribute to sustainable innovation in their future careers.

**Is biomimicry applied in industry? What are examples, cases, or good practices?**

Biomimicry is being applied in various industries in Spain, particularly in architecture, water management, and renewable energy. Spanish architects are integrating nature-inspired designs into sustainable buildings. A notable example is the Metropol Parasol in Seville, which draws from natural shapes like trees and mushrooms to create a wooden structure that provides shade and natural ventilation, helping to reduce energy consumption in public spaces. In water management, Spain's Centro Tecnológico del Agua (CETAQUA) uses biomimicry principles to develop sustainable water filtration and recycling systems that mimic natural processes.

Spain is also utilising biomimetic strategies in renewable energy. Researchers at Tecnalia, a leading Spanish research and development centre, are studying wind turbine designs inspired by birds' wing structures to improve energy efficiency and reduce noise. Additionally, several Spanish startups apply biomimicry to product design, particularly to develop eco-friendly packaging and waste-reduction solutions. These examples demonstrate how biomimicry is becoming an integral part of sustainable innovation in Spain's industrial sectors.

**What are government policies or initiatives related to biomimicry?**

Spain is actively exploring biomimicry to promote sustainability across various sectors, with government, educational institutions, and private organisations playing significant roles. While no policies are explicitly labelled as "biomimicry," sustainability and innovation frameworks align with its principles. Spanish institutions like Biomimicry Iberia are dedicated to promoting biomimetic innovation through research, education, and collaboration with

international networks. This includes projects across fields such as architecture, engineering, and design, focusing on nature-inspired solutions to environmental challenges.

Moreover, several Spanish universities are integrating biomimicry into their research and academic programs, fostering collaborations with the government to support nature-inspired innovation. This includes sustainable design research and educational outreach programs that engage students and professionals. Startups and businesses also benefit from government support when incorporating eco-friendly and biomimetic solutions into their offerings, especially as part of broader EU-aligned green-economy initiatives. of bi

### 3.2.6 In Portugal

**Is biomimicry applied in VET? How is biomimicry integrated into VET curricula? What are some examples of training that includes biomimicry?**

In Portugal, biomimicry is not yet part of the VET curriculum. However, the subject is becoming more common in the school system, with organised lectures and training programmes. In 2019, a short-term course was organised by the “Ciência Viva” Training Centre and was aimed at primary and secondary school teachers. Its main objective was to conduct experimental activities applicable at different levels of education, focusing on the study of biological structures and their functions to build more sustainable cities of the future. The same year, the presentation "Bionics and Biomimicry: Nature as a Tool for Technological Innovation" was also presented in higher education as part of the Master's Industrial and Product Design programme at the University of Porto.

In higher education, on the other hand, biomimicry is becoming increasingly common in different areas of education. The University of Evora has a "Design, Sustainability and Biomimicry" course in its Master's in Design. At the University of Beira Interior, on the other hand, the Fashion Design programme includes a course on "Biomimetic Sustainable Fashion Design". The “Instituto Superior Técnico” is the School of Engineering and Technology of the University of Lisbon and has a “Biomimicry” course in its Biomedical Engineering master's programme. Finally, in the health field, there is a postgraduate course in dental medicine, "Advanced Biomimetic Oral Rehabilitation," at CESPU.

**Is biomimicry applied in industry? What are examples, cases, or good practices?**

Until now, Portuguese companies have not explored or developed biomimicry, and there are no known reports of its use. Only research studies on the use of biomimicry have been presented. At the University of Aveiro, the CICECO, a research group that aims to advance the knowledge and development of efficient health-related materials, products and technologies, focuses on producing and applying biomimetic, biological and living materials to improve human health. The Faculty of Sciences of the University of Lisbon created, in 2018, “The Bioadhesion and Biomimicry Research Group”, which reinforces the scientific and economic potential of biomimetic-driven research by contributing to the development of new nature-inspired adhesives for biomedical and biotechnological applications.

In 2013, Industrial Design students from IPCA, the Polytechnic Institute of Cávado and Ave, participated in a biomimicry experiment entitled "Egg Drop." The project aimed to promote the development of innovative concepts to physically protect a delicate object from falling. The students had to design this structure and create their prototypes using only simple, daily-use materials.

In addition, and at the research level, there are some master's dissertations that present real examples of products that could be developed in the country using biomimicry, such as "Biomimicry as a concept for a boat in the Ria de Aveiro", which proposes the creation of an innovative biomimetic boat for bathing areas in the Aveiro delta (Fernandes, 2011); or the dissertation "Biomimicry and Ecodesign: Development of a creative tool to support the design of sustainable products", which proposes the development of a website entitled "BIODESIGNER" that aims to help designers regarding the growing demands for acquiring knowledge in the environmental area, applying biomimicry (Soares, 2008).

**What are government policies or initiatives related to biomimicry?**

No national initiatives or measures specifically focused on biomimicry are available to date. However, the Sustainable Bioeconomy Action Plan - Horizon 2025, approved in 2021 by the Council of Ministers, includes measures to encourage the sustainable production and intelligent use of regionally based biological resources, to promote research and innovation, to raise awareness of the importance of this transition and to produce knowledge and

recognition in this area. Although measures focussing on biomimicry are not described, their concept is presented.

## 3.3 Current practices for using PBL

### 3.3.1 In Greece

**Is PBL applied in VET, and how?**

PBL is a widely recognised and utilised educational approach worldwide, including in vocational education contexts. In Greece, VET institutions incorporate PBL into their courses to provide students with hands-on learning experiences and practical skills development. VET curricula are designed to include real-world problems that students must solve. These problems are typically complex, interdisciplinary, and relevant to professional contexts. Often, PBL is supported by online learning environments that encourage peer collaboration, offering learning benefits. PBL offers significant learning benefits, helping transfer knowledge to the real world. It enhances critical thinking, problem-solving, and collaboration skills, making students better prepared for the workforce. It also offers industry links, as working on real-world problems helps students gain practical experience and insights directly applicable to their future careers. However, it can be resource-intensive, requiring trained educators, industry partnerships, and access to real-world problems. Teachers need specialised training to facilitate PBL effectively, which can be a barrier to widespread adoption.

Some concrete examples of the use of PBL in courses include:

In technical fields such as automotive repair, students could engage in PBL activities focused on real-world projects, such as diagnosing and repairing vehicles. This hands-on approach allows students to apply theoretical knowledge to practical problems, enhancing their technical skills and problem-solving abilities.

In business-related VET courses, students could undertake PBL projects focused on entrepreneurship and business development. These projects might involve creating business plans, developing marketing strategies, or managing small business operations, providing students with valuable experience in the business world.

PBL could involve designing and constructing sustainable buildings or infrastructure projects in construction trades programs. This approach equips students with construction skills and fosters an understanding of sustainable design principles and environmental responsibility.

In hospitality and culinary arts programs, students could engage in PBL projects that involve planning and executing events, developing menus, and managing hospitality operations. Such projects offer practical experience in the culinary and hospitality industries, preparing students for real-world challenges.

PBL could focus on sustainable farming practices, biodiversity conservation, and ecosystem restoration in agricultural and environmental science courses. By working on environmental preservation projects, students can develop skills in managing natural resources and promoting sustainability.

In information technology or engineering programs, PBL projects could involve designing and prototyping innovative technologies or software applications. These projects allow students to explore new technological solutions and gain experience in technology and innovation, preparing them for careers in rapidly evolving industries.

### 3.3.2 In Romania

**Is PBL applied in VET, and how?**

The PBL methodology is used in Romania's VET institutions. VET is an integrated part of secondary education with a strong connection to the business environment. Practice activities that are an integral part of the VET curriculum and internships established through partnerships between schools and the business environment often lead to designing projects which allow students to develop not only technical competencies but also skills and competencies needed to succeed in the workplace and 21st-century society: creativity and innovation, critical thinking, problem-solving; communication, collaboration and teamwork, information & ICT literacy; adaptability, initiative, self-direction, social and intercultural skills, leadership and responsibility.

The methodology in Romania is primarily applied at the end of a study period, according to an algorithm established by the education institution, which involves an interdisciplinary assessment with multiple formative values. In Romania, PBL is implemented as the 6-step

method. The method is oriented around the curriculum's key questions that connect the performance standards, students' higher-level cognitive abilities, and real-life contexts. Educational units that use this method often include a variety of instructional strategies designed to engage students, regardless of their learning style. Also, students collaborate with outside experts or community members to reach a better understanding of the content. Another important aspect is the technology used to support the student throughout the activity. The realisation of a project within the units implementing this didactic method involves navigating through six specific stages. The first stage, Information, requires identifying a problem, theme, or subject and involves collecting, organising, processing, and evaluating information related to the chosen topic, which is aligned with the curriculum. Following this, the Planning stage focuses on developing possible solutions to the identified problem or theme. Next is the Decision stage, where the various solutions are evaluated, and the best option is selected. In the Execution phase, students explore the application of the chosen solution by developing an implementation plan that outlines tasks, resources, and responsibilities. The fifth stage, Control, concerns the means of monitoring and evaluating results, culminating in a concrete plan documented in writing. Finally, in the Evaluation stage, the results of the work, along with evaluation forms, are discussed by both the practitioner and the evaluator. This discussion aims to solidify the experiences gained during the project and minimise the likelihood of future mistakes.

The entire activity spans several days or even weeks, depending on the project's complexity.

### 3.3.3 In Turkey

**Is PBL applied in VET, and how?**

PBL is actively implemented in VET institutions in Turkey, where students engage in real-world projects that blend academic learning with practical experience. Implementing PBL in VET courses involves several vital elements. First, Industry Collaboration is crucial; VET institutions work closely with local industries to create projects that address actual problems, ensuring students gain hands-on experience relevant to their fields. For instance, students in technical disciplines like automotive engineering may collaborate with local car manufacturers to design and build prototype models.

Additionally, PBL fosters multidisciplinary projects by encouraging students from different programs to work together. For example, students in a health informatics program may team up to develop a health information system for local clinics, integrating their knowledge of healthcare and information technology. This approach enhances their technical skills and promotes teamwork across disciplines.

Another significant aspect of PBL is real-world problem-solving, in which students tackle challenges in their communities. In environmental studies, for instance, students might work on designing a sustainable waste management system, which raises their awareness of environmental issues while honing their technical skills. Moreover, technology plays a pivotal role in these projects. Students often utilise various software tools for design and simulation in engineering or develop mobile applications in IT courses. An example could include creating a mobile app that assists farmers in optimising crop yields by analysing soil data.

Concrete examples of PBL in Turkish VET programs include Agricultural Projects, where students develop innovative farming techniques or sustainable practices through fieldwork and collaboration with local farms. In Engineering Projects, students may construct renewable energy systems for local communities, such as solar panels or wind turbines, gaining valuable practical experience. Similarly, Healthcare Projects involve students in developing community health initiatives or healthcare solutions for underserved populations, often requiring interdisciplinary collaboration with healthcare providers.

Overall, PBL in Turkey's VET institutions aims to enhance students' practical skills and prepare them for the workforce by immersing them in meaningful, real-world projects that effectively bridge the gap between academic learning and practical application.

### 3.3.4 In France

**Is PBL applied in VET, and how?**

PBL is actively employed in France's VET institutions. It is recognised for its effectiveness in enhancing practical skills and fostering critical thinking—qualities essential in vocational education. PBL is integrated into the curriculum as a core teaching methodology, with courses designed to encompass multiple projects that students must complete during their training. Many VET programs feature capstone projects in their final year, where students tackle real-

world problems relevant to their field of study, thereby demonstrating their skills and knowledge in a practical context.

The implementation of PBL varies across disciplines. In Technical and Engineering Programs, for example, mechanical engineering students engage in projects that require designing and building functional machine parts or system prototypes. These projects necessitate the application of principles from mechanics, materials science, and computer-aided design (CAD). Students work in teams, assign projects aligned with current industry needs, conduct research, design components, and manufacture them using workshop tools and machinery, often under the mentorship of industry experts who provide valuable feedback.

In information technology (IT) programs, students may develop software applications or websites for local businesses or community organisations. They follow a structured project management process that includes planning, design, coding, testing, and deployment. They collaborate using agile methodologies and present their final products to stakeholders for evaluation.

In healthcare and nursing programs, nursing students engage in simulated clinical environments where they assess and treat patients based on case studies rooted in real-life scenarios. These projects involve role-playing with actors or advanced mannequins in simulated hospital settings, where students must demonstrate their ability to diagnose, plan care, and perform medical procedures under the supervision of experienced practitioners.

Environmental science and agriculture programs may assign students to design and implement sustainable agricultural systems, such as permaculture gardens or hydroponic setups. This work entails site assessment, planning, planting, and maintaining the system while considering environmental impacts, resource management, and sustainability practices. These projects often occur in collaboration with local farms or community gardens.

In hospitality and culinary arts programs, students might organise and execute themed dining events that involve menu planning, cooking, and service. Students work in teams to manage various aspects of the event, from sourcing ingredients to managing the kitchen and serving guests, allowing them to apply their culinary skills and knowledge of event management and customer service.

Collaboration with industry is another critical component of PBL in French VET institutions. Schools frequently partner with local businesses and industries to provide real-world projects, ensuring these initiatives align with current industry needs and standards. Many VET programs also incorporate internships or apprenticeships as part of the PBL approach, where students gain hands-on experience within a company, which is invaluable for applying theoretical knowledge in practical settings.

The evaluation and feedback process in PBL is robust, featuring continuous assessment through project milestones, presentations, and final reports. Students receive feedback at each stage, enabling iterative improvements to their work. Additionally, peer and self-assessment foster critical evaluation skills and contribute to a collaborative learning environment.

Overall, PBL in French VET institutions equips students with practical, hands-on experience that prepares them for the workforce. It emphasises collaboration, problem-solving, and applying theoretical knowledge to real-world challenges, making PBL a vital component of vocational education and training in France.

### 3.3.5 In Spain

**Is PBL applied in VET, and how?**

PBL is effectively implemented in VET institutions across Spain. Recognised for its educational impact, PBL enhances practical skills, critical thinking, and problem-solving abilities, essential for vocational and technical careers. As a core component of the VET curriculum, PBL often involves courses designed around projects that tackle real-world challenges relevant to specific vocational fields. These projects frequently integrate various subjects and skills, ensuring a holistic learning experience.

Hands-on projects within this framework emphasise addressing real-world problems. Students collaborate with local businesses and industries to develop practical solutions. This approach deepens their understanding of the relevance and application of their skills and strengthens industry connections. For instance, projects may include designing, prototyping, and testing solutions, enabling students to acquire essential hands-on technical skills.

In engineering and technology, projects might involve designing and building mechanical systems, developing software applications, or creating sustainable energy solutions. These projects require students to apply theoretical knowledge in practical contexts, enhancing their technical competence and innovation.

In healthcare and services, VET programs may involve projects that include developing patient care plans, conducting health education campaigns, or managing simulated medical emergencies. Such projects allow students to gain practical experience and prepare them for real-world healthcare challenges.

Students might engage in projects that organise events, develop tourism marketing strategies, or create innovative hospitality services in hospitality and tourism. These projects encourage creativity and practical application, equipping students with the skills necessary to succeed in dynamic work environments.

The PBL approach in Spanish VET institutions enriches the educational experience and prepares students for the workforce by linking academic learning with real-world applications. This fosters the development of well-rounded professionals equipped for their chosen careers.

### 3.3.6 In Portugal

**Is PBL applied in VET, and how?**

Portugal's VET institutions use the PBL methodology. VET courses are a type of secondary education whose pathways are characterised by a strong link with the professional world. The learning carried out in these courses emphasises developing skills for a career in collaboration with companies. In this way, work-based training is an integral part of the curriculum for these courses. In addition to the internship, VET centres often develop projects that allow students to develop technical competencies and critical soft skills such as teamwork, problem-solving, and communication.

One example of the application of PBL took place at the Secondary School D. Dinis, in a class of the Computer Systems Management and Programming Technician course. The intervention involved Information Systems Programming. The project-based learning methodology was adopted for teaching compound data structures to overcome difficulties and make the

teaching-learning process more effective. Analysing the data collected showed that using PBL positively impacted the subject, according to the student's final assessment (Alves et al., 2019).

## 3.4 Challenges and opportunities

### 3.4.1 In Greece

**What are the challenges of adopting biomimicry?**

One of the primary challenges is the lack of widespread awareness and understanding of biomimicry principles among policymakers, businesses, and the general public in Greece. To address this, there may be a need for educational campaigns and training programs to promote awareness and build capacity for biomimetic innovation. Another significant challenge is the regulatory hurdles. Current regulatory frameworks and standards may not explicitly address or incentivise biomimetic approaches, making it difficult for companies to integrate biomimicry into their practices. Streamlining regulations and offering incentives for sustainable innovation could help overcome this barrier.

Another obstacle is limited access to funding and resources for biomimicry research and development. This limitation could hinder the adoption of biomimetic technologies and practices in Greece. To address this challenge, government support, private investment, and collaboration with international funding agencies may be necessary. Biomimicry requires collaboration across diverse disciplines, including biology, engineering, design, and business. Building interdisciplinary networks and fostering collaboration among experts from different fields could be challenging but is essential for successful biomimetic innovation.

Greece's diverse ecosystems and rich biodiversity provide a wealth of inspiration for biomimetic innovation. Drawing upon nature's designs and strategies, Greek businesses and researchers can develop innovative solutions tailored to local environmental conditions and challenges. The tourism sector in Greece also presents opportunities for applying biomimicry principles to enhance sustainability and resilience. From eco-friendly infrastructure design to nature-inspired tourism experiences, there is potential for biomimetic innovation to contribute significantly to sustainable tourism development.

With industry, the concept of biomimicry is still emerging, and industries might not be fully aware of its potential applications and benefits, making it harder to establish industry-education linkages. Agriculture is a significant sector in Greece, and biomimicry offers numerous opportunities for sustainable agricultural practices. By mimicking natural ecosystems and biological processes, farmers can improve soil health, conserve water, and enhance crop resilience in the face of climate change. Additionally, Greece has been increasingly focusing on renewable energy and green technology initiatives. Biomimicry can be crucial in developing innovative clean energy solutions, efficient building designs, and environmentally friendly technologies contributing to Greece's transition to a low-carbon economy.

In educational contexts, developing and integrating biomimicry-focused modules into existing VET programs require significant effort and expertise. This involves creating new teaching materials, training educators, and ensuring alignment with national education standards. Biomimicry spans multiple disciplines, including biology, engineering, and design. Creating a cohesive curriculum that effectively integrates these diverse fields can be challenging. Implementing biomimicry in VET may require additional funding for new materials, training programs, and laboratory setups. Securing such resources can be difficult, especially under budget constraints. Furthermore, there is a need for educators and trainers with specialised knowledge in biomimicry. Recruiting and training such personnel can be time-consuming and costly. Integrating biomimicry in VET might need to start with pilot programs, which can be resource-intensive and require careful monitoring and evaluation. Scaling successful pilot programs to a national level involves logistical and administrative challenges, including consistent quality control and continuous curriculum updates.

**What are potential areas of growth in applying biomimicry?**

At the same time, significant opportunities emerge from biomimicry, highlighting the benefits of investing in the extra effort needed to integrate the method in VET and beyond. Integrating biomimicry into VET aligns with Greece’s commitment to the SDGs, particularly those related to quality education (SDG 4), sustainable cities and communities (SDG 11), and climate action (SDG 13). Emphasising biomimicry in education supports Greece’s transition to a green economy, preparing students for emerging job markets focused on sustainability. In education, biomimicry offers innovative and engaging ways to teach complex concepts,

making learning more interactive and inspiring creativity among students. Real-world applications of biomimicry can be integrated into hands-on training, enhancing students' practical skills and employability. Collaboration with industry can provide practical training opportunities, internships, and real-world projects, helping students gain valuable experience and industry insights. By adopting biomimicry, industries can drive innovation and improve competitiveness, creating a demand for skilled workers trained in these methods. Finally, integrating biomimicry into VET can spur research initiatives, encouraging partnerships between educational institutions and research organisations to explore new biomimetic solutions.

In summary, while there are challenges to overcome, Greece has significant opportunities to leverage biomimicry as a driver of innovation, sustainability, and economic growth. By addressing barriers and capitalising on its natural assets, Greece can position itself as a leader in biomimetic innovation within the Mediterranean region and beyond.

### 3.4.2 In Romania

**What are the challenges of adopting biomimicry?**

Technological innovations have significantly transformed educational institutions' teaching and learning processes in recent years. The widespread use of mobile devices, applications, and online platforms has enabled students and teachers to access information and educational resources anytime and anywhere. This technological advancement has also facilitated the development of interactive and personalised learning methods tailored to meet individual student needs, enhancing their ability to assimilate information. However, integrating innovative concepts such as biomimicry into the curriculum remains challenging.

One major hurdle is the lack of awareness about biomimicry in Romania, where the concept is not widely recognised and is implemented on a very small scale. This limitation is attributed to insufficient national coordination efforts, the absence of appropriate policy frameworks, and a lack of market promotion highlighting biomimicry's impact and processes. Furthermore, there is a lack of specific knowledge in biomimicry, as its complexity makes it difficult to understand and integrate into various subjects or practical activities. Educators face challenges in navigating the different phases of biomimicry, complicating its application for innovation and education.

Multidisciplinary collaboration and stakeholder support are essential to effectively incorporating biomimicry. It is recommended that biomimicry be included in higher education syllabi and that workshops and events be organised to facilitate the transfer of biomimicry knowledge across disciplines. Additionally, there is a lack of training and education in biomimicry within the Romanian education system. Although some university programs focus on biotechnology and bioengineering, they do not explicitly apply biomimicry principles. This gap stems from the fact that biomimicry is not part of any curriculum or educational program, nor is there collaboration between the education and industry sectors. Thus, specific training in biomimicry is necessary.

Moreover, the lack of multidisciplinary collaboration poses a challenge. Integrating various disciplines, such as design, engineering, biology, ecology, chemistry, business, and social sciences, can be beneficial for implementing biomimicry. However, establishing such collaborative teams can be difficult, as individuals often prefer to work with others in their field. Additionally, finding the right people with the requisite knowledge to address all aspects of biomimicry can be a barrier. Finally, the lack of funding presents another significant challenge, as the high costs associated with laboratory operations and research hinder the implementation of biomimicry in educational settings.

**What are potential areas of growth in applying biomimicry?**

In architecture and urban planning, biomimicry can create sustainable, energy-efficient, resilient, and innovative designs. Nature and its ecosystem are excellent examples and inspirations for circular resource use, intelligence, self-sustaining, and energy-saving features. Architects can seek inspiration from nature's processes, tactics, and systems to design durable and sustainable buildings beyond aesthetics.

In medicine and biotechnology, by mimicking the efficiency and functionality of natural systems, scientists and researchers can develop innovative treatments and biomaterials that respond to biological signals and can be used in regenerative medicine, diagnostics, and drug delivery.

Biomimicry can be highly used in manufacturing, especially in additive manufacturing, a promising manufacturing process focusing on complex structures in various configurations mimicked from biological materials. Many industries, such as automobile,

aerospace, defence and transportation, are in demand for materials with high impact resistance and energy absorption capacity, and biomimicry could be a solution to creating such materials.

In agriculture, biomimicry can be used to fight climate change and develop a stable and secure food production system. For example, studying different insects known for their capacity to collect fog, birds like pelicans or even plants, where their behaviour can be transposed in greenhouse technology for water harvesting needed in crop irrigation. Other problems that the agricultural sector faces more and more often, such as floods, soil erosion and degradation, and the lack of pollinating insects, can be tackled by biomimicry to address the environmental issues in agriculture.

Biomimicry can significantly improve the efficiency and economics of renewable energy. By studying nature, scientists can design wind, marine, and solar energy devices that increase efficiency and reduce environmental impact. Even if new technologies inspired by nature are more complex to implement and evaluate without designated test sites and dedicated funding from the government and industry, biomimicry can lead to several technological advancements in the energy sector towards a sustainable future.

In the fashion industry, biomimicry can be used to create sustainable textiles and materials. This could help reduce the usability of harmful chemical treatments in clothing production or reduce water consumption. Textiles and materials that are adaptive, thermo-resistant, superhydrophobic, or self-healing can also be created while creating unique and meaningful aesthetic designs inspired by nature.

### 3.4.3 In Turkey

**What are the challenges of adopting biomimicry?**

Adopting biomimicry in Turkey faces several challenges, particularly in raising awareness and expanding educational opportunities. Many industries and the general public have limited knowledge of biomimetic principles, and educational programs are still being developed. This lack of understanding hinders the widespread application of nature-inspired solutions. Additionally, while funding for research and development exists, there is a need for more targeted investment specifically for biomimetic projects, which often compete with other urgent technological advancements. The interdisciplinary nature of biomimicry also presents

challenges, as effective collaboration between fields such as biology, engineering, and design is complex within traditional academic and industrial frameworks.

Further challenges include regulatory and market-related barriers. Existing regulations may not easily accommodate innovative biomimetic solutions, requiring slow and complex policy adaptations. Industries may hesitate to adopt these solutions due to concerns about market acceptance, financial risks, and the preference for established technologies. Additionally, cultural resistance to change, scalability issues, and a shortage of technical expertise in biomimicry all contribute to the difficulties in expanding its use in Turkey. Overcoming these obstacles will require coordinated efforts from the government, industry, and educational institutions to build a culture of innovation and sustainability.

**What are potential areas of growth in applying biomimicry?**

Turkey has several promising areas for growth in the application of biomimicry across various sectors. Biomimetic approaches in architecture and urban design can lead to more sustainable building solutions, optimising energy usage, water management, and materials. Concepts like green roofs and natural ventilation systems, inspired by ecosystems, are precious in urban environments. Water management is another critical area, especially given Turkey's water scarcity challenges. Biomimetic techniques, such as water filtration systems inspired by wetlands, offer innovative solutions for improving water conservation and agricultural practices. Additionally, in renewable energy, designs inspired by natural structures, such as wind turbines mimicking bird wings or solar panels inspired by leaves, could significantly enhance energy efficiency and reduce environmental impact.

Other growth areas include agriculture, where biomimetic methods such as permaculture and agroecology can enhance biodiversity and crop resilience, fostering sustainable farming practices. Material science is also poised for advancement, with innovations in self-healing plastics and biodegradable materials that could transform packaging and textiles. In transportation, designs inspired by animal locomotion could improve energy efficiency. At the same time, biomimetic solutions in healthcare could lead to new medical technologies, such as adhesives modelled after gecko feet or advanced drug delivery systems. Expanding educational programs on biomimicry will further cultivate innovation, driving sustainability and economic growth across various sectors in Turkey.

### 3.4.4 In France

**What are the challenges of adopting biomimicry?**

The widespread adoption of biomimicry faces several key challenges. One major issue is the lack of awareness among educators and industry professionals, which hampers the integration of biomimicry into education and industrial practices. Many are unfamiliar with the concept and its potential applications, making increasing awareness through education and outreach crucial for its broader acceptance.

Resource limitations are another significant barrier. Developing and implementing biomimetic solutions often requires substantial investments in research and development, which can be a deterrent for institutions and industries operating on tight budgets or with limited funding.

Finally, integrating biomimicry into existing systems, whether in educational curricula or industrial processes, can be challenging. Stakeholders who are more comfortable with traditional approaches may resist adopting new methods, making it difficult to overhaul long-established practices. Overcoming these hurdles will require a strategic approach that combines education, investment, and collaborative efforts to promote biomimicry as a valuable tool for innovation and sustainability.

**What are potential areas of growth in applying biomimicry?**

Biomimicry offers significant potential for advancing various sectors. In renewable energy, biomimicry can lead to more efficient systems, such as wind turbines inspired by bird-wing aerodynamics or solar panels that mimic photosynthesis. Natural filtration systems and sustainable water-harvesting techniques can be developed in water management by mimicking plant and animal processes.

Urban planning also benefits from biomimicry by designing sustainable cities with buildings and infrastructure replicating natural systems, improving energy efficiency and reducing environmental impacts. In healthcare, biomimicry can inspire new medical technologies and treatments, utilising nature's self-healing properties and efficient structures for innovative solutions.

By overcoming existing challenges and maximising these opportunities, France can boost biomimicry's role in education and industry, fostering more sustainable practices and driving innovation across sectors.

### 3.4.5 In Spain

**What are the challenges of adopting biomimicry?**

Adopting biomimicry in Spain faces several hurdles, much like in other countries. One key challenge is awareness and education. The general public and industry professionals have a limited understanding of biomimicry principles. Although there is growing interest in sustainability, biomimicry remains a relatively niche concept within Spain's educational and industrial landscape. Additionally, research and development (R&D) funding for biomimetic projects is often scarce, as R&D priorities in Spain are typically directed toward conventional technologies, making it difficult for nature-inspired solutions to receive sufficient investment.

Interdisciplinary collaboration also presents challenges. Biomimicry requires cooperation among biologists, engineers, designers, and policymakers, but cross-sectoral collaboration in Spain can be difficult due to the traditional division between academic fields and industry. Moreover, market readiness is a significant barrier, as industries may be cautious about adopting new, unproven biomimetic technologies, mainly when initial costs or scaling issues are concerns. Regulatory frameworks in Spain may also need to be adjusted to accommodate innovations inspired by nature, especially in industries such as construction and agriculture, where biomimicry could play a transformative role.

**What are potential areas of growth in applying biomimicry?**

Spain presents numerous opportunities for growth in applying biomimicry, especially in sectors such as architecture and urban design. Given the country's focus on sustainable construction, there is potential for biomimetic design principles, such as natural ventilation systems and energy-efficient buildings, to become more integrated into urban development projects. Water management is another area with significant potential, as Spain faces water scarcity issues in many regions. Biomimetic solutions mimicking natural filtration systems could greatly improve water conservation and recycling.

Additionally, Spain's emphasis on renewable energy creates opportunities for biomimicry to improve the efficiency of solar panels and wind turbines by taking inspiration from natural forms and processes. Agriculture also offers a promising field for biomimetic practices such as permaculture, which could help farmers develop more sustainable methods in the face of climate change. Lastly, product design and material science could benefit from bio-inspired innovations, particularly in creating more efficient, biodegradable materials for packaging and textiles.

### 3.4.6 In Portugal

**What are the challenges of adopting biomimicry?**

Despite its benefits, this design approach poses several challenges when applied. One of the main obstacles to its adoption is its complexity, which makes it difficult to fully understand and subsequently integrate into design processes. The existing limitations are a challenge, given that not all natural systems apply to human problems. Intellectual property can also pose a problem, as biomimicry involves studying and reproducing natural systems. As such, intellectual property issues may arise from using these systems at the design stage. In addition, the design process using biomimicry can be pretty complex in its different phases. In the first stage of prospecting, designers usually follow a design process that encourages them to look outside the box when they find a problem to solve. Still, they don't always focus on looking at nature or see it as a solution.

Furthermore, to apply biomimicry to a problem, designers must decompose it into parts to search for analogies in nature. Another challenge could be the accessibility of information. To create designs inspired by nature, designers must understand certain biological principles that will guide them toward solutions. Finally, challenges can arise in the implementation phase, as it is not always easy to have the funds to produce prototypes.

Finally, Bio-inspired design faces the same obstacles as regular product design. Still, it's especially tricky given the high risks, limited manufacturing technology, and uncertain business models for biomimetic products.

**What are potential areas of growth in applying biomimicry?**

Biomimicry offers numerous innovative solutions across various fields, reflecting its potential to inspire sustainable practices and designs. In energy efficiency, studying how organisms and ecosystems optimise energy use can lead to the development of more efficient systems, encompassing everything from streamlined transportation methods to energy-efficient buildings that reduce overall consumption.

In materials science, biomimicry allows the creation of sustainable materials by mimicking natural materials and their production processes. This approach fosters innovations that minimise environmental impact while enhancing functionality. Sustainable agriculture also benefits from biomimetic principles, as it seeks to emulate the diverse and interconnected relationships of ecosystems. This leads to the creation of food systems that reduce waste, conserve resources, and enhance soil health, promoting a more sustainable approach to food production.

Architecture is increasingly embracing biomimicry to design sustainable building structures. Architects are inspired by nature's ingenious solutions, such as the temperature regulation capabilities of termite mounds, which inform the design of inventive facades. Additionally, mimicking natural ecosystems in urban planning enables effective water management, resulting in resilient, energy-efficient buildings that ultimately contribute to sustainable development.

In information technology, biomimicry inspires the creation of more efficient algorithms, data storage systems, and computing architectures modelled after biological systems that process and transmit information. Medicine and healthcare also benefit from biomimetic approaches, leading to innovative medical devices, advanced drug delivery systems, and biomaterials suitable for implants.

Consumer products are another area where biomimicry shines, as companies develop more sustainable packaging solutions inspired by natural materials. Furthermore, in textiles and materials science, the properties of natural fibres, such as the strength of spider silk or the water-repellent nature of lotus leaves—are being mimicked to produce more robust, lightweight materials with unique characteristics. Through these diverse applications,

biomimicry demonstrates its significant potential to foster sustainable innovation across multiple sectors.

# 4. Questionnaires

The results presented below constitute an overall analysis of the responses received in the countries covered by this study: Greece, Romania, Türkiye, France, Spain, and Portugal. 201 VET students and 126 VET teachers participated in the survey by answering the questionnaires. For the detailed questions, see Tables 2 and 3 above: Questionnaire for VET students and teachers.

## 4.1 Questionnaire for VET students

### Part 1: Background information

**Question 1.1 What educational program are you enrolled in?**

The students who responded to the questionnaire were enrolled in various educational programs, including Agronomy, Applied Arts, Architecture, Business Administration, Communication, and Computer Science. Many are pursuing careers in Environmental Sciences, Health Sciences, and Marketing. Several students also participate in Vocational Education and Training (VET) programs. Other fields include Economics, Electrical Engineering, Landscape Work, Medicine, and Multimedia. The programs reflect students' broad range of interests and career aspirations.

**Question 1.2 Have you ever studied sustainability, biomimicry or similar topics such as eco-friendly solutions, sustainable product design, sustainable engineering, sustainable buildings, sustainable agriculture, etc?**

The responses indicate diverse experiences and exposure to sustainability-related topics among the students. Many have studied areas such as environmental responsibility, environmental innovation, and sustainable living and solutions. Topics like sustainable product design, sustainable engineering, sustainable buildings, and sustainable agriculture are also prevalent. Several students have explored specialised concepts such as biomimicry, the circular economy, bioclimatic architecture, and water resources management. A few have focused on sustainable solutions in lifestyle, energy, and design. However, some respondents

have not received any formal education on sustainability, though many express interest in learning about these areas in the future. A few mention no exposure or lack of awareness of these topics.

**Question 1.2.1 If the answer to the question above is "yes", please provide a brief description.**

The students described their experiences with sustainability, biomimicry, and related topics. Some students mentioned receiving formal education through presentations, lectures, or seminars covering environmental responsibility, sustainable agriculture, product design, and renewable energy. Several highlighted hands-on experiences, such as tree planting, hydroponics training, and working with sustainable materials like ecological bricks and vertical wind turbines. Others shared insights on environmental protection efforts, recycling, and personal choices to minimise waste and reduce environmental impact. A few students delved into advanced topics such as water resource management, biomimicry, and sustainable engineering, where they learned to apply nature-inspired solutions to design and infrastructure. Despite some not having direct exposure, many expressed interest in the importance of these topics, demonstrating a collective awareness of the need for sustainable solutions for a better future.

### Part 2: Understanding of biomimicry

**Question 2.1 Have you been exposed to the concept of biomimicry before?**

The majority of the respondents, namely 83.6%, have not been exposed to biomimicry before.

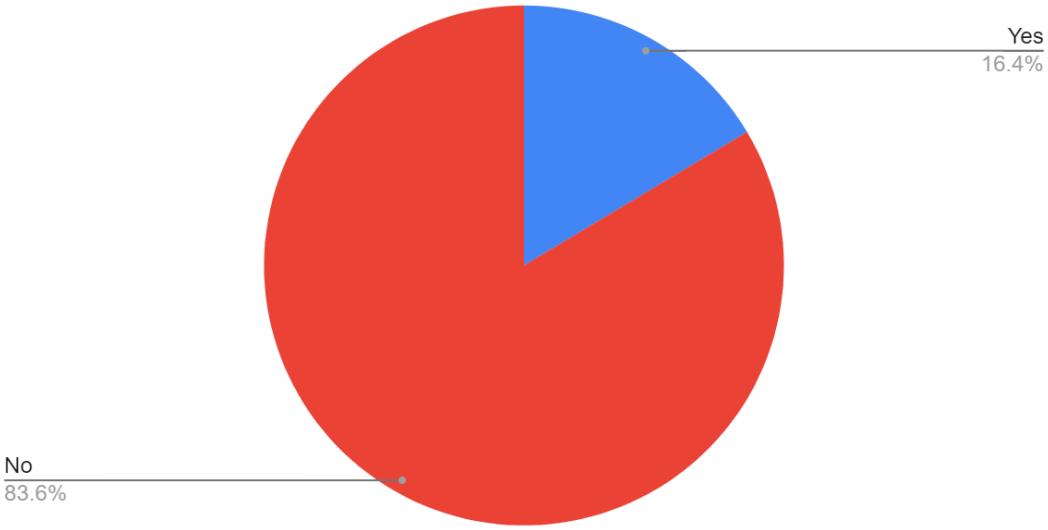


*Figure 1. Have you been exposed to the concept of biomimicry before?*

**Question 2.1.1 If the answer to the question above is "yes", please provide a brief description.**

Students who answered "yes" to studying biomimicry provided various insights into their experiences. Many described biomimicry as an innovative approach that imitates nature's patterns, systems, and elements to solve complex human problems, particularly in design, engineering, architecture, and medicine. Some students highlighted specific examples, such as studying honeycomb structures for solid and lightweight materials or using fungal growth patterns to design metro networks. Others discussed their exposure through academic courses, design classes, or self-study, learning how biomimicry can lead to sustainable, efficient solutions inspired by natural ecosystems. Several also mentioned applications in areas such as decision support systems, the circular economy, and biological systems, emphasising the relevance of biomimicry in creating environmentally friendly technologies and practices.

**Question 2.2 Can you give an example of an environmental solution based on biomimicry? For example, aeroplane wings are inspired by birds; the cyclical economy is inspired by the cycle of life in nature; the fabric of Olympic athletes' swimsuits is inspired by shark skin; mussels inspire the underwater adhesive; the shoes' non-slip soles are inspired by snakeskin; termite mounds inspire self-cooling buildings; forests inspire chemical-free water filtration systems.**

In the questionnaire, students provided detailed responses about the benefits of biomimicry in creating sustainable solutions by mimicking nature. They explained that aeroplane wings are designed like those of birds to improve aerodynamics and fuel efficiency. At the same time, high-speed bullet trains are modelled after the kingfisher's beak, enabling faster and quieter travel by reducing noise. They also mentioned innovative self-cooling buildings, such as the Eastgate Centre in Zimbabwe, inspired by termite mounds to regulate internal temperatures without external energy, thereby reducing air conditioning use. In water management, students highlighted chemical-free filtration systems that replicate natural processes found in forests and green roofs that mimic desert plants' water retention, helping to reduce runoff and cool urban buildings. They also pointed to materials design, such as Velcro, inspired by burdock seeds, and Olympic swimsuits that emulate sharkskin to reduce drag.

Students further noted that wind turbine blades have become more efficient by mimicking humpback whale fins, solar panels draw on how leaves capture sunlight, and mosquito-inspired needles offer pain-free injections in the medical field. They emphasised that nature continues to inspire advancements in adhesives and other materials.

**Question 2.3 How do you think biomimicry can contribute to sustainable design?**

Students expressed strong support for biomimicry as a way to improve energy efficiency, reduce waste, and foster innovation. They emphasised that natural systems, refined through evolution, are inherently energy-efficient, highlighting examples like buildings inspired by termite mounds that regulate temperature naturally, reducing the need for heating and cooling. The Esplanade Theatre in Singapore, inspired by the durian fruit, was cited as another example of energy-saving design through optimised natural light, reducing energy use by 30%. Waste reduction and resource efficiency were also key themes. Students noted that nature operates in closed-loop systems, where waste is recycled into resources. Biomimetic designs, such as chemical-free water filtration systems inspired by forest ecosystems, reflect these principles, yielding biodegradable, durable, and resource-efficient products that align with nature's minimal-waste approach.

Students also highlighted the adaptability and resilience of nature-inspired designs, suggesting that mimicking natural organisms can help create systems that withstand environmental

changes, especially climate change. Biomimetic solutions, they argued, are more sustainable because they are based on nature's proven strategies. Finally, students saw biomimicry as a critical driver of innovation. They pointed to examples like spider silk's strength and bird wings' aerodynamic form, showing how nature offers a wealth of inspiration for solving complex design problems sustainably.

### Part 3: Skills assessment

**Question 3.1 Rate your skill level in the following areas on a scale from 1 (no experience) to 5 (expert).**

Students were asked a series of questions related to the level of their skills regarding:

- Creativity and innovation.
- Problem-solving.
- Technical drawing (manual or CAD).
- Scientific research.
- Team collaboration.

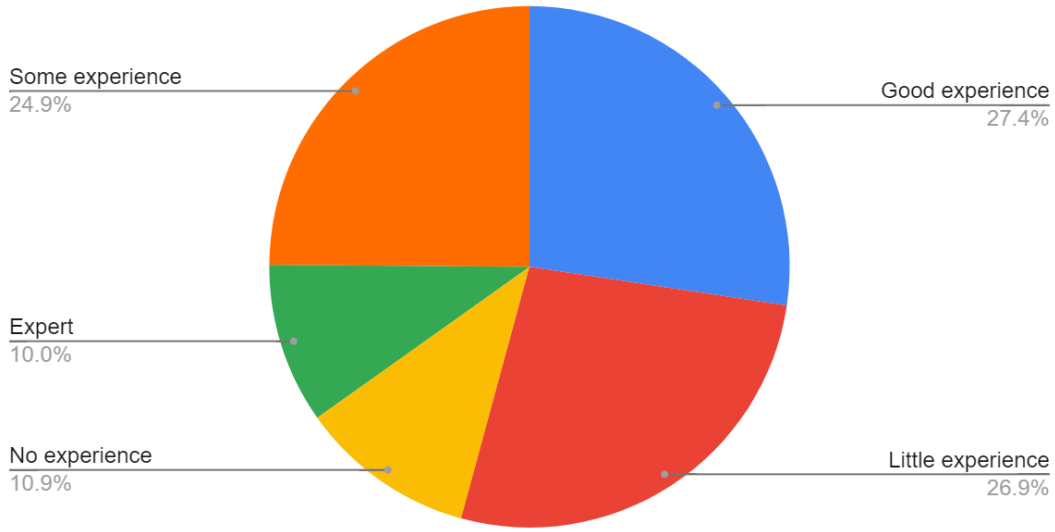


*Figure 2. Creativity and innovation.*

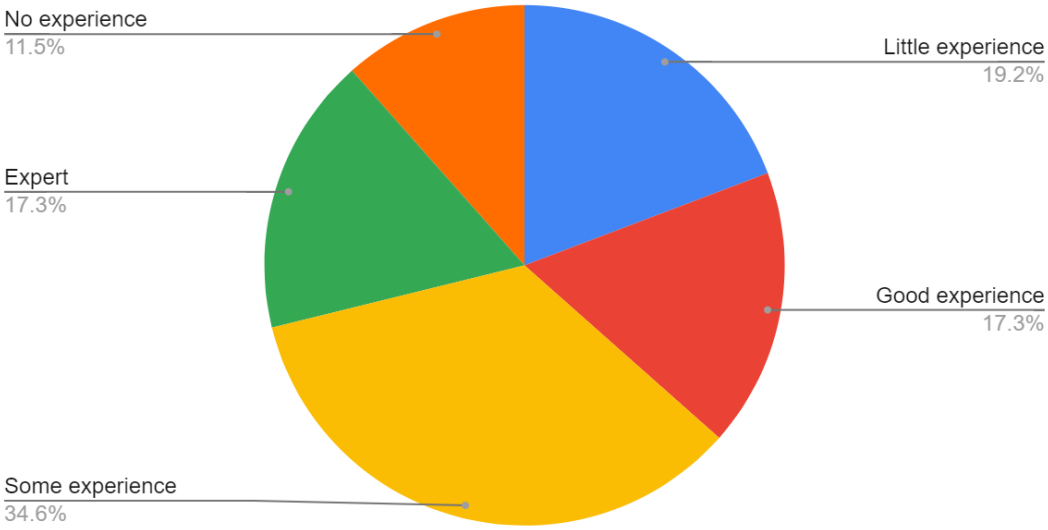


*Figure 3. Problem-solving.*

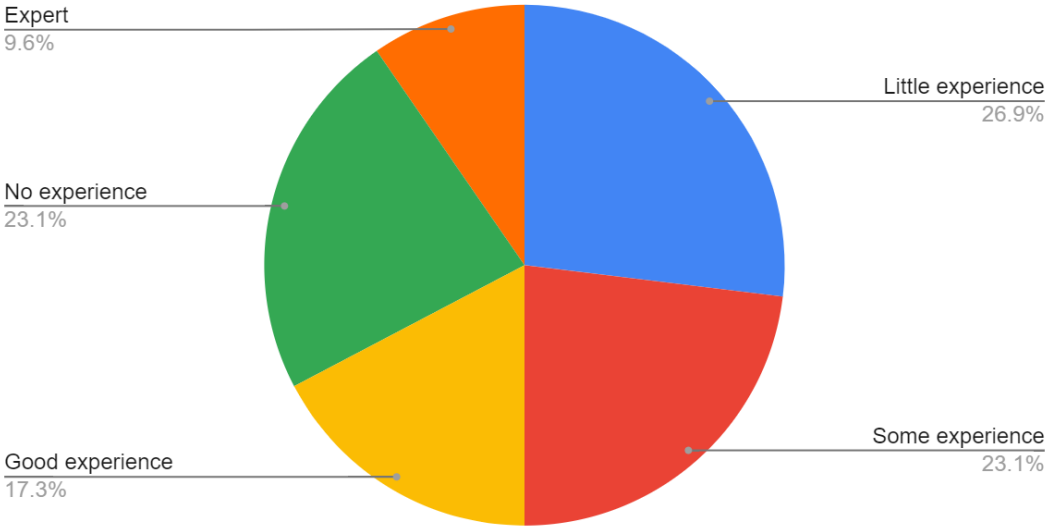


*Figure 4. Technical drawing (manual or CAD).*

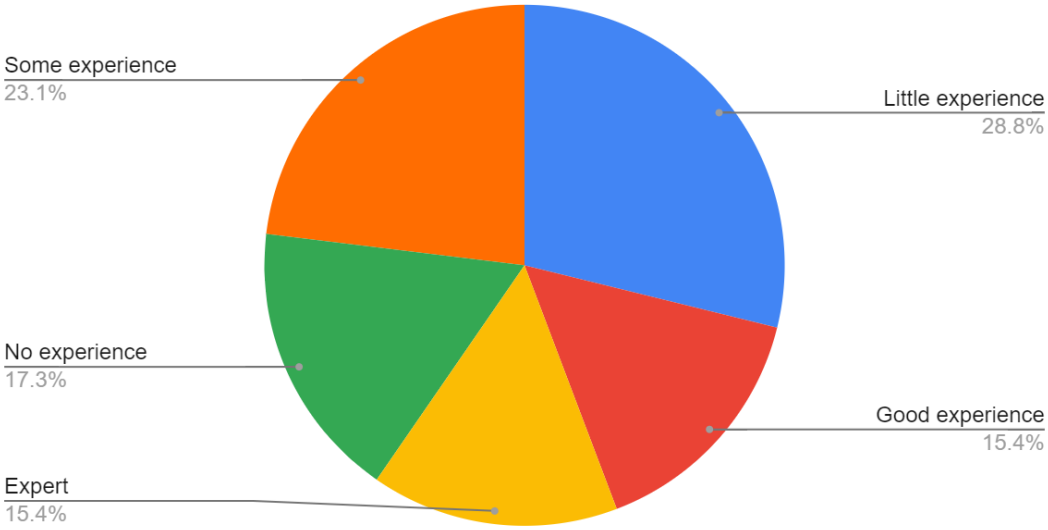

*Figure 5. Scientific research.*

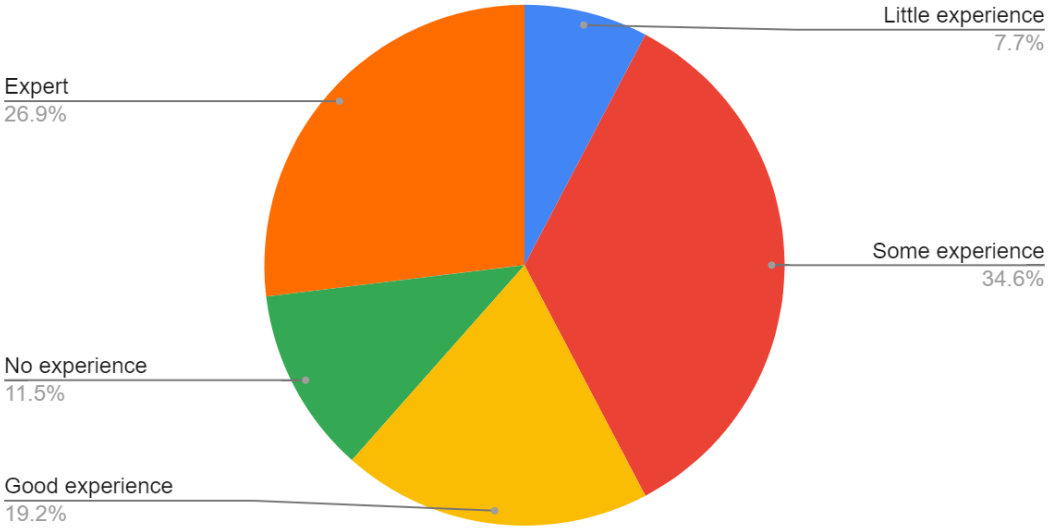


*Figure 6. Team collaboration.*

The graphics above show that an average of 60% of the students have no or some experience in creativity and innovation, problem-solving, and technical drawing skills; 74% have no experience in scientific research, while almost 60% feel very good or expert in team collaboration.

**Question 3.2 Have you worked on any projects where you applied biomimicry principles? If yes, please describe the project briefly.**

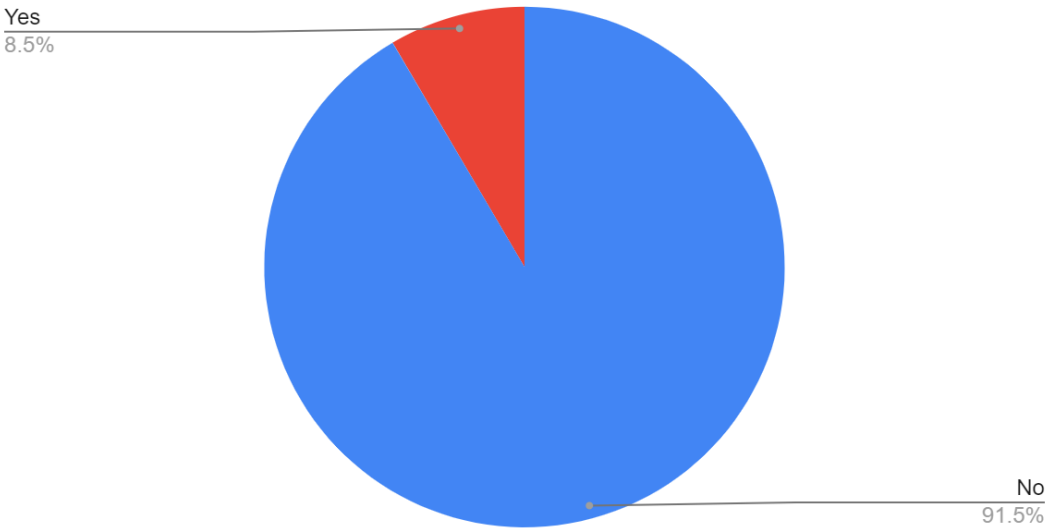


*Figure 7. Have you worked on any projects where you applied biomimicry principles?*

Out of 201 students, less than 15 participated in projects where they applied biomimicry principles.

**Question 3.2.1 If the answer to the above question is "yes", please briefly describe the project you worked on.**

Several students described projects incorporating biomimicry principles, reflecting their commitment to environmental sustainability. One student worked on a submarine design inspired by the pistol shrimp's powerful pincers, showcasing how nature's mechanisms can drive engineering innovation. Another student in a high school biology group explored hand pollination, highlighting an interest in natural processes that could support sustainable practices. In terms of design, a student created a floating backdrop modelled after a water lily, with hinged walls that open like petals to optimize light intake. Another project focused on using solar panels as an eco-friendly energy solution, emphasising the importance of renewable energy.

Students also engaged in environmental issues through various projects. One group studied the rise of sea level in Greece using satellite altimetry, addressing climate change. Another project examined beehive structures to inspire lightweight, durable building materials, demonstrating how natural designs can enhance construction. Additionally, a street furniture design inspired by bird nests aimed to improve public benches' durability and aesthetics. Finally, a student expressed interest in applying biomimicry to create more sustainable packaging, reflecting a broad application of these principles across different fields.

## Part 4: Interest and motivation

**Question 4.1 Why are you interested in biomimicry or environmental design?**

Σtudents shared diverse motivations for their interest in biomimicry and environmental design, often pointing to nature's inherent wisdom. They emphasised that animals and ecosystems, having evolved over millions of years, offer remarkable solutions to human challenges. By learning from these natural systems, students believe humans can improve their quality of life and cultivate a more sustainable relationship with the environment. Many highlighted the importance of achieving balance with nature and educating others on environmental awareness. The beauty and fascination of biomimicry also stood out, with students appreciating how nature can inspire and refresh the human spirit. They see great

potential for future applications of biomimicry, particularly in addressing environmental challenges and managing resources efficiently.

Several students highlighted the educational value of biomimicry, noting how it sparks creative thinking and provides practical design insights without confusion. They acknowledged nature as a critical source of inspiration, offering solutions to modern problems like resource depletion and environmental degradation. Examples such as aerodynamic submarines inspired by fish were mentioned for their efficiency and durability. Students also stressed the importance of environmental planning in sustainable development, expressing a strong commitment to contributing to a cleaner world and reducing the carbon footprint through responsible innovation.

**Question 4.2 What areas of biomimicry or environmental design are you most interested in exploring?**

Architecture emerged as students' dominant field of interest, reflecting a strong desire to integrate sustainable practices into building design and urban planning. Many students expressed interest in sustainable buildings, indicating a commitment to environmentally responsible construction methods. They are eager to explore how architecture can incorporate natural principles to enhance energy efficiency and minimise environmental impact. Additionally, students showed a keen interest in clean water initiatives, emphasizing the importance of addressing water scarcity and pollution. This concern aligns with their interests in environmental preservation and protection against natural disasters, showcasing a holistic approach to sustainability that includes resilient infrastructure. The field of product design was frequently mentioned, with students interested in creating innovative solutions that promote sustainability and address environmental challenges. They focus on integrating material science into product development, aiming to use eco-friendly materials that reduce waste and environmental harm.

Robotics also captured students' attention, as they saw the potential for technology to aid in environmental conservation and improve water management systems. The intersection of robotics and environmental design suggests a forward-thinking approach to tackling ecological issues through advanced technology. Many students expressed interest in medicine and healthcare, recognizing the role of biomimicry in developing solutions for medical

challenges and promoting overall public health. They see opportunities to draw inspiration from nature to create more effective medical technologies and practices. Lastly, there is a notable emphasis on sustainable cities as a critical area of exploration. Students are interested in understanding how urban environments can be designed or modified to be more sustainable, integrating elements like clean water access and environmental preservation into city planning.

### Part 5: Practical Application

**Question 5.1 Imagine you are tasked with designing a new product to collect water in dry areas. What are the first steps in your solution?**

In the questionnaire, students described their approach to designing a product for water collection in dry areas, emphasizing the importance of thorough research. They highlighted the need to analyze climate, geography, rainfall patterns, and local challenges while also studying organisms like cacti and desert plants that have adapted to water scarcity. They hoped to develop innovative and efficient water collection mechanisms by learning from these organisms. Students stressed the value of engaging with local communities through interviews, surveys, and workshops to understand their needs and ensure the product is functional, culturally appropriate, and accessible. This feedback would guide the design process, fostering a sense of ownership among users.

Using biomimicry, they brainstormed ideas inspired by nature, such as mimicking plant moisture condensation to create surfaces for collecting dew or rainwater. Prototyping and testing these designs in controlled environments and real-world conditions was essential for assessing water collection efficiency, durability, and user-friendliness. Community feedback would help refine the design. Students also focused on optimizing water collection capacity, material strength, and sustainability, using eco-friendly materials and ensuring affordability for mass production. They emphasised the importance of training local communities on product use and maintenance to ensure long-term success and ongoing monitoring to evaluate the product's effectiveness and adaptability in real-world conditions.

### Part 6: Feedback

**Question 6.1 Do you think learning about biomimicry can enhance your professional skills?**

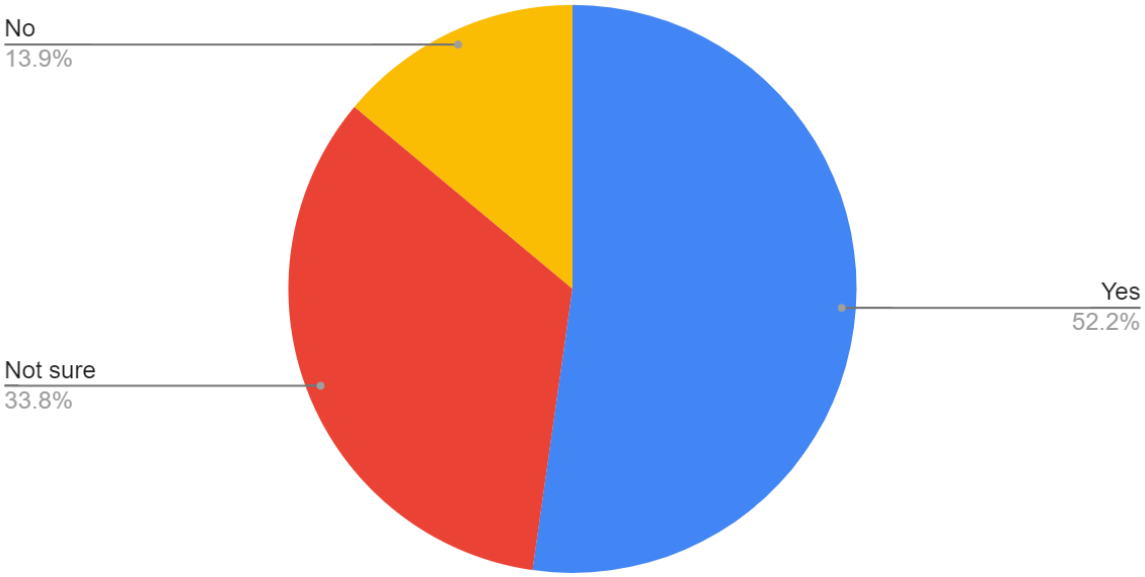


*Figure 8. Do you think learning about biomimicry can enhance your professional skills?*

The majority of the respondents answered positively (52%), some students were not sure (37%), and just a few answered no (11%).

**Question 6.2 What resources or tools would help you better understand and apply biomimicry in your designs?**

Students identified several vital resources and tools that could enhance their understanding of biomimicry in design. They emphasized the importance of educational literature, particularly foundational books like Biomimicry: Innovation Inspired by Nature and academic articles that provide real-world case studies. Online courses and workshops were highlighted as valuable for structured learning and practical implementation. Collaboration with biologists, ecologists, and engineers was noted as essential for gaining insights into natural systems. At the same time, access to simulation and modelling tools like CAD and ANSYS would help test and refine designs. Students also expressed the desire for hands-on experience through labs and research facilities and opportunities to attend workshops and conferences to network with professionals in the field. Engaging in practical activities and spending time in nature were vital for inspiring innovative designs and understanding biomimicry principles. Overall, the students highlighted a mix of educational resources, collaborative efforts, practical experiences, and nature observation as crucial for effectively applying biomimicry in their designs.

## 4.2 Questionnaire for VET teachers

### Part 1: Background information

**Question 1.1 What subjects do you teach?**

The teachers participating in the questionnaire represent various subjects across various educational fields. Many educators are involved in mathematics, teaching subjects including general mathematics and its application in science. Environmental sciences are also a prominent focus, with several teachers emphasising environmental awareness and sustainability in their curricula. This reflects a growing recognition of ecological issues and the need for education incorporating environmental stewardship. In addition to core subjects such as mathematics and environmental sciences, teachers bring expertise in the humanities and social sciences, including history, philosophy, and intercultural education. This blend of subjects provides a comprehensive educational approach, fostering critical thinking and ethical reflection among students. Arts education, specifically in plastic arts and applied arts, showcases the creativity and expression aspects of the curriculum, further enriching the educational experience.

Furthermore, specialised subjects such as computer science, informatics, and information technologies highlight the importance of digital literacy in today's educational landscape. These subjects prepare students for a technology-driven world, integrating skills necessary for future careers. Other disciplines, such as health and nutrition, sports psychology, and nursing, demonstrate the interdisciplinary connections between education and well-being, addressing physical and mental health. Teachers also cover practical fields such as tourism, entrepreneurship, and business management, focusing on real-world applications and preparing students for professional environments. This pragmatic orientation is further complemented by subjects such as mechanics, engineering, and technical integration, which equip students with hands-on skills and knowledge vital to various industries.

**Question 1.2 How many years of teaching experience do you have?**

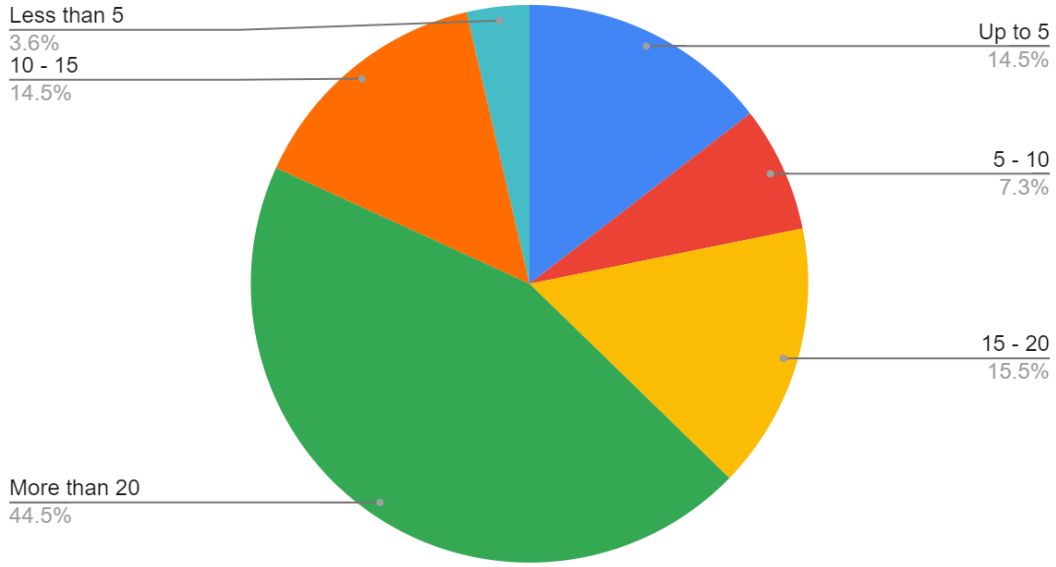


*Figure 9. How many years of teaching experience do you have?*

The majority (namely 44.5%) of the teachers that participated in the questionnaire answered that they have more than 20 years of teaching experience, 15.5% responded that they have 15-20 years of teaching experience, 14.5% answered that they have 10 - 15 years of teaching experience, 14.5% responded that they have up to 5 years of teaching experience, 7.3% answered that they have 5-10 years of teaching experience. Only 3.6% reported having less than 5 years of teaching experience.

**Question 1.3 Have you previously taught or used concepts related to environmental sustainability or biomimicry in your courses?**

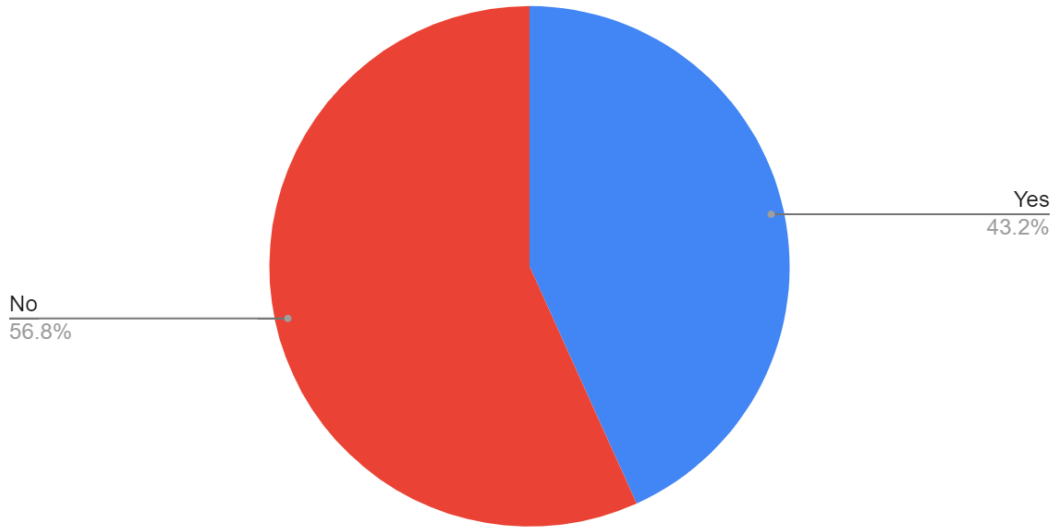


*Figure 10. Have you previously taught or used concepts related to environmental sustainability or biomimicry in your courses?*

Considering that only 9.5% of them teach subjects directly related to the environment/sustainability, it is interesting to note that 42% confirmed that they teach (or have taught) concepts related to environmental sustainability or biomimicry in their courses.

**Question 1.3.1 If the answer to the question above is "yes", please briefly describe how.**

Teachers reported various ways to integrate concepts of biomimicry and environmental sustainability into their lessons. Many emphasised the importance of hands-on, outdoor learning experiences, such as conducting classes in parks to observe ecosystems directly, gardening projects, and composting activities to teach nutrient cycles and waste reduction. Several educators highlighted the use of recycled materials in art projects to promote sustainability and engage students in creatively applying these concepts. They also discussed incorporating relevant case studies, practical examples, and discussions about real-world applications of biomimicry and environmental sustainability into their curricula.

Teachers mentioned using various teaching methods, including videos, documentaries, and interactive activities, to raise awareness of environmental issues. They emphasised the relevance of topics such as the ecological footprint, renewable energy sources, and consumer protection, fostering discussions around environmental sustainability in different subject

areas. Additionally, some educators noted the importance of interdisciplinary approaches, linking lessons to biology, economics, and chemistry topics. They highlighted collaborative projects that engage students in analysing environmental impacts and developing strategies for sustainability.

### Part 2: Understanding and application of biomimicry and PBL

**Question 2.1 Define biomimicry in your own words.**

Teachers provided varied interpretations of biomimicry, describing it as a scientific approach that draws inspiration from nature to solve human challenges. They emphasised how biomimicry involves imitating biological forms, processes, and ecosystems to develop sustainable, innovative solutions. Teachers noted its applications in technology, architecture, and environmental conservation, showing how nature-inspired designs can improve daily life.

Several educators highlighted the importance of using natural strategies to address complex human problems, fostering creativity and environmental awareness. They also viewed biomimicry as an educational tool, encouraging students to actively engage with nature, learn from its efficiencies, and apply these insights practically. Overall, the responses reflected the potential for biomimicry to connect scientific knowledge with real-world solutions while promoting a sense of environmental responsibility.

**Question 2.2 Please cite examples of environmental sustainability or biomimicry you have discussed with your students.**

Teachers shared various examples of incorporating environmental sustainability and biomimicry into their lessons. Many focused on contemporary environmental issues like global warming, pollution, and recycling, highlighting the need to protect ecosystems, preserve biodiversity, and promote conservation. They discussed biomimicry by showing how nature inspires design and technology, using examples such as aeroplanes modelled after birds, termite mound-inspired buildings for natural cooling, and bio-inspired materials for energy efficiency. Some teachers also explored natural patterns in art and architecture, like the Fibonacci sequence. Sustainability practices were a key focus, with teachers emphasising composting, using renewable energy sources like solar and wind, and promoting circular

economy principles through recycling and repurposing materials. They encouraged waste reduction and responsible consumption, particularly discouraging single-use products and promoting selective waste collection.

Real-world applications of biomimicry were discussed, including green roofs for thermal insulation and urban biodiversity. Teachers also used examples from animal behaviour, such as ants' resource efficiency, to teach cooperation and ecological responsibility. Several teachers mentioned incorporating the 2030 Agenda goals into their curriculum, fostering discussions on climate change, conservation, and sustainable technology to cultivate environmental awareness and responsibility in their students.

**Question 2.3 What role does biomimicry play in modern design and environmental education?**

Teachers widely acknowledged the importance of biomimicry in modern design and environmental education. They highlighted its potential to inspire sustainable solutions to energy development, pollution, and environmental degradation. Many emphasised the value of biomimicry in promoting sustainable materials and nature-based design principles to reduce ecological impact. Teachers view biomimicry as an essential educational tool that fosters awareness of natural ecosystems and encourages students to observe and learn from nature, deepening their understanding of biodiversity and the interconnectedness of living systems.

Several educators mentioned specific applications of biomimicry across industries such as aviation, architecture, and medicine, citing examples such as bird-inspired aircraft designs and energy-efficient systems inspired by natural processes. While they recognise biomimicry's practical benefits, some expressed concern about its limited coverage in current curricula and advocated for greater inclusion in environmental education to better prepare students to tackle environmental challenges.

**Question 2.4 Do you apply PBL as a teaching method?**

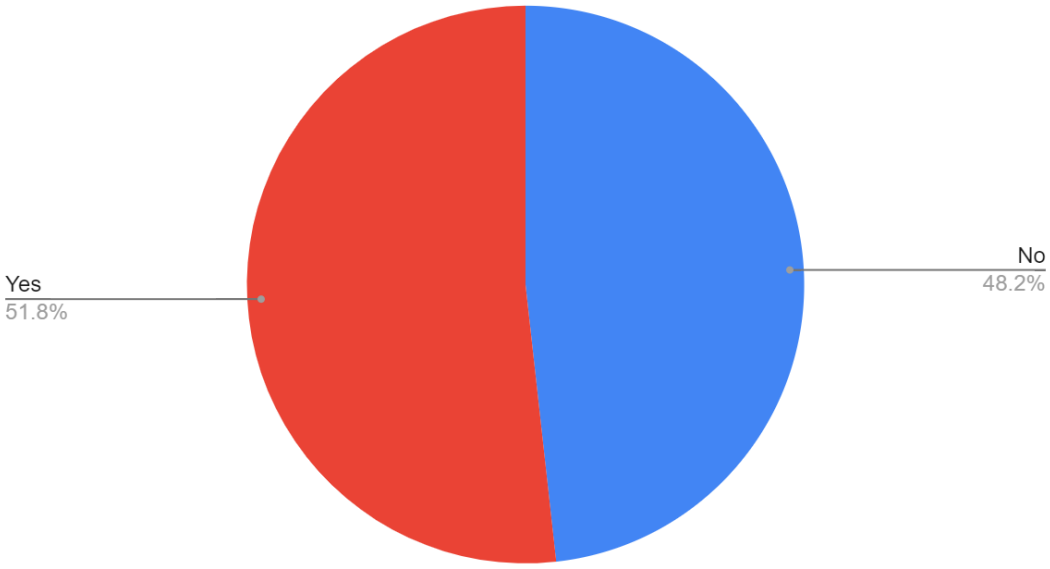


*Figure 11. Do you apply Project Based Learning as a teaching method?*

51.8% of the teachers who participated in the questionnaire confirmed using PBL as a teaching method.

**Question 2.5 If your answer is "yes", please provide some examples and how often you use this method.**

Teachers emphasised the value of project-based learning (PBL) in helping students apply theoretical concepts practically. Many reported regularly integrating PBL into their curricula, from individual modules to year-long projects. Examples included designing business plans, exploring sustainable practices, and conducting ecological studies, often linked to subjects like economics, biology, and technology. Environmental themes were a primary focus in these projects, with teachers engaging students in activities such as designing biodegradable packaging, creating ecological gardens, and developing renewable energy solutions inspired by nature. These projects deepened students' understanding of environmental issues while encouraging them to propose innovative, nature-based solutions.

Collaboration and cross-disciplinary learning were also crucial strategies, with students working together across subjects like history, science, and art to tackle complex problems. Teachers noted the use of technology and platforms like eTwinning and Erasmus+ to facilitate collaborative projects, including international partnerships, enriching the learning experience. However, some educators expressed concerns about student engagement, noting that while

many students thrive in hands-on projects, others are reluctant to participate fully. Despite this challenge, teachers remain committed to motivating students and enhancing their learning through PBL.

### Part 3: Teaching skills and curriculum integration

**Question 3.1 Rate your confidence level in teaching the following aspects of biomimicry on a scale from 1 (not confident) to 5 (very confident).**

Teachers were asked a series of questions related to the level of their confidence regarding:

- Teaching principles of ecology.
- Applying biomimicry in practical design projects.
- Integrating biomimicry into other subjects.
- Encouraging innovative thinking through biomimicry.
- Applying the project-based learning method.

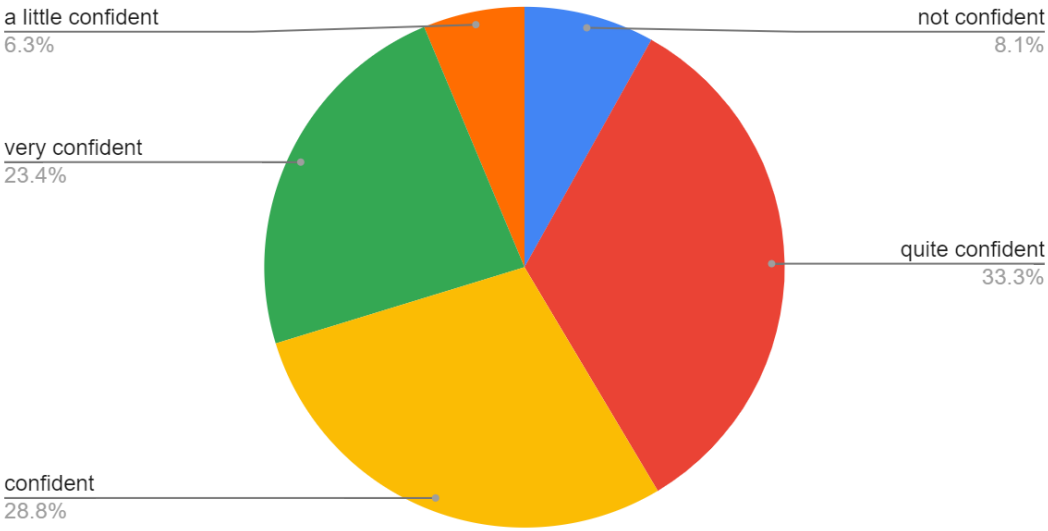


*Figure 12. Understanding ecological principles.*

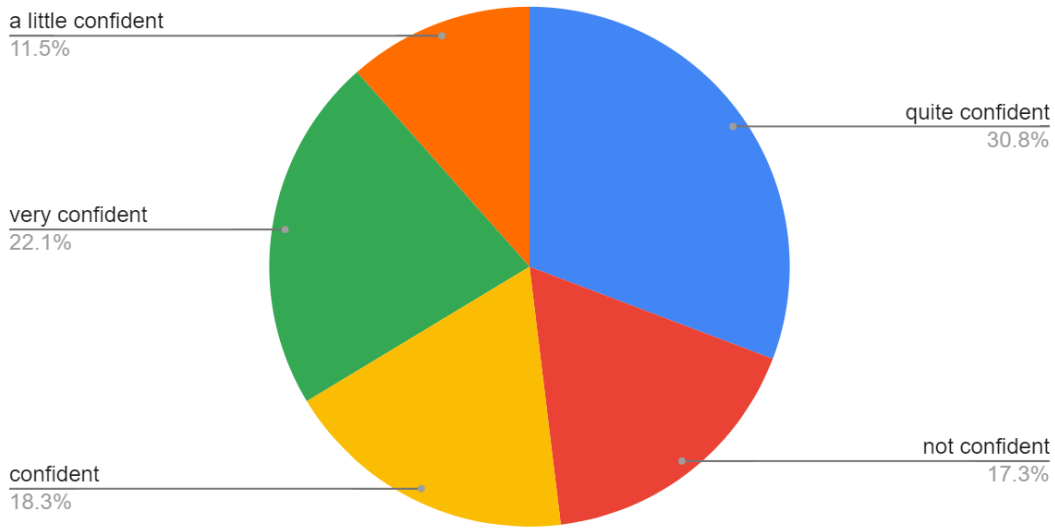


*Figure 13. Applying biomimicry in practical design projects.*

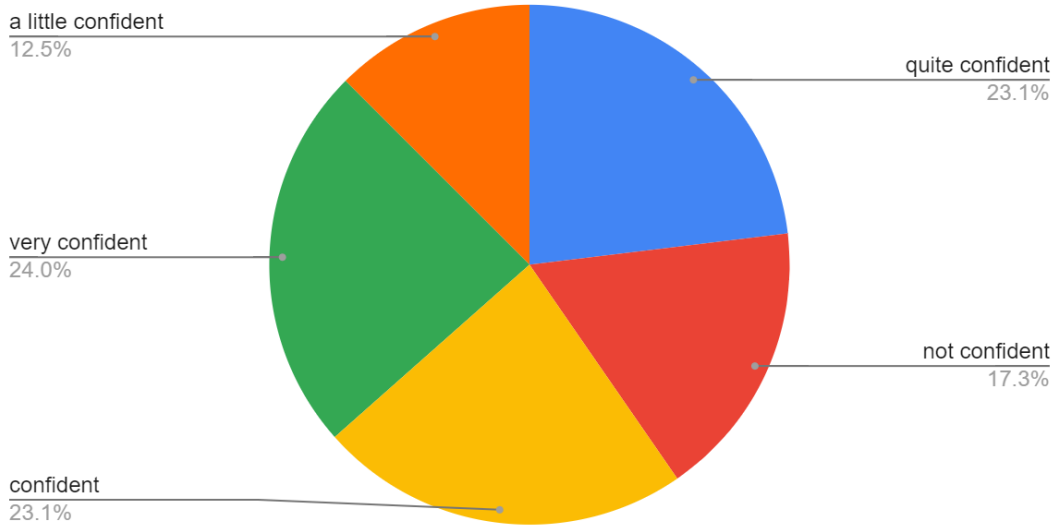


*Figure 14. Integrating biomimicry with other subjects (e.g., mathematics, science).*

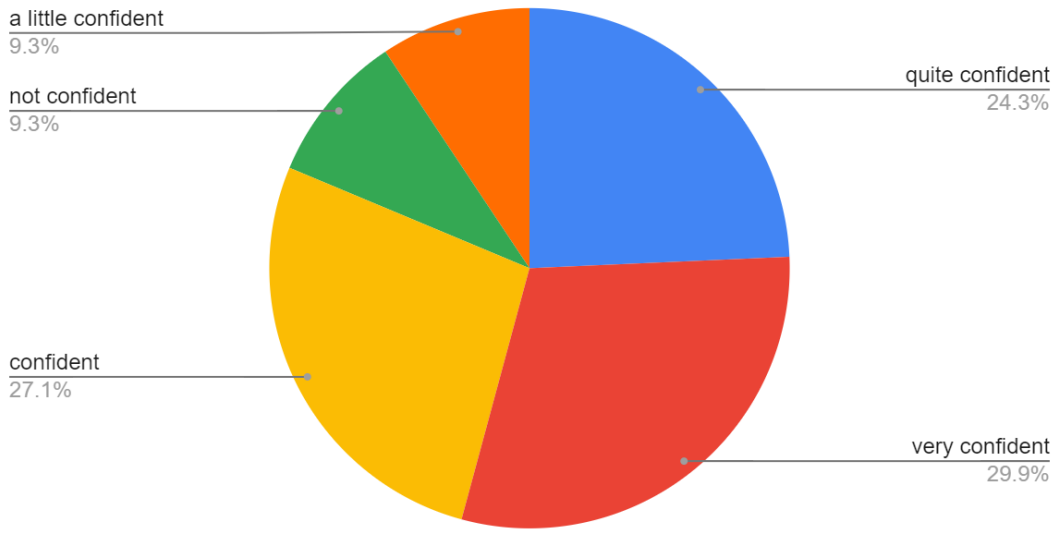

*Figure 15. Encouraging innovative thinking through biomimicry.*

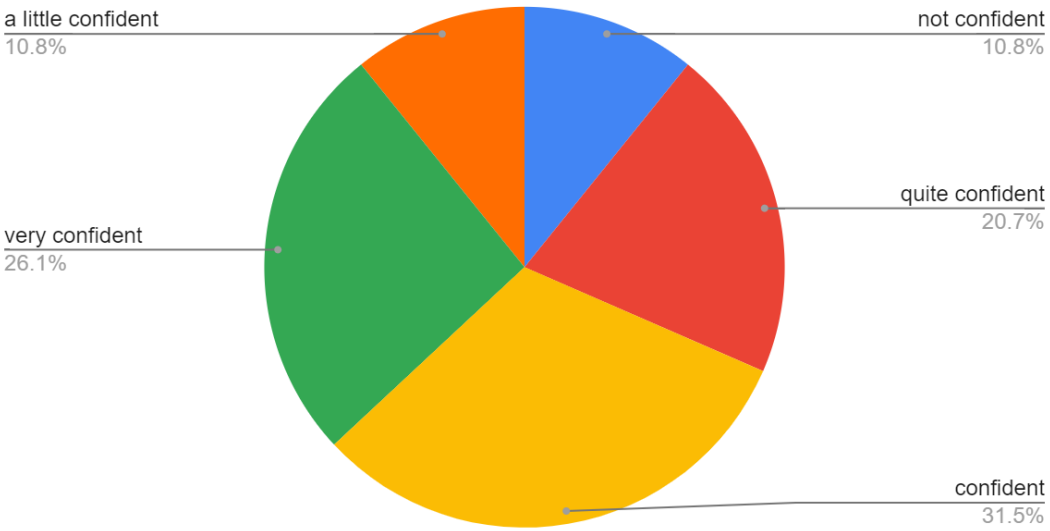


*Figure 16. Applying PBL method.*

The overall level of self-confidence regarding the subjects mentioned above is positive. Most teachers feel confident/very confident in teaching the principles of ecology, applying biomimicry in practical design projects, integrating biomimicry into other subjects, encouraging innovative thinking through biomimicry, and applying the project-based learning method.

**Question 3.2 Have you faced challenges integrating environmental sustainability or biomimicry into your curriculum?**

The graphic below shows that integrating environmental sustainability or biomimicry into their curriculum represents a concrete challenge for 74%.

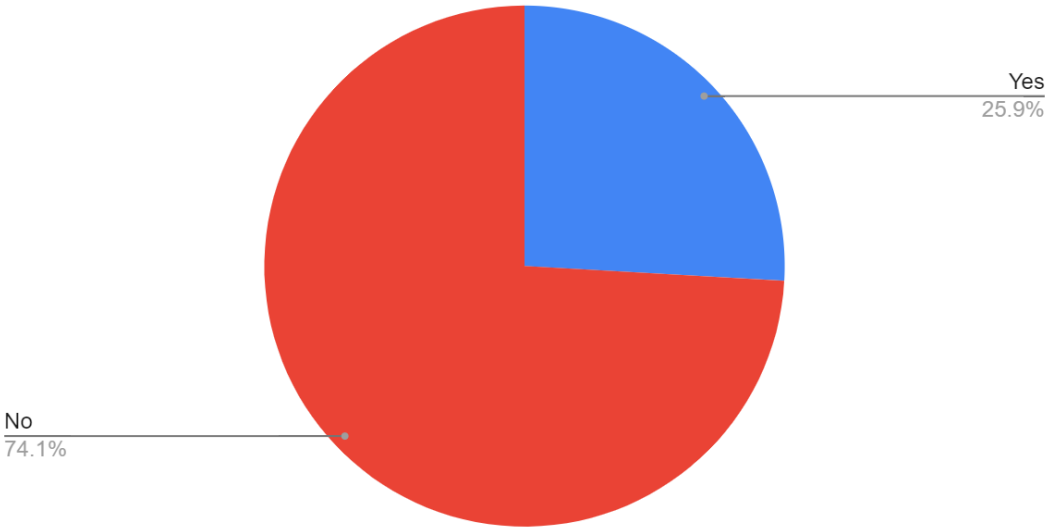


*Figure 17. Have you faced any challenges integrating environmental sustainability or biomimicry into your curriculum?*

**Question 3.2.1 If the answer to the question above is "yes", please comment briefly.**

Teachers generally view integrating environmental sustainability and biomimicry into their curricula as beneficial but challenging. Many educators expressed that while they recognise the importance of these topics, the rigid structure of the existing curricula often makes it challenging to incorporate them effectively. The overwhelming nature of the prescribed content leaves little room to explore sustainable themes, requiring careful planning and creativity in integrating these concepts. Several respondents noted a lack of suitable educational resources and materials aligned with sustainability themes, hindering their ability to teach these concepts comprehensively. Additionally, some teachers reported needing further training to feel confident delivering lessons on biomimicry and environmental sustainability, highlighting a gap in professional development opportunities in these areas.

The time constraints imposed by curricular demands were also a significant concern. Many teachers feel pressured to cover extensive content within limited class time, which can prevent deeper exploration of complex sustainability concepts. This lack of time may lead to superficial treatment of the subject matter, diminishing students' understanding and engagement. Moreover, educators pointed out challenges in student motivation and interest. Some reported that students often respond “carelessly” to lessons on sustainability and biomimicry, potentially due to a lack of positive examples or role models in their environment.

Teachers emphasised the importance of providing relatable and engaging content to foster a genuine interest in these topics.

### Part 4: Professional development and resources

**Question 4.1 What types of resources would assist you in teaching environmental sustainability or biomimicry more effectively? (Select all that apply)**

Participants identified several resources that would effectively enhance their ability to teach environmental sustainability or biomimicry. These resources include textbooks and academic articles, online courses or workshops, and guest lectures from industry professionals. Additionally, hands-on project materials, as well as cases or examples of environmental sustainability or biomimicry solutions, were deemed essential. Software tools, such as digital presentations, games, simulations, and audiovisual materials, such as images and videos, were also highlighted. Finally, exchanging knowledge with other educators was recognised as a valuable resource for enhancing teaching practices.

**Question 4.2 Would you like to attend a professional development program focused on biomimicry?**

78% of the teachers who participated in the survey stated they would be interested in a professional development program focused on biomimicry.

**Question 4.3 What specific biomimicry topics would you like to learn more about for teaching purposes?**

Teachers expressed a strong interest in various aspects of biomimicry, indicating a desire to deepen their understanding for educational purposes. Many respondents conveyed eagerness to learn about practical applications of biomimicry, particularly in sustainable product design, materials science, and architecture. They emphasized the integration of biomimicry across multiple disciplines and identified specific applications such as renewable energy conversion and storage, innovative food production systems, and herbal medicine development.

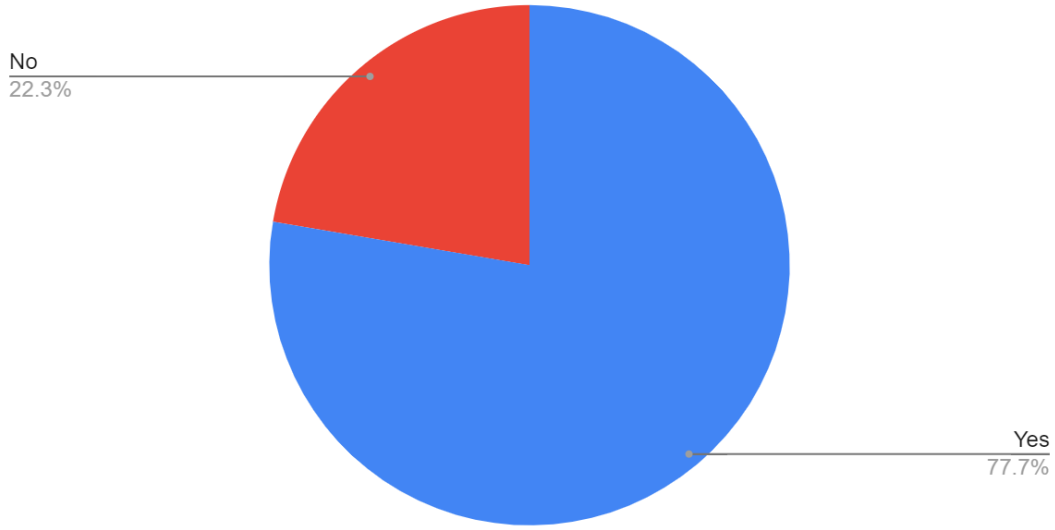


*Figure 18. Would you be interested in attending a professional development program focused on biomimicry?*

Additionally, educators showed interest in using biomimicry to tackle environmental challenges like maritime pollution and enhancing sustainability in industries such as plumbing and mass production. They highlighted the need for resources covering the fundamentals of biomimicry, including methodologies for integrating these concepts into environmental education. Teachers requested concrete examples and case studies that showcase successful biomimicry applications and topics such as green chemistry, nutrient recycling, and urban planning. Furthermore, educators emphasised the importance of effective teaching strategies and hands-on projects that engage students in learning about biomimicry. Many noted a need for workshops, online courses, and planning resources to facilitate the successful incorporation of biomimicry into classroom settings.

## Part 5: Feedback and Suggestions

**Question 5.1 How could biomimicry be integrated into learning more effectively?**

Teachers offered a range of suggestions for effectively integrating biomimicry into educational curricula. A key theme was the need for a multidisciplinary approach, advocating that biomimicry be taught as a cross-cutting subject across modules. Educators suggested developing interdisciplinary curricula combining theory and practical applications, allowing students to explore natural phenomena in contexts relevant to mathematics and science. Many teachers emphasised the importance of real-world applications and hands-on projects,

recommending practical lessons in natural environments, field trips, workshops, and training sessions with biomimicry experts. Such experiences would provide students with tangible examples of how biomimicry principles apply in real life, fostering curiosity and critical thinking about its implications across various fields.

Additionally, teachers highlighted the need for educational resources and training for educators. They called for new materials that facilitate the integration of biomimicry into existing curricula and proposed training sessions to deepen teachers' understanding of its practical applications. Some suggested creating an independent discipline or extracurricular activities focused on biomimicry , and offering elective courses exploring its complexities. Furthermore, increasing awareness and communication about biomimicry was considered essential. Teachers recommended inviting specialists to speak about its relevance, which could enhance understanding and spark student interest. They also suggested using visual aids and multimedia resources in lessons to engage students and illustrate the importance of biomimicry in addressing contemporary environmental challenges.

**Question 5.2 Any other comments or suggestions regarding teaching biomimicry in professional education?**

Teachers expressed a strong interest in enhancing the teaching of biomimicry in professional education, highlighting the need for comprehensive professional development and additional resources. They emphasised the importance of ongoing training programs for educators across various fields, including agriculture and healthcare, to equip them with the knowledge and skills in biomimicry and its applications. Many educators suggested establishing partnerships with industries and environmental organisations to facilitate experiential learning opportunities, such as internships and mentoring programs. Additionally, organising design competitions centred around biomimicry was proposed to stimulate creativity and provide students with practical experience.

Teachers also stressed the importance of incorporating practical examples and case studies into the curriculum to deepen students' understanding of biomimicry concepts. They recommended hands-on projects relevant to students' professions and hosting workshops led by experts in the field. Some educators suggested offering biomimicry as an elective, allowing

students to explore the topic in greater depth. While recognising the long-standing connection between human innovation and nature, they highlighted the necessity of raising awareness about biomimicry as a formal concept in education. Overall, responses emphasised the importance of a solid theoretical foundation and practical demonstrations to showcase biomimicry's effectiveness in addressing contemporary challenges.

# 5. Learning Outcome Matrix for sustainability skills in VET learners

The research and study described in the preceding paragraphs served as the foundation for determining the knowledge students must acquire to build sustainable habits, civic sensibilities, and the skills and competencies required by the labour market.

This enabled us to develop a Learning Outcomes Matrix for Sustainability Skills in VET Learners based on sustainability goals.

| Area | Knowledge | Skills | Responsibility and autonomy |
|---|---|---|---|
| **SOFT SKILLS**<br>**Creativity and innovation, problem-solving, and team collaboration** | Recognise the importance of creativity and innovation in personal and professional life. | Explore creative, innovative strategies to find solutions at both personal and professional levels. | Generate original ideas and solutions by thinking outside the box and applying imaginative approaches to challenges. |
| | Outline the principles of problem-solving to find alternatives for a solution. | Acquire a problem-solving mindset to identify, prioritise, and select alternatives for a solution. | Develop practical solutions to complex situations by breaking down problems into manageable parts, identifying root causes, and applying logical reasoning to find practical resolutions. |
| | Recognise the importance of team collaboration to achieve better results than working individually. | Employ team collaboration to achieve common goals. | Develop collaboration strategies with team members to achieve specific, shared objectives. |

| | | | |
|---|---|---|---|
| **TECHNICAL SKILLS**<br>**Scientific research and technical drawing** | Cite the fundamental principles and methodologies that underpin scientific research. | Illustrate the core principles that guide scientific research. | Develop scientific research methods to explain natural or social phenomena. |
| | Describe the fundamentals of technical drawing. | Explain the main principles of technical drawing. | Create accurate technical drawings by applying fundamental principles to visually communicate how something functions or is constructed. |
| **SUSTAINABILITY**<br>**Sustainable habits and behaviours** | Define sustainability and its main aspects. | Compare potential sustainable activities depending on the specific circumstances. | Develop specific actions to improve sustainability in a specific context. |
| | Recognise the cross-sectoral application of sustainability. | Apply sustainability principles across multiple sectors. | Develop an interdisciplinary approach to sustainability. |

| | | | |
|---|---|---|---|
| | Select the most effective communication tools and techniques to promote sustainability. | Analyse the most effective outreach methods for promoting sustainability, tailored to context and target groups. | Develop strategies to encourage sustainable choices through education, awareness and communication. |
| **CIVIC SENSIBILITY** | Explain the rights and responsibilities of citizens in a democratic society. | Outline the principles of democracy and the responsibilities of citizens. | Apply the principles of democracy and citizen responsibilities in everyday life. |
| | Indicate current social, political, and environmental issues affecting the community. | Analyse current social, political, and environmental issues affecting the community | Evaluate civic issues and policies, considering multiple perspectives and the potential impact on different groups. |
| | Recognise the diverse perspectives and cultures within their community and beyond. | Demonstrate ethical reasoning and social responsibility. | Cultivate inclusivity and participation in civic life. |

| | | | |
|---|---|---|---|
| | Identify effective communication techniques for expressing opinions and influencing public discourse in civic engagement. | Apply effective communication techniques to express opinions and influence public discourse in civic engagement. | Develop well-reasoned arguments on civic issues and advocate for solutions through various forms of communication. |
| **BIOMIMICRY**<br>**Fundamentals, principles, and applications** | Comprehend the key biological systems and processes that serve as models in biomimicry. | Explain the core principles of biomimicry, including how natural processes and organisms inspire innovative solutions to human challenges. | Apply biomimicry principles to solve real-world problems. |
| | Provide concrete examples of biomimicry applications. | Analyse real-world applications of biomimicry through concrete examples | Critically evaluate existing biomimicry designs and processes by identifying strengths, weaknesses, and opportunities for improvement. |

| | | | |
|---|---|---|---|
| | Outline ethical considerations and sustainability principles in biomimicry solutions. | Investigate the ethics and sustainability of biomimicry solutions. | Evaluate the ethical implications and sustainability of biomimicry solutions. |

*Table 4. Learning Outcome Matrix for sustainability skills in VET.*

# 6. Summary of needs analysis results

Proactive risk management is a cornerstone of ensuring the success of the LET'S MIMIC digital platform for biomimicry practices. By systematically identifying, assessing, and mitigating potential risks, the project team can effectively navigate the challenges that may arise during development and deployment. Integrating risk management into every project phase safeguards resources and enhances the platform's chances of meeting its goals on time and within budget.

Risk management will be an ongoing process throughout the project's lifecycle. Continuous assessment and adaptive mitigation strategies will ensure that emerging risks are addressed promptly while established risks are controlled. By maintaining vigilance, the project team will protect the platform's integrity, ensure user adoption, and safeguard compliance with legal and regulatory standards. Ultimately, a structured risk management approach will help deliver a robust, scalable, and sustainable digital platform that supports biomimicry practices across design, research, and innovation.

The desk research carried out in six different European countries (Greece, Romania, Türkiye, France, Spain, and Portugal) and the survey delivered to 201 VET students and 126 VET teachers allowed us to define the level of understanding and implementation of sustainability skills, biomimicry, and PBL as well as the level of interest and motivation to improve knowledge and competence regarding these concepts.

The survey results reveal that most students have limited prior knowledge of biomimicry, with only those enrolled in programs directly related to the concept being familiar. This indicates a lack of exposure to biomimicry in broader educational settings. Regarding skills, around 60% of students reported having little or no experience with creativity, innovation, problem-solving, and technical drawing. Additionally, 74% of students indicated they had no experience in scientific research, although a majority felt confident in their ability to collaborate effectively in teams. This suggests a gap between research skills and teamwork capabilities.

Students' motivations for exploring biomimicry varied widely, from curiosity to a desire to help preserve the planet. Many students also believe learning biomimicry could improve their professional prospects, highlighting its perceived relevance in their future careers. When asked about resources that would help them better understand and apply biomimicry, students expressed interest in online courses, workshops, collaborations with experts, and access to reliable resources such as books, articles, and case studies. They also valued study visits to biomimicry institutions and access to databases of practical examples.

The survey results show that, despite only 9.5% of teachers teaching subjects directly related to the environment or sustainability, 42% have incorporated concepts of environmental sustainability or biomimicry into their courses. This demonstrates a broader interest in integrating sustainability into various subjects. Most teachers view biomimicry as a critical or essential component of modern design and environmental education, with 55% confirming they use PBL as a teaching method. Many teachers feel confident in teaching ecological principles and applying PBL, although 74% acknowledge the challenge of integrating environmental sustainability or biomimicry into their curricula.

Interest in professional development programs focused on biomimicry is high, with 78% of teachers expressing a desire for such opportunities. Teachers are particularly keen on learning the fundamentals of biomimicry and exploring how to integrate it into diverse fields such as languages, IT, food management, and the arts. Several teachers also offered suggestions for integrating biomimicry into education, such as developing interdisciplinary curricula emphasising practical applications and real-world case studies, organising teacher training, promoting collaborations among educators, and conducting workshops and outdoor activities led by experts.

Finally, the report defined the knowledge, skills, responsibilities, and autonomy VET students must possess to build sustainable habits, civic sensibility, and specific competencies required by the labour market, elaborating a Learning Outcomes Matrix for sustainability competencies in VET learners.

# PART B – Project-Based Learning Framework through Biomimicry Process Design

# 7. Introduction to learning framework design

PART B of this report elaborates on a constructive framework for incorporating biomimicry into a PBL environment to build green and problem-solving skills in demand by industry and society. The LET'S MIMIC framework defines the desired learning outcomes, including the knowledge, skills, and competencies students are expected to acquire. It also outlines specific learning activities and assessment strategies, ensuring a comprehensive and coherent approach to teaching and learning.

This document provides a detailed blueprint for teachers and curriculum developers to facilitate the effective implementation of PBL in biomimicry design projects through the LET'S MIMIC framework. The ultimate goal is to enhance student engagement and learning outcomes while fostering innovation and sustainability in design.

# 8. The need for climate action and green skills development

Climate change, a pressing issue of the 21st century, demands immediate and sustained action to mitigate its impacts. The escalating frequency and severity of natural disasters, rising global temperatures, and deteriorating ecosystems underscore the urgency of addressing climate change (IPCC, 2021). There is a critical need for climate action and the development of green skills as integral components in combating climate change and fostering sustainable development.

The scientific consensus on climate change is unequivocal: it's us, human activities, particularly the burning of fossil fuels and deforestation, that are driving unprecedented changes in the Earth's climate. These changes pose profound risks to natural and human systems, including:

- **Environmental degradation**: Loss of biodiversity, ocean acidification, and deforestation are directly linked to climate change, resulting in disrupted ecosystems and diminished natural resources.
- **Economic impacts**: Climate change affects economic stability through increased costs associated with disaster response, health care, and infrastructure damage, potentially reducing global GDP significantly.
- **Social and health risks**: Vulnerable populations, particularly in developing regions, face heightened risks of food and water scarcity, health issues, and displacement due to climate-induced disasters.

Urgent climate action is required to limit global warming to well below 2°C above pre-industrial levels, as outlined in the Paris Agreement (UNFCCC, 2015). Achieving this goal demands a multifaceted approach involving policy changes, technological innovation, and widespread societal engagement. The transition to a green economy is imperative to mitigate the adverse effects of climate change and promote sustainable development. This transition involves significant changes in energy production,

industrial processes, waste management, and lifestyle choices. Green skills are necessary for several reasons:

- **Economic transformation**: As industries move towards greener practices, there is a growing demand for a workforce skilled in sustainable technologies and processes.
- **Environmental protection**: Green skills enable individuals and organisations to reduce their environmental footprint, conserve resources, and protect ecosystems.
- **Social equity**: Equipping all societal groups with green skills ensures inclusive participation in the green economy, promotes social equity, and reduces disparities.

Building green skills constitutes a strategic and needed response to climate change (UNESCO, 2017). Green skills encompass the knowledge, abilities, values, and attitudes needed to live in, develop, and support a sustainable and resource-efficient society (ILO, 2019). The transition to a green economy requires a workforce equipped with these skills to implement and maintain sustainable practices across various sectors (OECD, 2020).

Green skills can contribute to all aspects of social and economic sustainable growth and quality of life by introducing environmentally friendly solutions in diverse sectors, such as:

- **Renewable energy**: Biomimicry can inspire more efficient renewable energy technologies. For example, wind turbine blades designed based on the shape of whale flippers or the structure of bird wings can capture wind more effectively, increasing energy output.
- **Water management**: Nature-inspired water collection and purification solutions can enhance water security. Techniques such as mimicking the water-collection methods of desert beetles or the filtration systems of mangrove trees can lead to more sustainable water management practices.

- **Sustainable architecture**: Biomimicry can inform the design of energy-efficient buildings. Structures that mimic termite mounds' natural ventilation systems or cacti's cooling mechanisms can reduce the need for artificial heating and cooling, lowering energy consumption.
- **Agriculture and food security**: Adopting agricultural practices inspired by natural ecosystems, such as polycultures that mimic the diversity and resilience of natural plant communities, can improve soil health, increase yields, and reduce reliance on chemical inputs.
- **Waste management**: Biomimicry offers solutions for waste reduction and recycling. For instance, circular economy models inspired by closed-loop systems in ecosystems can minimise waste and enhance resource efficiency.

Education systems and training programs play a pivotal role in developing green skills. Integrating sustainability into curricula at all levels, from primary education to higher education and vocational training, ensures that future generations are equipped to address climate challenges. Additionally, continuous professional development and reskilling opportunities for the current workforce are necessary to adapt to the evolving demands of a green economy.

Given climate change's far-reaching and potentially catastrophic impacts, the urgency of climate action cannot be overstated. Building green skills is a strategic imperative that supports the transition to a sustainable, low-carbon future. By investing in education and training, societies can empower individuals to contribute to climate solutions, drive economic growth through green jobs, and ensure a resilient and equitable world for future generations. Concerted local, national, and global efforts are essential to achieve these objectives and secure a sustainable future for all.

# 9. Overview of Project-Based Learning

## 9.1 Definition of Project-Based Learning

Project-Based Learning (PBL) is an instructional methodology that encourages students to learn and apply knowledge and skills through an engaging experience centred around complex, real-world, and meaningful projects (Thomas, 2000). Unlike traditional instructional methods that rely on rote memorisation and passive learning, PBL places students at the centre of the learning process, allowing them to explore and solve meaningful problems and emphasising active learning, critical thinking, collaboration, and the application of knowledge to real-world situations. PBL fosters deep learning by allowing students to explore and respond to complex questions, problems, or challenges.

Key characteristics of PBL include (Larmer & Mergendoller, 2010):

- **Student-centered learning**: Students take ownership of their learning, working independently or in groups to explore and address the project's central question or challenge.
- **Interdisciplinary approach**: PBL projects often integrate multiple subject areas, helping students make connections between different fields of knowledge.
- **In-depth inquiry and research:** Students engage in inquiry-based learning, researching and gathering information to inform their projects.
- **Collaboration**: Students collaborate with peers, educators, and sometimes external experts, fostering teamwork and communication skills.
- **Authentic assessment**: Assessment in PBL is performance-based, focusing on the process and final product rather than traditional tests and exams. Authentic assessment evaluates student skills in a manner that simulates their actual use in the real world. It validates that students can use the skills and transfer them from the academic environment to everyday life.

- **Student voice and choice**: Students have a say in the direction of their project, including decisions about the process and outcome.
- **Reflection**: Continuous reflection on learning experiences, processes, and outcomes is integral to PBL.
- **Critique and revision**: Students give, receive and use feedback to improve their work and understanding.
- **Benefitting communities**: Project results are often shared with an audience beyond the classroom.

## 9.2 Learning advantages of Project-Based Learning

PBL offers numerous advantages that enhance educational outcomes and prepare students for future challenges (Blumenfeld et al, 1991):

- **Deeper learning**: By engaging with real-world problems, students develop a deeper understanding of the subject matter and its applications.
- **Critical thinking and problem-solving**: PBL promotes higher-order thinking skills as students analyse, synthesise and evaluate information.
- **Collaboration and communication**: Working in teams, students improve their ability to collaborate, communicate effectively, and manage conflicts.
- **Engagement and motivation**: The authenticity and relevance of projects increase student engagement and intrinsic motivation.
- **Soft skill development**: PBL helps students acquire essential skills such as research, project management, and self-directed learning.
- **Preparation for the future**: PBL prepares students for the complexities of the modern world by developing adaptability, creativity, and lifelong learning skills.

## 9.3 Project-Based Learning steps and implementation

The four critical steps of PBL are (Bell, 2010):

- **Project launch:** Introducing the project, setting goals, and initiating brainstorming sessions.
- **Ideation and inquiry:** Engaging in research and exploration to generate ideas and formulate hypotheses.
- **Develop, critique, and revise:** Creating prototypes, receiving feedback, and making iterative improvements.
- **Present and defend solutions:** Presenting the final solution and defending the design choices through formal presentations and reflective discussions.

## 9.4 Challenges and considerations

Implementing PBL in educational settings requires thoughtful planning and support. Regarding activity design, projects must be carefully structured to align with academic standards and learning objectives while allowing student agency. Teachers' roles evolve as facilitators and guides, providing resources, scaffolding, and support as needed. Assessment in PBL is multifaceted, including formative assessments, peer evaluations, and summative assessments of the final product and process. Educators need ongoing professional development to effectively design, manage, and assess PBL experiences. Implementing PBL can require significant resources, including time, materials, and access to expertise (Krajcik & Blumenfeld, 2006).

# 10. Biomimicry and its importance in design

## 10.1 Biomimicry definition and main aspects

Biomimicry, derived from the Greek words "bios" (life) and "mimesis" (imitation), is an interdisciplinary approach that seeks to solve human challenges by emulating nature's time-tested patterns and strategies (Benyus, 1997). The concept involves studying biological entities and processes to inspire innovative solutions in various fields such as engineering, design, architecture, and technology. The goal is to create more efficient, sustainable, and resilient products and systems by harnessing the genius of nature. Biomimicry involves studying and imitating nature's forms, processes, and ecosystems to get inspiration for addressing modern challenges. This interdisciplinary approach bridges biology, engineering, design, and innovation, aiming to create sustainable solutions by learning from the efficiencies and resilience inherent in natural systems. It leverages the millions of years of evolutionary refinement inherent in natural systems, resulting in inherently sustainable and efficient solutions (Vincent et al, 2006).

The main aspects of biomimicry are (Bhushan, 2009):

- **Emulation of natural forms**: Designing structures and materials that mimic the shapes and forms found in nature, such as the streamlined body of a fish for hydrodynamic vehicles or the hexagonal structure of a honeycomb for lightweight, strong materials.
- **Emulation of natural processes**: Adopting processes observed in nature, such as photosynthesis for energy production or the self-cleaning properties of lotus leaves for surfaces that repel dirt and water.
- **Emulation of natural ecosystems**: Creating systems that function like natural ecosystems, where waste from one process becomes input for another, aiming for zero waste and closed-loop systems.

## 10.2 Biomimicry examples

Biomimicry is evident in solutions used widely in everyday life and within businesses. Examples of products or solutions designed through biomimicry include:

- **Velcro®**: Inspired by the way burrs stick to animal fur, Velcro uses tiny hooks and loops to create a robust, reusable fastening system.
- **Bullet train design**: The shape of the Shinkansen bullet train's nose was inspired by the beak of a kingfisher bird, reducing noise and improving energy efficiency.
- **Self-healing materials**: Inspired by biological systems that repair themselves, researchers are developing materials that can automatically heal cracks and damages.
- **Lotus effect**: Inspired by lotus leaves' ability to repel water and self-clean, self-cleaning surfaces for windows, paints, and textiles repel water and dirt.
- **Gecko tape**: Inspired by gecko feet, which use microscopic hair structures to adhere to surfaces, adhesive tapes and climbing robots that can stick to walls without glue.
- **Whale fin wind turbines**: Inspired by humpback whale fins with tubercles (bumps), wind turbine blades with a serrated edge increase efficiency and stability by reducing drag.
- **Termite mounds**: The natural ventilation systems of termite mounds inspired passive cooling and ventilation designs in buildings, such as the Eastgate Centre in Harare, Zimbabwe.
- **Butterfly wings**: The iridescent scales of butterfly wings inspired colour-changing materials for textiles, sensors and displays without dyes or pigments.
- **Shark skin**: The microscopic ridges on shark skin that reduce drag and prevent bacteria from attaching inspired anti-fouling coatings for ships, antibacterial surfaces for medical devices and streamlined swimsuits.
- **Beetle condensation**: The Namib Desert beetle, which collects water from the fog on its textured shell, inspired water harvesting systems in arid regions that utilise surfaces that capture and channel moisture from the air.

Biomimicry offers a way to innovate sustainably by learning from and mimicking the strategies that have enabled life to thrive on Earth for billions of years. Integrating biomimicry into the design curriculum through PBL equips students with cutting-edge knowledge and skills and fosters an ethical and sustainable mindset. This holistic approach to education prepares students to become innovative and responsible designers capable of addressing the pressing challenges of the 21st century.

## 10.3 Biomimicry steps and implementation

The biomimicry design process involves several key steps to ensure that the principles and strategies found in nature are effectively applied to human challenges. Following is a detailed overview of the typical steps in a biomimicry design process:

- **Define**: Clearly define the impact you wish your design to have on the world and the criteria and constraints that will determine its success. The purpose of this phase is not to determine the content of your design or creation but rather to comprehend its purpose, audience, and context. It may be tempting to expedite this process; however, it can lead to premature conclusions.
- **Biologise**: Examine the critical functions and context that your design solution must address. Rephrase them in biological terms so you can "consult nature." This step aims to formulate one or more "How does nature..." inquiries that can serve as a foundation for your research as you seek biological models in the subsequent step (Discover) of the Design Spiral.
- **Discover**: Seek natural models (e.g., organisms and ecosystems) that address your design solution's functions and context. Determine the strategies that facilitate their survival and prosperity. This phase emphasises the acquisition of information and the conduct of an investigation.
- **Abstract**: Conduct a thorough examination of the critical components or mechanisms that contribute to the effectiveness of biological strategies. Ensure you understand the features accurately by utilising sketches and writing them down in clear language. Developing a design strategy aims to facilitate the conversion of biological insights into design solutions.

- **Emulate**: Search for patterns and relationships among the strategies you have identified and concentrate on the primary lessons that should guide your solution. Formulate design concepts informed by these strategies. Emulation is the fundamental principle of biomimicry; it involves applying insights gained from living organisms to the problems humans seek to resolve. Emulation is an exploratory process that aims to capture a "recipe" or "blueprint" in nature's example that can be replicated in our designs rather than rote copying of nature's strategies.
- **Evaluate**: Evaluate the design concepts concerning their alignment with the design challenge's criteria and constraints and compatibility with Earth's systems. Evaluate the feasibility of the technical and business model. Revise and revisit previous steps as necessary to generate a viable solution.

Each step in the biomimicry design process emphasises learning from nature's wisdom, ensuring that solutions are effective, sustainable, and harmonious with the natural world.

## 10.4 Biomimicry advantages in design

Biomimicry offers advantages in design, which can be summarised as follows (Kennedy, 2016):

- **Innovation:** Biomimicry inspires innovative design solutions that often outperform conventional approaches. By learning from nature, designers can develop new materials, structures, and processes that are both effective and sustainable.
- **Sustainability:** Natural systems are inherently sustainable, operating in closed loops with minimal waste. Biomimicry promotes the development of sustainable technologies and practices that reduce environmental impact.
- **Resilience:** Nature has evolved to thrive under various conditions, leading to resilient and adaptable designs. Biomimetic designs can better withstand changing environmental and societal conditions.

- **Aesthetics:** Natural designs are often inherently beautiful, appealing to human aesthetics and enhancing the user experience.
- **Efficiency**: Nature's designs are optimised for energy and resource efficiency, leading to solutions that reduce waste and minimise resource consumption.

## 10.5 Challenges and considerations

While biomimicry holds excellent promise, challenges and considerations must be addressed. This includes the complexity of nature, as understanding and replicating it can be difficult, requiring extensive research and interdisciplinary collaboration. It further involves scalability, translating biomimetic principles into scalable solutions that can be widely adopted, which remains challenging. Finally, a challenge in applying biomimicry is intellectual property, as innovations inspired by nature may raise questions about intellectual property rights and the sharing of biomimetic knowledge (Bar-Cohen, 2006).

# 11. The LET'S MIMIC framework for integrating Biomimicry Design into Project-Based Learning

The PBL framework for the biomimicry process design project is structured around the key principles of PBL, ensuring a systematic and practical learning process. As stated above, the key steps of PBL are project launch, ideation and inquiry, developing, critiquing, revising, presenting, and defending solutions.

The LET'S MIMIC framework has been designed using PBL as the basis for its learning structure, integrating biomimicry. The result incorporates the best of both methodologies, empowering students to innovate by drawing inspiration from nature. Below is the Biomimicry Design Process and how it aligns with Project-Based Learning (PBL)

**1. Identify the challenge (PBL) / Define the problem (Biomimicry)**

- **PBL**: Identify a real-world problem to explore and solve.
- **Biomimicry**: Define the design challenge by understanding the specific issue that nature might have already solved.
- **Integration**: Frame projects around natural challenges or sustainability-focused problems, like renewable energy or waste reduction.

**2. Research and inquiry (PBL) / Biologize the challenge (Biomimicry)**

- **PBL**: Research the problem and inquire into possible solutions.
- **Biomimicry**: Break the challenge into its fundamental needs and processes, viewing the problem through nature's strategies.
- **Integration**: Analyse the problem by asking, "How does nature solve this challenge?" For example, they might research how animals insulate their homes and apply those principles to building design.

**3. Ideation and solution design (PBL) / Discover natural models (Biomimicry)**

- **PBL step**: Brainstorm and generate ideas for potential solutions.
- **Biomimicry step**: Look for organisms, ecosystems, or natural processes that solve similar challenges.
- **Integration**: Explore examples of nature's solutions, such as the structure of a honeycomb for efficient space use or the water repellence of a lotus leaf for self-cleaning materials.

**4. Abstract (Biomimicry)**

- **Biomimicry**: Abstract the underlying principles or strategies from natural models (e.g., efficiency, adaptability, resilience).
- **Integration**: Generalise nature's strategies, such as the lightweight strength of a bird's bones, to apply these principles to their project design. This step encourages students to think more broadly about how biological principles can be adapted to human challenges.

**5. Prototype development (PBL) / Emulate (Biomimicry)**

- **PBL**: Create prototypes of suggested solutions and start testing.
- **Biomimicry**: Emulate abstracted principles from nature to build a sustainable design that solves the problem.
- **Integration**: Build prototypes that mimic nature's strategies, such as creating ventilation systems inspired by termite mounds or designing surfaces inspired by shark skin for antifouling purposes.

**6. Testing and feedback (PBL) / Evaluate and refine (Biomimicry)**

- **PBL**: Test prototypes, gather feedback and make necessary refinements.
- **Biomimicry**: Evaluate the design's effectiveness and sustainability, refining the solution based on feedback and ensuring it aligns with nature's principles.
- **Integration**: Test how effectively suggested nature-inspired solutions work and iterate based on efficiency, environmental impact, and functionality.

**7. Present the solution (PBL) / Contextualise and apply (Biomimicry)**

- **PBL**: Present solutions to the class or community.
- **Biomimicry**: Contextualise the biomimetic solution by applying it to real-world situations while keeping it aligned with natural and sustainable principles.
- **Integration**: Explain how their final design solves the problem and follows nature's example, contributing to sustainable solutions.

## 11.1 The LET'S MIMIC Matrix

The following matrix aligns the Project-Based Learning (PBL) steps with the Biomimicry Design Process within the LET'S MIMIC Framework, highlighting how each PBL stage can incorporate biomimicry principles. This integration encourages students to analyse and solve real-world problems by looking to nature for inspiration, ultimately fostering creative, sustainable, and efficient solutions. By combining these processes, students engage in hands-on learning while applying natural strategies to human-centred design challenges.

| PBL step | Biomimicry Design Process step | Integration example |
|---|---|---|
| Identify the challenge | Define the Problem | Frame the challenge as a sustainability issue that nature can help solve |
| Research and inquiry | Biologise the challenge | Analyse the problem through a biological lens |
| Ideation and solution design | Discover natural models | Use natural examples, like plant growth patterns, for solutions |
| Ideation and solution design | Abstract | Generalise natural principles (e.g., strength, efficiency) for broader application |

| | | |
|---|---|---|
| Prototype development | Emulate | Build prototypes based on abstracted natural principles (e.g., designing a structure based on a spider's web) |
| Testing and feedback | Evaluate and refine | Test solutions with sustainability and ecological fit in min |
| Present the solution | Contextualise and apply | Present how the solution integrates biomimicry and sustainability |

*Table 1. Integration of Project-Based Learning and Biomimicry Design in LET'S MIMIC methodological framework.*

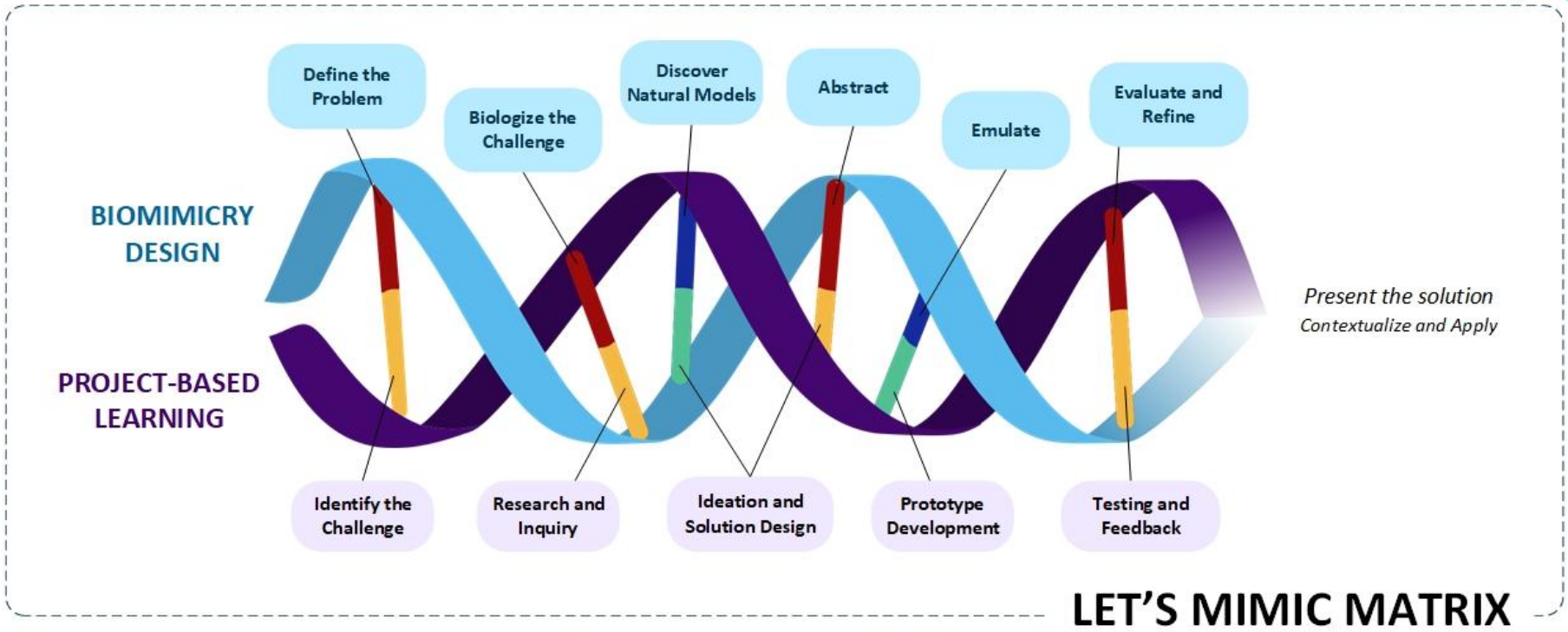


*Figure 1. LET'S MIMIC methodological framework that integrates the Biomimicry Design Process with Project-Based Learning.*

## 11.2 Examples illustrating how each step of the biomimicry process can be integrated into PBL

Integrating the **Biomimicry Design Process** with **Project-Based Learning (PBL)** enhances students' ability to solve real-world problems by looking to nature for sustainable solutions. Each step of PBL aligns with a corresponding stage of the biomimicry process, allowing students to approach challenges with creativity and systems thinking. By studying how nature has evolved to address similar challenges, students can design innovative solutions that are both efficient and ecologically sound.

The following examples illustrate how each step of the biomimicry process can be integrated into PBL, using a water conservation challenge as the central theme. These examples highlight the natural models and principles students can draw from, encouraging them to emulate nature's time-tested strategies in their project designs.

**1. Identifying the challenge (PBL) / Define the problem (Biomimicry)**

- **Example**: Students identified the challenge of water scarcity in urban areas due to inefficient water usage and waste.
- **Biomimicry Focus**: Define the problem by asking how nature conserves and uses water efficiently. Nature often employs efficient water storage, minimal loss, and reuse mechanisms.
- **Integration**: Frame the project around designing a water-efficient system inspired by nature, like how plants conserve water in dry environments.

**2. Research and inquiry (PBL) / Biologize the challenge (Biomimicry)**

- **Example**: Research the problem of urban water scarcity and examine existing solutions, such as water filtration and conservation technologies.
- **Biomimicry focus**: Break the problem into core needs, such as storing, filtering, and minimising water loss. Investigate how natural systems perform similar functions.
- **Integration**: Investigate biological solutions to water conservation, such as how desert plants store water or how certain animals survive in arid conditions.

**3. Ideation and solution design (PBL) / Discover natural models (Biomimicry)**

- **Example**: Begin brainstorming potential solutions and discover natural models. Look at natural examples, such as how cacti store water or beavers create natural filtration systems in their dams.
- **Biomimicry focus**: Search for specific organisms or ecosystems that have evolved solutions for water conservation.
- **Integration**: Identify a natural model, for example, how certain beetles in the Namib Desert collect water from fog on their wings, and brainstorm how this can be applied to human technology.

**4. Abstract (Biomimicry)**

- **Example**: Extract the key principle from the beetle's fog-harvesting technique: **surface texture and shape** are used to capture water.
- **Biomimicry focus**: Abstract this strategy into a design principle: use specialised surfaces to collect water from the air.
- **Integration**: Generalize the principle of using structure and texture for water collection and think about how this can be applied to the design of urban water systems, such as rooftops that capture moisture from the air.

**5. Prototype development (PBL) / Emulate (Biomimicry)**

- **Example**: Develop a prototype of a water collection system for urban homes. Their design emulates the beetle's strategy by creating a surface that captures water from fog or dew.
- **Biomimicry Focus**: Design the prototype by emulating the form and function of natural models, using the abstracted principles to inform the design.
- **Integration**: Create a rooftop system with a textured surface similar to the beetle's wings, optimised to collect and channel water into a storage tank.

**6. Testing and feedback (PBL) / Evaluate and refine (Biomimicry)**

- **Example**: Test the suggested water collection system under different environmental conditions, measuring its effectiveness at collecting water from moisture in the air.

- **Biomimicry focus**: Evaluate the design's performance and ensure it aligns with sustainability and natural efficiency principles.
- **Integration**: Refine their design based on testing feedback, adjusting the surface texture or size to improve water collection. They ensure the design is energy-efficient, just like nature's processes.

**7. Present the solution (PBL) / Contextualise and apply (Biomimicry)**

- **Example**: Present the final design of the suggested water collection system to the class or community, explaining how their design is inspired by nature and how it can help address urban water scarcity.
- **Biomimicry Focus**: Contextualise the design by explaining how it fits into real-world applications and contributes to solving sustainability challenges.
- **Integration**: Highlight how the suggested water collection system mimics natural processes and can be implemented in urban areas to reduce reliance on traditional water sources and make cities more resilient to drought.

These examples illustrate how the **Biomimicry Design Process** can be applied to each step of **Project-Based Learning**, from identifying a challenge to presenting a final solution, all while fostering creative problem-solving inspired by nature.

# 12. Learning outcomes

The proposed learning framework that integrates biomimicry in PBL contributes to the development of sustainability **knowledge**, **skills** and **competencies** in demand by industry and society:

- **Knowledge:** The understanding and comprehension of key concepts, principles, and theories related to sustainability skills in VET, as informed by desk research and questionnaire findings.
- **Skills:** The practical abilities and competencies developed through hands-on learning experiences and activities aimed at applying sustainability principles effectively within VET contexts.
- **Competences:** The broader capabilities and capacities acquired, including critical thinking, problem-solving, and decision-making skills, are necessary for integrating sustainability into vocational education curricula.

In addition, it helps develop soft green **skills**, which are appreciated in the job market. This includes:

- **Curiosity and inspiration**: Biomimicry involves solving real-world problems by mimicking nature's designs and processes, making learning more relevant and engaging for students. The natural world provides fascinating examples that can spark curiosity and inspire students to explore and learn.
- **Critical thinking, complex problem-solving, and systems thinking skills**: Biomimicry challenges students to solve complex, authentic problems, promoting critical thinking and innovative problem-solving skills. Understanding how natural systems work and applying these principles require and develop systems-thinking abilities.
- **Contextual learning**: Biomimicry helps develop integrated knowledge by inherently integrating biology, engineering, design, and environmental science, providing a rich, interdisciplinary learning experience. Students can establish the connections between different subjects and understand how they apply in real-world contexts.
- **Environmental consciousness and ethical thinking**: Learning from nature fosters an appreciation for the environment and the importance of sustainability. Students learn

to consider ethical implications and the long-term impact of their designs and solutions.

- **Creativity and innovation**: Biomimicry encourages students to think creatively, using nature as a model, mentor, and measure for innovative solutions.
- **Design thinking**: Integrating design thinking principles with biomimicry promotes creativity and iterative development processes.
- **Collaboration**: PBL often involves collaborative projects, helping students develop teamwork and communication skills.
- **Communication**: Students frequently present their findings and solutions, enhancing their ability to communicate complex ideas effectively.
- **Hands-on and experiential learning to learn**: PBL and biomimicry involve hands-on activities, experiments, and real-world applications, which can enhance understanding and retention. Students gain practical skills in research, prototyping, testing, and iteration.
- **Resilience and adaptability**: Studying how organisms adapt to their environments teaches students resilience and adaptability, essential skills for the modern world. The iterative nature of biomimicry projects helps students learn to cope with failure and persist in facing challenges.

# 13. Assessment strategies

Assessment in the LET'S MIMIC Framework context builds upon the PBL methods and self-regulated learning approaches. It involves formative assessment to monitor student progress and performance assessment to evaluate outcomes. These strategies are crucial for ensuring that learning objectives are met effectively.

## 13.1 Formative assessment

The formative assessment, driven by the PBL framework, focuses on providing ongoing student feedback. It allows mentors to monitor student understanding, adjust teaching strategies, and guide students towards achieving the desired learning outcomes. Formative assessment methods may include:

- **Peer assessment**: Opportunities for students to evaluate each other's work, promoting collaboration and critical thinking as they discuss and reflect on their peers' contributions.
- **Self-reflection**: Reflection activities where students assess their learning and progress, identifying areas where they need further development. This is connected to the self-regulation learning approach supported by the LET'S MIMIC methodology, which aims to improve students' ability to manage their learning processes by planning, monitoring, and evaluating their learning strategies and progress. At a more granular level, it assesses students' abilities to understand and explore a task, set goals and plan activities, and achieve objectives.

Formative assessment supports the iterative nature of PBL by encouraging continuous improvement and fostering a supportive learning environment where students can experiment and learn from mistakes.

Here are some practical formative assessment methods, paired with tools, for gauging students' understanding and progress during learning. These methods help provide timely feedback to both educators and students for ongoing improvement.

**1. Exit tickets**

- **Method**: At the end of a lesson, ask students to submit a quick response to a specific question or prompt.
- **Tools**:
    - **Google® Forms** or **Microsoft® Forms** for digital exit tickets.
    - **Padlet®** for shared class exit tickets with comments or ideas.

**Example**: Ask, "What's one thing you learned today and one question you still have?" Students can quickly type or submit responses, providing insight into their understanding.

**2. Quizzes and polls**

- **Method**: Use quick quizzes or polls during or after lessons to check for understanding of key concepts.
- **Tools**:
    - **Kahoot®** for fun, competitive quizzes.
    - **Mentimeter®** for live polling and interactive quizzes.
    - **Socrative®** for creating real-time quizzes with immediate feedback.

**Example**: After a lesson on ecosystems, you could use Kahoot to test students' knowledge of ecological relationships in a game format.

**3. Think-pair-share**

- **Method**: Students think about a question individually, discuss it with a partner, and finally share their responses with the class.
- **Tools**:
    - **Zoom® breakout rooms** or **Google® Meet breakout rooms** for virtual pair discussions.
    - **Jamboard®** or **Padlet®** for sharing collective class responses.

**Example**: After introducing a new math concept, ask students to think about how they would solve a problem, pair up to discuss strategies, and then share with the whole class using Jamboard®.

**4. Concept mapping**

- **Method**: Have students create visual maps to show their understanding of connections between ideas.
- **Tools**:
    - **MindMeister®** or **Coggle®** for creating digital concept maps.
    - **Lucidchart®** for more advanced mind mapping and diagramming.

**Example**: Students can create a concept map to visualise the relationship between water cycles and ecosystems, helping the teacher assess their understanding of interconnections.

**5. Peer review**

- **Method**: Students provide feedback to their peers on assignments or projects, helping them reflect on their work.
- **Tools**:
    - **Google® Docs** or **Microsoft® Word** for shared commenting features.
    - **Peergrade®** for structured peer feedback assignments.

**Example**: After writing an essay, students can exchange papers and provide feedback using Google Docs' comment feature. Teachers can also monitor the comments for both content and quality.

**6. One-minute paper**

- **Method**: Ask students to write down the most important thing they learned in one minute or any lingering questions.
- **Tools**:
    - **Padlet®** or **Google® Keep** for quick, digital responses.
    - **Flipgrid** for short video responses.

**Example**: After a lesson on climate change, students take one minute to write down their key takeaways and any uncertainties, helping the teacher know what to review.

**7. Self-assessment rubrics**

- **Method**: Using a rubric, students can reflect on their learning progress.
- **Tools**:
    - **Google® Sheets** for custom rubrics and tracking.
    - **Seesaw®** for interactive self-assessment activities, where students can
    - annotate their work and reflect.

**Example**: Provide students with a rubric for a group project and have them rate their contributions and areas for improvement. Then, follow up with a reflection activity on Seesaw®.

**8. Digital journals or blogs**

- **Method**: Encourage students to keep a journal or blog to reflect on their learning, encouraging metacognition and ongoing assessment.
- **Tools**:
    - **Google® Docs** or **Microsoft® OneNote** for digital journals.
    - **Edublogs®** for creating student blogs for public or private reflections.

**Example**: After each lesson, students write a brief reflection on what they learned and any challenges they faced. This helps the teacher track their thought process over time.

**9. Interactive whiteboards for real-time feedback**

- **Method**: Use interactive whiteboards for real-time brainstorming or collaboration. Teachers can assess understanding as students contribute.
- **Tools**:
    - **Miro®** or **Jamboard®** for real-time collaboration and visualisation of student ideas.
    - **Nearpod®** for interactive presentations where students can respond live.

**Example**: During a lesson on fractions, students can solve problems collaboratively on a shared Jamboard®, allowing the teacher to assess problem-solving strategies.

**10. Video and Audio Reflections**

- **Method**: Have students record short videos or voice notes explaining their understanding of a topic or responding to prompts.
- **Tools**:
    - **Flipgrid®** for student video reflections.
    - **Vocaroo®** or **Audacity®** for audio reflections.

**Example**: After a science experiment, students record a Flipgrid video explaining their findings and what they would do differently next time. This allows for reflection and self-assessment.

## 13.2 Performance assessment

Performance assessment in the PBL framework focuses on evaluating the final products or solutions developed by students and their ability to communicate and defend their work effectively. It aims to measure how students have achieved the intended learning outcomes. Methods of performance assessment include:

- **Final presentations**: Students present their biomimicry-inspired design solutions to a panel of instructors, peers, and possibly external experts. They demonstrate their understanding of biomimicry principles, the effectiveness of their design, and its sustainability implications.
- **Portfolio reviews**: Evaluation of a portfolio that documents the entire project process, including research, prototypes, iterations, and reflections. Portfolios showcase the evolution of students' ideas and their application of biomimicry concepts.
- **Defence sessions**: Structured sessions in which students defend their design choices, explain how biomimicry principles informed their decisions, and address questions from the assessment panel.
- **Performance rubrics**: Criteria-based assessment tools that guide evaluators in assessing the quality of students' work and progress, providing specific and actionable feedback. From the self-regulated learning perspective, this includes assessing a student’s willingness and drive to engage in self-assumed learning paths and activities, set goals, plan, and complete tasks independently.

Therefore, to foster a deeper understanding and application of biomimicry principles in design, the performance assessment in the LET'S MIMIC context builds not only on PLB strategies that measure the student's mastery of content knowledge and skills and evaluate their ability to apply learning in an authentic context but also on self-regulated learning assessment methods that consolidate the students' self-awareness, self-efficacy, as well as their abilities to maintain motivation, to manage time, be resilient, etc.

# 14. Summary of the LET's MIMIC framework

The LET'S MIMIC framework, developed to integrate PBL with biomimicry process design, provides a structured approach to fostering sustainability skills among vocational education and training (VET) learners. It presents the matrix that summarises the alignment between the Project-Based Learning (PBL) steps and the Biomimicry Design Process.

## 14.1 Expected impact

The implementation of this framework is expected to yield several significant impacts:

- **Enhanced learning outcomes**: Students will develop a deeper understanding of biomimicry principles and their application in design, along with essential skills in research, critical thinking, and collaboration.
- **Promoting sustainability**: Students will contribute to sustainable practices and innovations that address real-world challenges by integrating biomimicry into the curriculum.
- **Skill development**: Through hands-on projects and assessment strategies, students will acquire practical skills directly applicable to future careers and educational pursuits.
- **Innovation and creativity**: Encouraging students to explore biomimetic solutions fosters creativity and innovation, preparing them to tackle complex problems in diverse fields.

## 14.2 Future directions

Looking forward, there are several avenues for further development and enhancement of this framework:

- **Scaling and adaptation**: Expanding the framework to other educational contexts and disciplines to promote broader adoption of biomimicry and PBL methodologies.

- **Integration of technology**: Leveraging emerging technologies such as artificial intelligence and digital simulation to enhance biomimetic design capabilities and student learning experiences.
- **Continuous improvement**: Iteratively refining the framework based on feedback from educators, students, and industry partners to ensure relevance and effectiveness.
- **Research and evaluation**: Conducting longitudinal studies to assess the long-term impact of the framework on student learning outcomes, career readiness, and sustainability practices.

The framework aims to remain at the forefront of educational innovation by continuously evolving and adapting. Through biomimetic design and sustainable practices, it equips learners with the knowledge, skills, and competencies needed to address global challenges.

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