Biomimicry in Science Education

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The Concept of Biomimicry

It is known that design is not only an action specific to humans, but many living things realize it unconsciously by changing or adapting to their environment and conditions (Çakır, 2019). The main purpose of design is to ensure the safety of living things, solve problems and improve life. Living things participate in designing by recognizing their environment and using the possibilities they have by considering their benefits. In this process, living things need to have technological abilities such as perception, analysis, reasoning and sensory memory. Design allows living things to adapt and survive in situations where change is not possible (Kuday, 2009). Thus, design also functions as an adaptation strategy and emerges as an important process that supports the survival abilities of living things.

Since prehistoric times, humans have developed various designs to meet their basic needs and find solutions to environmental challenges. Most of these designs were created by observing nature or inspired by the natural environment. For example, in Ancient Egypt, dams and canal systems were built to control the flooding of the Nile River and to use water resources more efficiently. During this construction, engineering studies were inspired by the water cycle in nature and developed as a water management strategy. This shows that long before the concept of biomimicry was scientifically defined, people were studying the natural systems around them and producing engineering solutions by utilizing the working principles of these systems. The observation and imitation of natural processes or the application of their adaptations in man-made systems have formed the basis of the engineering and architectural practices of many civilizations throughout history (Aydın, 2023).

Nature has managed to survive by developing adaptation mechanisms against changing environmental conditions. As a result of this process, the solutions offered by nature are highly efficient and sustainable or functional in terms of resource utilization. Biomimicry is an interdisciplinary science that examines nature and the adaptations that living organisms have developed over millions of years of evolution and aims to be inspired by these processes or to imitate them in engineering, design and technology (Benyus, 1997). Biomimicry is defined as the transformation of these processes into design with qualified techniques and the development of new products by imitating the features that enable living things that have existed in nature for billions of years to be successful in fulfilling their tasks (Karabetça, 2018). The conceptual foundations of the term biomimicry were laid by Janine Benyus. Benyus first discussed the concept of biomimicry in her book “Biomimicry: Innovation Inspired by Nature” published in 1997 and assumed a pioneering role in this field. Benyus stated that the basic functioning principles of nature can be applied in the fields of engineering, design and technology (Canbazoğlu Bilici et al., 2021; Avcı, 2019). This term is a combination of the concepts of “biology” (life science) and “mimicry” (imitation) (Volstad & Boks, 2012).

The basis of biomimicry is the use of nature as a source of inspiration in engineering and design processes. In the literature, the concept of biomimicry is defined on three main components. First, imitating the form or function of structures in nature. Second, modeling the processes occurring in nature. The third is to copy the functioning of systems in nature (Benyus, 1997). These three components are used in the development of innovative designs to serve sustainability, which is the basic principle of biomimicry. Biomimicry enables the design of sustainable products and processes that do not harm the environment by taking inspiration from nature. Therefore, biomimicry can be considered as an "innovative design approach" and "sustainable development ethics" (Tavşan, 2022). Therefore, integrating these qualities into the fields of engineering and design enables achieving sustainable development goals in the long term (Karabetça, 2018).

Biomimicry applications are basically handled with two different approaches (Çakır, 2019). Reductive-shallow biomimicry generally aims to make wider use of biology-based technologies in engineering and design and is based on the simple imitation of forms in nature. This approach allows to increase and diversify knowledge in certain areas (Benyus, 1997). However, this method does not take into account the deeper systemic processes of nature. Therefore, it does not focus on ecological sustainability. On the other hand, holistic biomimicry advocates adopting an ecologically sustainable and environmentally benign approach. In this approach, it is essential to fully mimic nature's ecosystems and processes, thus creating "eco-design". Holistic biomimicry aims to ensure that man-made products and processes work in harmony with nature and use the most efficient production methods without harming the environment. In between these two approaches is the imitation of natural processes. In nature, production processes work in the most energy-efficient way without harming the environment. For example, the development of self-opening and self-closing water bottle designs for cyclists inspired by the opening and closing mechanism of heart valves is an example of this intermediate level (Volstad and Boks, 2012). This intermediate level focuses on the design of environmentally friendly and efficient processes while producing practical solutions based on the workings of nature.

As Kennedy (2004) notes, environmentally friendly and sustainable designs can be developed by mimicking the way organisms and ecosystems in nature function. Nature uses only the energy that is necessary and prevents waste by optimizing this energy use. This provides an excellent model for energy efficiency. Nature develops form-fitting designs for functionality. Natural systems maintain ecological balance by developing mechanisms to control excesses within themselves. Organisms that tend to overgrow or spread are often controlled by limiting factors such as food, space or competition. For example, when a population grows excessively, it is stabilized by mechanisms such as reduced food resources, increased disease or predator pressure. Such internal regulation mechanisms help natural systems to persist sustainably, and biomimicry practices offer strategies to prevent excessive resource consumption or system imbalance.

Biomimicry is a scientific approach that examines the biological functions and strategies that living things in nature have developed to survive and applies this knowledge to the design of man-made products and processes (Biomimicry Institute, 2017). Biomimicry involves students directly in the making and engineering processes by using nature as a source of inspiration. In this context, by observing and analyzing nature, students have the opportunity to find solutions to environmental and technical problems facing humanity. The interdisciplinary nature of biomimicry enables students to integrate different scientific fields such as life sciences, chemistry, physics and engineering (Williams et al., 2019). Thus, they can not only learn about existing problems, but also actively participate in scientific thought processes in these fields by developing original solution strategies inspired by nature.

What is not Biomimicry?

Biomimicry, “bioinspired”, “biomimetic”, “biomimetic” or more rarely “bionic” (Aydın, 2023; Sharma and Sarkar, 2019). Although there is no functional difference between these terms, the term biomimicry is generally preferred in sustainable design solutions, while the term biomimetic is more frequently used in fields such as military technology (Badini et al., 2023). In order to better understand what biomimicry is, it is important to consider what is not biomimicry. Although many designs and visual examples inspired by nature are nature-based, they cannot be considered as biomimicry (Aydın, 2023). For example, brand logos, aesthetic designs that mimic nature, drones that look like insects, or nature-themed decorations on smartphone screens only use nature as a superficial source of inspiration rather than mimicking biological functions or processes. Biomimicry aims to deeply understand the principles of nature’s functioning and adaptation processes and integrate them into innovative solutions. In this context, biomimicry is a scientific approach that provides sustainable solutions to real-world problems by replicating functional and systematic processes in nature.

Although biomorphism and biomimicry refer to designs inspired by nature, they are different concepts. Biomorphism is the use of the form and aesthetic characteristics of living organisms in nature in design processes. In other words, the shape of a design may resemble a living creature in nature. However, this is only a visual similarity (Hanzad, 2019). Biomimicry is the development of man-made products by imitating the functional and structural characteristics of organisms in nature. This involves adapting the functional solutions developed by nature through evolutionary processes to engineering and technology. Biomorphism can be an inspiration for biomimicry. However, they are not the same thing. For example, the use of a bird’s aerodynamic wing structure in aircraft design is an example of biomimicry. Because here, an engineering solution is produced by taking into account its functionality and aerodynamic properties. In biomorphism, on the other hand, only formal similarity is taken as basis (Aydın, 2023).

Biophilic design is an approach based on the deep human connection to nature and the psychological and physical benefits of this connection. Biophilic refers to the innate human desire to connect with nature, which is internalized through evolutionary processes (Blair, 2009). This intrinsic need triggers people’s desire to be close to the natural environment. In this context, biophilic design tries to strengthen people’s connection with nature by incorporating the colors, patterns and materials of nature into architecture and interiors. The human desire to be close to natural stimuli such as animals, plants, water elements and seasonal changes is one of the basic principles of biophilic design. For example, the tranquility we feel when walking in a forest or our tendency to keep plants and animals in our homes is an indication of the ancient human connection with nature (Ernst, 2014). Biophilic design aims to support both the physical and mental health of individuals by integrating such natural elements into people’s living spaces. Thus, it is aimed to create healthier living spaces that are more integrated with nature instead of built environments isolated from nature (Aydın, 2023).

Bio-assisted technologies are a technological approach to the development of man-made products using biological systems, organisms and processes (Öztoprak, 2020). These technologies aim to optimize product design and manufacturing processes by taking advantage of the structural or functional properties of living organisms. In bio-assisted technologies, components derived from molecules, cells, tissues or biological processes are integrated to improve the performance, sustainability or function of products (Naveira et al., 2023). This approach can be extended to many areas of biotechnology. For example, products such as biosensors, biomaterials or biofuels are concrete applications of bioassisted technologies (Aydın, 2023).

Biorobotics is an interdisciplinary field that aims to design and develop robotic systems by mimicking the functional properties of biological systems (Erden et al., 2011). In this field, biological properties of living organisms, especially their movement and perception abilities, are used in the development of robots and robot-like devices. Examples of biorobotic applications include unmanned aerial vehicles (drones) that resemble the structural and movement characteristics of insects or birds. These drones mimic the efficient and aerodynamic designs of biological models (Aydın, 2023). Biorobotics has a similar approach to biomimicry, examining the functional mechanisms of organisms in nature and integrating them into engineering designs. However, unlike biomimicry, biorobotics does not attempt to produce an exact copy of a form found in nature. Instead, it models the basic functionality of biological systems for robotic solutions and develops these systems by adapting them for more advanced technological purposes.

Uses and Examples of Biomimicry

In the historical process, it has been documented that people have developed various tools and equipment by adapting the natural structures and living things they observe in their environment. This process shows that before the formal emergence of the biomimetic phenomenon, it was a common practice inspired by nature (Çakır, 2019). For example, the Romans developed defense mechanisms inspired by the durable outer shell of an animal called Armadillo. These defense systems were adapted to military equipment by imitating the flexible standard of the animal's shell. These examples show that sciences throughout history have been able to analyze biological forms and continuity in nature and adapt them to their own technological and rechargeable form. Thus, these early applications based on biomimetic principles guided their own innovations by observing the structures of organisms in human nature (Yılmaz, 2021).

Sevencan (2020) emphasizes that the main purpose of the tools and equipment that people have developed inspired by nature is to protect themselves from the threats they face in the natural environment and to maintain their way of life. In order to survive, humans have developed various defense and shelter systems to protect themselves from both animals and weather conditions (for example, cold and rain). Observing natural adaptation mechanisms, humans have aimed to make life more sustainable and safe by integrating this center in nature into technology and architecture.

Inspired by snails, the robotic swarm system offers a revolutionary innovation in terrestrial robotics thanks to its bimodal coupling mechanisms that mimic the biological characteristics of land snails. This system increases the adaptability and robustness of robots, enabling them to operate smoothly in different and challenging environments. The system uses two main modes. The first mode is the free motion mode in which the robots are equipped with magnet embedded rails. This mode allows the robots to quickly adapt to their environment and move freely. It is optimized for tasks that require high maneuverability. In more challenging conditions, for example on rough terrain or in bad weather, the robots switch to strong mode. This mode provides more robust connections using polymerized vacuum absorbers that mimic the sticky properties of snail feet. This creates a strong bond between robots in a swarm and increases the stability and durability of the overall system. The dual-mode capability allows robots to switch between fast and agile movements and strong and stable configurations as needed. This adaptive structure offers great advantages for a variety of applications in many fields such as environmental monitoring, agriculture, search and rescue (Figure 1).

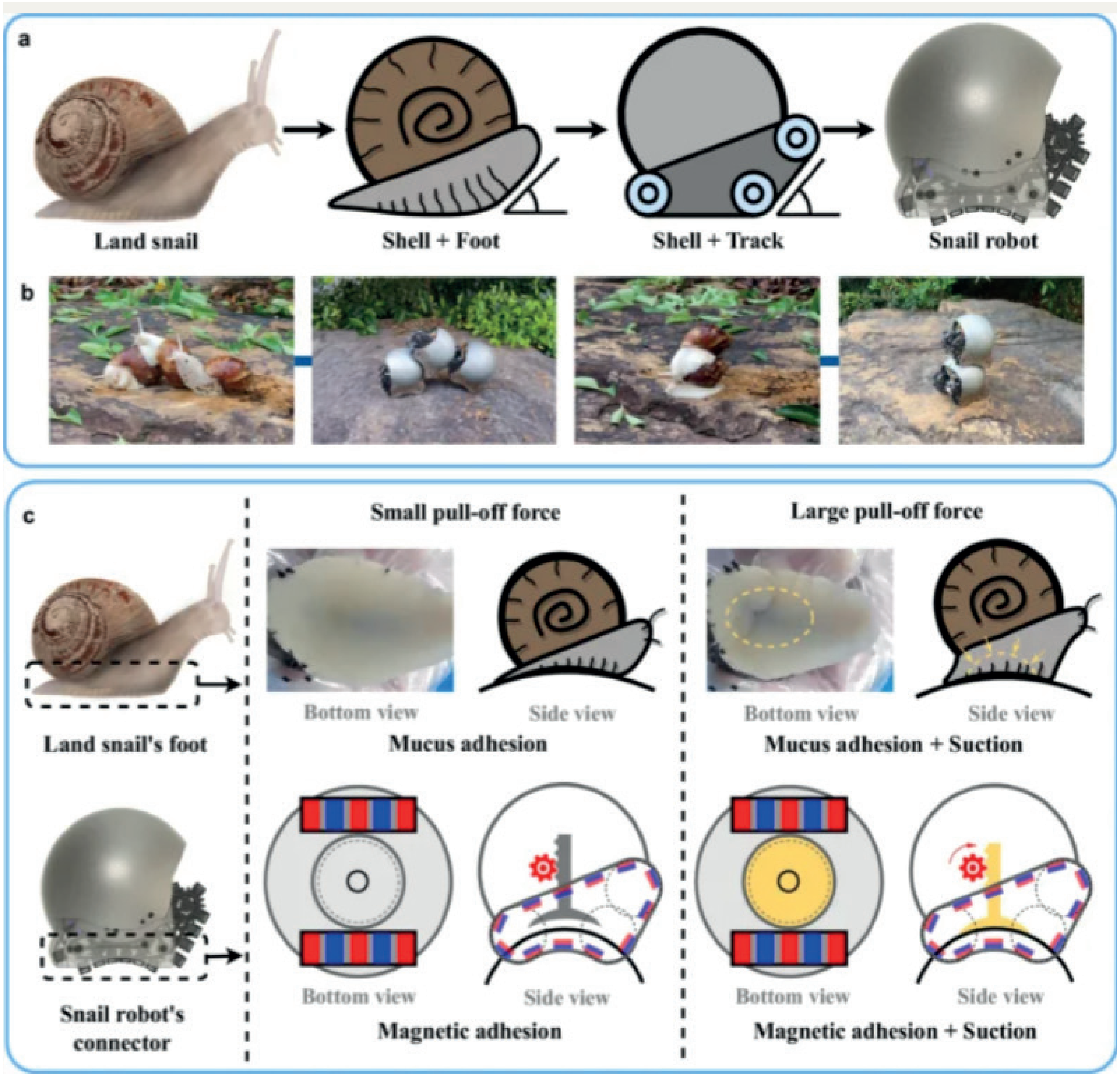

Figure 1. *Example of nature and Innovation*

Figure 2. *Ask nature (2021d)*

Plant reproduction is also a natural process that inspires biomimicry. Maple seeds, in particular, create a tornado-like vortex as they spin in the wind, and this aerodynamic structure allows them to generate more buoyancy than other seeds. Such natural mechanisms allow plants to spread their seeds over larger areas. While wind turbines play an important role in the production of environmentally friendly energy, their efficiency can be limited and costs can increase due to shortcomings in their aerodynamic design. Biome Renewables has developed a device called "PowerCone" inspired by the aerodynamic structure of maple seeds. PowerCone is designed to improve the aeroacoustics of turbine blades and reduce turbulence. Placed in the center of the turbine, this device provides additional torque by directing the airflow more smoothly to the blades, thereby increasing the turbines' efficiency and electricity generation capacity. This biomimicry-based design aims to achieve sustainability and cost-effectiveness in energy production (Figure 2).

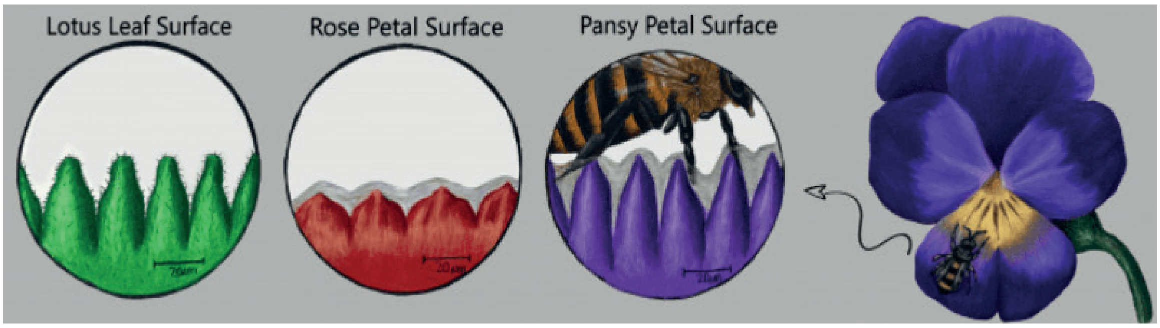

Figure 3. *Ask nature (2021d)*

The microscopic ridges on the surface of violet petals are unusually long and pointed, reaching a height of about 45 microns. This is about three times the height of rose petals with similar ridges. The ridges on both violet and rose petals have a wrinkled surface. In rose petals, these wrinkles allow water to penetrate these areas by capillary action, keeping the droplets stable on the surface and preventing them from rolling. On violet petals, the wrinkles are much narrower, which prevents water from entering these surfaces. In addition, the ridges on violet leaves have smaller tips and are located closer together than on rose and lotus leaves. This structure minimizes the contact area between the leaf and the water droplet and prevents water from settling on the surface, creating air bubbles. As a result, violet leaves are characterized by both enhanced hydrophobic properties and self-cleaning ability. This allows the leaf surface to remain clean without retaining water and dirt. However, it also provides a surface on which insects can attach (Figure 3).

Figure 4.*Ask nature (2021d)*

In the field of biomimicry, the similarity between the teeth and jaw structure of the American lion (Panthera atrox) can be considered as an important example of biomimicry in terms of biomechanics. The teeth and jaw structure of the American lion, especially the front teeth are longer and sharper than the back teeth, providing a strong biting ability. These morphological features are important for the function of catching and tearing prey. The jaw joint supports the mobility of both the upper and lower jaws, giving the American lion a wide biting angle and helping it to hold the prey firmly. The staple remover mimics this mechanical structure. The two ends of the staple remover are designed to resemble the American lion's pointed and long front teeth. These ends grasp the staple and hold it firmly as the teeth do, and the upper and lower parts move with a mechanism similar to a jaw joint to remove the staple. This structure effectively combines both strength and mobility. Kuday (2009) states that this similarity is an important example of how biomimicry works. The functional features of the jaws and teeth of the American lion inspired the design of a simple engineering tool such as a staple remover.

Biomimicry and Science Education

Research on the integration of biomimicry in science education programs is limited (Fried et al., 2020; Canbazoğlu Bilici et al., 2021; Yao et al., 2020; Gencer et al., 2020). However, biomimicry is considered as an important approach in the context of STEM (Science, Technology, Engineering and Mathematics) education. Biomimicry is a natural fit with STEM education as it involves thinking and design processes inspired by nature. STEM education brings together disciplines such as science, technology, engineering and mathematics through engineering design processes. This process aims to develop students' understanding of fundamental concepts as well as 21st century skills such as critical thinking, problem solving, creativity and collaboration. Biomimicry contributes to enriching these processes in science education. Because by examining the structures and processes in nature, students can make innovative designs and produce sustainable solutions to engineering problems. This understanding was defined as a core component of STEM education in the Next Generation Science Standards (NGSS) adopted in the United States in 2012 (Bybee, 2019). The NGSS provide a framework that promotes interdisciplinary learning while developing students' scientific knowledge and skills. Within this framework, biomimicry is seen as a powerful tool that combines science and engineering education with nature-based innovative thinking (Kaya, 2022).

In the 21st century, revising curricula to adapt to rapid changes in science and technology has become an important field of study (Başar & Demiral, 2019). Biomimicry is also defined as biotechnology applications and these two terms are often used interchangeably during studies. Biomimicry is based on the process of developing products by observing and imitating the structures and processes of organisms. This process consists of two basic stages. The first is the careful observation of nature and the second is the transformation of the information obtained from these observations into design (Yıldırım, 2019). Since natural sciences are accepted as a reflection of the functioning of nature, integrating the biomimicry approach into science education should include design studies inspired by nature. Understanding science necessitates understanding nature. Therefore, designing new products inspired by nature has a critical role in providing students with science and technology literacy. In this context, solving technology-based problems in the 21st century requires an interdisciplinary approach such as biomimicry.

The 2005 science and technology curriculum was prepared based on the constructivist approach, but practical difficulties such as lack of time were encountered during the implementation process. While this program aimed to ensure students' active participation in knowledge, it could not be fully efficient due to time constraints in classroom practices (Bakaç, 2019). In the program updates made in 2013, 2018 and 2024, a research and inquiry-based approach was adopted. These new approaches focused on learning processes that would enable students to understand and explain the natural and physical world. The 2018 science curriculum aims to emphasize applications of scientific knowledge. The program aims to provide students with the ability to use scientific knowledge in practice rather than theoretical knowledge. In addition, students are encouraged to integrate their scientific studies with engineering processes and to address the economic aspects of these studies. At the end of the academic year, students are expected to exhibit what they have learned and the projects they have developed in this process at events such as science festivals (Bakaç, 2019). This approach aims to enable students to produce creative solutions with scientific knowledge and to understand the relationship between science and engineering.

In the 2013 science curriculum, goals such as understanding nature, developing scientific process skills, gaining awareness of sustainable development, understanding and exploring the nature of science were prioritized (Başar & Demiral, 2019). These objectives are also included in the 2018 science curriculum. However, the 2018 program focused more on scientific and technological developments and added new fields such as engineering and entrepreneurship to science. In the 2013 curriculum, there was no emphasis on the STEM approach, while in the 2017 curriculum, a "Science and Engineering Practices" section was added. In 2018, this section was expanded and an area called "Science, Engineering and Entrepreneurship Practices" was created. These developments aim to help students relate the subjects they learn in science courses to daily life, improve their problem-solving skills and design creative products for the problems they face. These changes add engineering and entrepreneurship dimensions to science education and aim to provide students with a more hands-on, interdisciplinary and solution-oriented learning experience (Başar & Demiral, 2019).

Starting in 2004, the vision of science and technology literacy continued with the 2013 Science curriculum and was updated in 2024. The 2018 and 2024 Science curricula aimed to develop students' interdisciplinary thinking skills by emphasizing science, engineering and entrepreneurship practices in the context of STEM (MoNE, 2018). With this curriculum, it is aimed for students to be able to produce solutions to the problems they face, organize information and apply the knowledge they have acquired across different disciplines. STEM applications based on biomimicry in "Physical Phenomena," "The World and the Universe," "Living Things and Life," and "Matter and its Nature," which are included in the knowledge stages of the science curriculum, enable students to develop problem-solving skills by imitating the processes and functions in nature. Integrating biomimicry into science teaching in this way allowed students to be inspired by nature for problems they may encounter in daily life or problems they may encounter in the future. The combination of STEM and biomimicry makes science education more applied, innovative and oriented towards producing sustainable solutions (Aydın, 2023).

The Place of Biomimicry in Science Education

Integrating biomimicry into education requires an inquiry into how nature solves the problems faced by humans. In order to improve students' problem solving skills, it is important to take nature's solutions to challenges in areas such as energy, nutrition, shelter and social interaction as a model (Aydın, 2023). Seeing nature as a "teacher" and integrating this perspective into science education is possible through a planned and structured biomimicry education. This educational approach allows students to produce innovative solutions inspired by nature (Rowland, 2017).

Biomimicry provides students with different perspectives as an educational approach that develops sustainability and creative thinking skills. Students seek answers to the question "how would nature find a solution to this problem?" by examining the solutions that exist in nature (Aydın, 2023). Thus, they learn the mechanisms in nature and use them in problem solving. In this process, they understand how nature inspires innovative and sustainable designs (Biomimicry Instute, 2006a). Students obtain scientific findings as a result of these observations and reinforce their scientific thinking skills by questioning these findings in a cause-effect relationship (Boga & Timur, 2016).

Biomimicry is a concept related to the discovery of wonders in nature and teaching this concept to students in primary school years can help them recognize nature, increase their awareness and develop their creativity (Aydın, 2023). At the high school level, teaching biomimicry through integrated projects through biology, environmental science and art courses can help students better understand nature, improve their design skills and produce sustainable solutions. In this way, biomimicry education can be integrated into education programs at primary and high school levels and contribute to students' better understanding of both nature and the design process (Silveira & Mburu, 2023).

Science Education Activities Based on Biomimicry

Today, rapidly advancing science and technology require individuals to develop the skills to adapt to and contribute to these innovations. In this context, various teaching methods and techniques are used in schools to effectively transfer increasing information density to individuals. The science of biomimicry is an approach that aims to develop man-made products inspired by living and non-living things in nature. There are two basic steps in the implementation of this process (Avcı, 2019). The first is the observation of nature and the second is the integration of the information obtained from these observations into design processes (Alawad & Mahgoup, 2014). This approach can be applied in schools with various methods and adapted to different fields. The systematic process used in biomimicry design studies consists of the following steps:

1. Exploring Models in Nature (Exploration Phase): Students discover patterns in nature by examining the structures and behaviors of organisms in nature. At this stage, the functioning of natural systems is observed.
2. Abstraction of Biological Principles: The biological functions of these models observed in nature are abstracted through different disciplines and their scientific foundations are revealed. At this stage, it is aimed to understand how biological principles work and to transfer these principles to design.
3. Determining Which Problems the Solution Responds to: It is detailed in which areas the designed solution will bring innovation and which problems it can solve. This stage is critical in terms of determining the functionality and application areas of the design.
4. Imitating Nature's Strategy: The solutions reached are developed within the framework of sustainability principles, taking into account the strategies of nature. By imitating the solutions found by living creatures in nature to the problems they face, an environmentally compatible and sustainable product design is realized.
5. Evaluating the Solution with the Principles of Life: Finally, the solutions developed are evaluated according to the basic principles of life. At this stage, the long-term effects of the solution are examined by taking into account the sustainability, efficiency and adaptation strategies offered by nature (Avcı, 2019).

The biomimicry design process does not end after the completion of the stages listed. On the contrary, an important process of questioning and thinking awaits students after this point. At this stage, the rough version of the solution developed for the current problem should be reflected upon and further improvements should be made. This refinement process involves elaborating the solution and identifying more specific questions. The process cannot be completed without considering sustainability aspects such as environmental compatibility of the design, material and energy conservation. Students should focus on these aspects of the design and try to develop more efficient and environmentally friendly solutions. Successful completion of the design process is possible by producing detailed and feasible solutions that are compatible with sustainability principles.

In the study conducted by Velioğlu and Yakışan (2019), it was examined that 4th grade primary school students developed biomimicry designs inspired by the characteristics of animals. This process involves students creating innovative technological product designs by utilizing the different characteristics of various animal species during a lesson period. The researchers analyzed the drawings created by the students to determine how these designs were influenced by the geographical environment and socialization environments. In particular, it was found that the war-themed content that students were exposed to through computer games and media had a significant impact on the design process. According to the results of the research, the technological products designed by the students are mostly for war and defense technologies. This draws attention to the importance of integrating the biomimicry design process into education. Biomimicry is an approach that encourages the process of learning from nature in order to understand the functioning of nature and use this knowledge to develop innovative designs. As emphasized by Arhon (2017), this process requires learning and interpretation by expanding the perspective on nature. This study provides a concrete example of how the concept of biomimicry can be applied in education and is an important sign for the development of educational programs in this context.

The study conducted by Sumrall, Sumrall, and Robinson (2018) focused on a classroom practice for first-year students' understanding of the concept of biomimicry. This study was carried out by using cooperative learning methods in groups of four. First, students were introduced to various specific examples of biomimicry. This process encouraged students to create creative camouflage designs inspired by nature. The research aimed to increase group interaction and communication by having students present their designs to their classmates. The results show the importance of integrating biomimicry designs into education by emphasizing the inspirational role of nature in student learning processes.

Çoban (2019) aimed to integrate the concept of biomimicry in the context of science education for fifth grade students and to examine the results of this application. At the beginning of the research process, it was aimed to improve students› ability to observe organisms. These observation activities contributed to the development of scientific thinking and analytical skills by providing students with the opportunity to make connections between the structures and functions of organisms. In the later stages of the study, students were asked to design creative products inspired by various organisms through drawing and modeling. The results revealed that students adopted different approaches in the modeling process. While some students tended to design by directly imitating the structures of organisms, other students developed more functional and innovative designs by focusing on their functional features. These findings emphasize the role of biomimicry practices in education and show how students can be inspired by natural organisms to produce creative and functional solutions. It also provides an important contribution to the effectiveness of biomimicry-themed teaching methods in science education by examining the interaction of students› scientific observation skills and creative thinking skills.

Sanne et al. (2019) aimed to teach middle school students how the concept of biomimicry can bridge the disciplines of biology and engineering and encourage mathematical thinking in this context. The researchers designed an instructional activity to develop students' understanding of biomimicry and used the pretest control group model in this activity. The activities developed in the implementation phase of the study were carried out in a modular manner in the laboratory environment. This modular structure allowed students to grasp the relationships between various disciplines and gain hands-on learning experiences. The results of the study show that students were able to effectively learn the intersection of engineering, mathematics and biomimicry concepts. In conclusion, this study reveals that biomimicry-themed teaching activities can contribute to students' development of a deeper understanding of STEM fields through an interdisciplinary approach. This emphasizes the importance of integrating biomimicry into the education curriculum and provides students with the skills to make connections between concepts in various fields.

The study by Han et al. (2020) aims to examine the effectiveness of a teacher professional development program using the STEAM (Science, Technology, Engineering, Arts and Mathematics) education model for science teachers with two years of experience. The study was conducted using case study methodology and teachers were provided with an overview of pedagogical approaches to science and engineering technologies. The study focused on science and technology teaching competencies and beliefs to examine changes in teachers' self-efficacy. At the end of the training program, science teachers became more active in science practices such as data collection and observation during the implementation process. In this process, teachers were able to better recognize the problems in their environment and increase their competence in solving these problems with the knowledge they gained. These findings reveal the positive effects of the STEAM model on teacher professional development and show that teachers' pedagogical competencies as well as their problem solving skills have improved. By emphasizing the impact of applications in education, the study reveals the contributions of science teachers to the educational processes and the importance of such programs. They provided teachers with an overview of pedagogical approaches to science and engineering technology in education. They also tried to focus on science and technology teaching competence and beliefs to investigate the change in teachers' self-efficacy. As a result of the study, science teachers reported that with this program, they were now able to recognize problems around them and solve problems with the knowledge they gained while engaging in science practices, including data collection and observation in the field.

Biomimicry-based design studies provide versatile gains in educational environments by increasing students' interest in nature (Yıldırım, 2019). Such studies support engineering process skills and enable the emergence of original and innovative products. Students are expected to consider criteria such as realism, economic efficiency, functionality and durability while developing their designs in the process of biomimicry applications (Aydın, 2023). This contributes to the development of multidimensional thinking, planning and problem solving skills in design processes. Biomimicry studies enable students to interact directly with nature by taking the learning environment beyond the classroom walls and to produce creative solutions to solve the problems they encounter in the concrete world (Alemdar et al., 2021). This process supports project-based learning approaches by allowing students to use their innate creativity potential and develop visionary perspectives. Students who learn to develop environmentally friendly technologies inspired by nature also increase their sensitivity to social and environmental problems and adopt an understanding of sustainability. Eryılmaz (2015) emphasized the importance of ergonomics and user-friendly features in biomimicry-based designs. As a result, biomimicry studies stand out as an important educational method that develops students' design and engineering skills at both individual and social levels with a holistic approach. Incorporating biomimicry into the science education curriculum can provide multifaceted benefits to students.

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