Biomimicry Lessons for Teaching and Learning in Higher Education

Olusegun Oguntona[1](✉) and Clinton Aigbavboa[2]

[1] Department of Built Environment, Faculty of Engineering and Technology, Walter Sisulu University, South Africa
[2] cidb Centre of Excellence, Faculty of Engineering and the Built Environment, University of Johannesburg, South Africa
architectoguntona12@gmail.com; ooguntona@wsu.ac.za

Abstract. Teaching and Learning (T&L) in higher education is an important discourse that determines the teacher and learner's experience, effectiveness, and efficiency in the classroom. Biomimicry, a practice that draws inspiration from nature's forms, strategies, and systems to solve human challenges has the potential to inform curriculum design, pedagogical practices, and assessment strategies that promote sustainability, creativity, and critical thinking skills among learners. This paper presents a conceptual framework for applying biomimicry principles to T&L in higher education. Drawing from the core principles of biomimicry, the paper provides examples of nature-inspired teaching methods, such as experiential learning, collaborative learning, and real-world problem-solving. It acknowledges that incorporating biomimicry into higher education may require rethinking traditional educational paradigms, addressing faculty and institutional resistance, and overcoming logistical and resource constraints. The paper also highlights the potential challenges and limitations of incorporating biomimicry thinking into higher education but argues that the benefits of biomimicry-inspired T&L outweigh the challenges. Overall, this paper highlights the potential of biomimicry as a guiding framework for transforming T&L practices in higher education, preparing students to address complex challenges in the 21st century. Finally, this paper revealed that biomimicry can guide curricula development that integrates interdisciplinary approaches, inspires innovative teaching methods that promote active engagement, and informs the development of assessment strategies that align with the principles of biomimicry. Further research and experimentation are needed to fully explore the potential of biomimicry as a guiding framework for T&L in higher education.

Keywords: Biomimicry, Innovation, Nature, Sustainability, Teaching and Learning.

1 Introduction

Teaching and learning (T&L) in higher education (HE) form the bedrock of knowledge dissemination and intellectual growth in our society. The landscape of HE

M. Makua et al. (eds.), Proceedings of the 10th Focus Conference (TFC 2023), Advances in Social Science, Education and Humanities Research 788,
https://doi.org/10.2991/978-2-38476-134-0_12

has undergone significant transformations in recent years due to various factors [1]. For example, advancements in technology, natural disasters, pandemics, changes in learner demographics, evolving pedagogical theories, and shifting societal demands have all contributed to the present dynamic educational environment [2,3]. Other factors such as mentorship, learner engagement, and classroom/campus culture all play pivotal roles as well. Similarly, a robust evaluation system assists in determining the effectiveness of teaching strategies, and ensuring learners acquire the necessary skills and knowledge for their professional and academic development. In this context, gaining insights into the intricacies of T&L becomes indispensable for creating effective and relevant educational experiences in higher educational institutions (HEIs). To gain a holistic understanding of the propelling forces that dictate educational outcomes, an examination of the opportunities, challenges, methodologies, and underlying theories of T&L in HE is imperative. Also, as institutions of higher learning continue to evolve, understanding the intricate dynamics of this process becomes paramount for educators, administrators, policymakers, and stakeholders. Notably, pivotal roles are played by learners, educators, and institutional frameworks in defining the learning process. Therefore, exploring the multifaceted aspects of T&L in HE opens channels to enhance educational practices and ultimately nurture a generation of skilled and enlightened individuals poised to shape the future.

Globally, there has been much focus and clamour on the use of emerging technologies for T&L [4,5]. Truly, the integration of digital tools and online platforms has revolutionised the educational landscape, offering new opportunities for personalised learning, collaboration, and access to vast repositories of information [6]. Along similar lines, Kümmel and Kimmerle [7] suggested that the success of T&L in HE is anchored on the integration of digital learning technologies, the creation of a supportive T&L community, and the sustainable improvement of student learning. However, analysing these technologies has revealed their potential and pitfalls in HE thereby informing the need for relevant stakeholders to minimise the challenges and at the same time maximise the benefits. It is therefore important to create a supportive and inclusive learning environment that will shape the learners' overall educational experience. By synthesising best practices from diverse HE settings, research studies, and case analyses, novel insights can be generated with the potential to reinvent the future of HE and the pedagogical techniques well-suited in an ever-changing world of work. Hence, the discovery of biomimicry as a concept has gained appreciable recognition and attention worldwide for its capability to address human challenges [8].

In recent years, there has been a growing recognition of the significance of sustainable education practices that align with the principles of nature's wisdom [9,10]. The traditional approach to education, while successful in imparting knowledge, has often faced challenges in engaging learners, promoting critical thinking, and fostering a deep understanding of complex subjects [11,12]. As educators seek more effective and sustainable methods to cultivate future-ready graduates, the integration of biomimicry principles into higher education holds immense promise. Biomimicry, a discipline inspired by nature's time-tested strategies, has emerged as a promising model for innovation and problem-solving across various fields [13]. However, its

potential applications extend beyond technology and design, offering profound insights into the realm of T&L in HE.

As the world faces pressing challenges such as climate change, resource depletion, and social inequality, HEIs must equip learners with the values, mindset, and skills required to tackle these complex issues. Biomimicry, at its core, is rooted in the belief that nature, through millions of years of evolution, has developed amazing and efficient solutions to address challenges like that of humans [14]. These solutions, honed by natural selection, are inherently sustainable and well-adapted to their specific contexts. By drawing inspiration from the genius of nature, biomimicry offers a novel perspective on how to approach T&L processes within HE. It provides an innovative approach that aligns education with the principles of sustainability, adaptability, and resilience observed in nature [15]. Hence, the objective of this paper is to explore the various biomimicry lessons and principles that can be applied to T&L methodologies in HE. By understanding and incorporating these nature-inspired approaches, educators have the potential to create transformative learning experiences that not only impart knowledge but also instill a deeper appreciation for the interconnectedness of all disciplines and the natural world. The next section delves into the key concepts of biomimicry and how they can be translated into effective T&L strategies. This is followed by examples and case studies of the successful implementation of biomimicry in educational settings, demonstrating its potential impact on learner engagement, problem-solving abilities, and overall learning outcomes. The last section discusses the challenges/limitations and benefits of incorporating biomimicry into T&L in HE.

2 Methodology

This paper presents a review of scholarly articles on the numerous possibilities and innovative ideas locked up in the natural world and how they can reinvent and revolutionise teaching and learning (T&L) in higher education (HE). As described by Snyder [16], a literature review is an exceptional means of synthesising research findings, presenting compelling evidence, and uncovering avenues for future investigation to establish and develop robust theoretical and conceptual frameworks. An extant review of the literature (scholarly publications such as conference proceedings, journal articles, book chapters, books, etc.) on biomimicry vis-à-vis T&L in HE was conducted. As presented in Figure 1, the pictorial representation of the integrative literature review approach employed in this study followed the framework for conducting a literature review as postulated by Snyder [16]. This framework was employed to critique and synthesise the subjects (biomimicry, nature, HE, T&L). Qualitative analysis and evaluation were done resulting in the three classifications of biomimicry T&L methods. These contributions gave credence to the vast potential that is embedded in biomimicry to propel T&L in HE towards sustainability in its entirety.

Fig. 1. Pictorial representation of the study's integrative literature review approach.

3 Biomimicry principles for teaching and learning

Biomimicry principles, also referred to as nature principles or life principles, represent the inherent values exhibited by living organisms to ensure their survival, growth, and adaptation to their environments. Each organism possesses unique attributes that have evolved over the years, enabling them to thrive in their respective ecosystem. These principles encompass abstracted biological strategies, some of which are readily apparent and manifest, prevalent across a wide range of organisms. They play a crucial role in facilitating successful self-regeneration and sustainability within the natural world [17]. As essential guidelines, these principles serve as checklists to ensure the responsible application of biomimicry, leading to sustainable outcomes. They encapsulate replicated concepts and sequences derived from observations of natural organisms and ecosystems. As further expounded upon by Janine Benyus in her book "Biomimicry: Innovation Inspired by Nature," where she outlines nine nature principles, these principles serve as the foundational tenets that underpin the concept of biomimicry. They are nature runs on sunlight, uses only the energy it needs, fits form to function, recycles everything, rewards cooperation, banks on diversity, demands local expertise, curbs excesses from within, and taps the power of limits [18,19].

Applying biomimicry principles to T&L in HE has the potential to reinvent the methodology of knowledge transmission and acquisition. By looking to nature as a source of emulation, inspiration, imitation, and guidance, educators can create a T&L environment that fosters sustainability, innovation, and creativity [20]. One of the key

principles of biomimicry is the idea that nature has already solved many of the challenges we face. By studying and emulating natural forms, strategies, processes, and ecosystems, learners can develop a deeper understanding of the world around them and apply this knowledge to create sustainable designs and solutions. This approach to education offers a multidisciplinary approach, blending life sciences, creative problem-solving, design, systems thinking, and science, technology, engineering, and mathematics (STEM) subjects. Existing studies have also demonstrated the effectiveness of integrating biomimicry concepts into higher education through coursework and workshops [21]. To enhance T&L which promotes sustainable, innovative, and interdisciplinary education, the following can be explored.

3.1 Collaborative and Interdisciplinary Teaching and Learning

Organisms in nature operate through intricate networks of collaboration and interconnectedness [22]. A natural ecosystem consisting of different species of flora and fauna has evolved over the years through collaboration [23]. This principle can inspire educators to design interdisciplinary projects and activities that involve learners from various subjects and demographics working together to solve complex problems. By promoting collaboration, learners can learn to combine their diverse skills and perspectives, bridging the inequality gap, and fostering holistic and innovative solutions. Another avenue is biomimicry thinking which involves observing and understanding nature's solutions to problems and applying those principles to solve human challenges [24,25]. Educators can encourage biomimicry thinking among learners by presenting real-world problems and prompting the learners to explore how nature might have already solved similar challenges. This approach has the potential to stimulate creativity, encourage inquisitive research, and nurture an appreciation for nature's wisdom.

3.2 Sustainable and Regenerative Teaching and Learning

The natural environment is inherently sustainable, with many ecosystems capable of regenerating, self-healing, and self-repairing [26,27]. Educators can tap into these principles exhibited and operational in the natural world to guide learners in designing and developing solutions that minimise negative environmental impacts and support regenerative practices. This will instill a sense of environmental responsiveness, responsibility, and eco-consciousness in the next generation of learners. Biomimicry also emphasises the importance of biodiversity in ecosystems, where each species plays a unique role in maintaining ecological balance [28,29]. Similarly, educators can foster diversity and adaptability in their teaching methods and classroom environments. Recognising and valuing the diverse learning styles and strengths of learners can lead to more inclusive and effective educational practices.

3.3 Outdoor and Experiential Teaching and Learning

Biomimicry often begins with a sense of wonder followed by a curiosity about the natural world. Educators can encourage this awe-inspiring and subsequent inquisitive perspective by incorporating outdoor learning experiences, nature walks, and observa-

tion exercises in T&L [30]. Cultivating a sense of wonder can spark lifelong learning and a deep appreciation for the natural environment which in turn will lessen the extinction of rare species of organisms. Similarly, nature has perfected the development and utilisation of materials and technologies that exhibit remarkable properties, such as self-healing, self-cleaning, and energy efficiency [31,32]. By studying, mimicking, and emulating these materials, learners can develop innovative solutions to engineering and design challenges. This principle can be integrated into STEM (Science, Technology, Engineering, and Mathematics) education, inspiring learners to create more sustainable and efficient solutions and technologies [33].

Nature as a treasure trove of diverse forms and patterns has evolved over millions of years. By incorporating these designs into educational settings, educators can inspire creativity and critical thinking among learners. For instance, geometry lessons could explore the efficient hexagonal pattern found in honeycombs or the aerodynamic structure of bird wings to understand engineering and design principles [34,35]. Natural ecosystems are also regarded as excellent models of interconnected and adaptive systems. Educators can draw on these examples to teach learners about sustainable resource management, cooperation, and resilience which are key to achieving sustainable development. By examining how the natural ecosystems maintain balance and recycle nutrients [36,37], learners can learn valuable lessons about creating sustainable human societies.

4 Challenges of Incorporating Biomimicry for Teaching and Learning

Implementing biomimicry for T&L in HE comes with its own set of challenges. A major challenge is the lack of an interdisciplinary and integrative approach because it cannot be effectively implemented for T&L by focusing solely on a single discipline [38]. Biomimicry requires a holistic understanding of concepts and principles from various fields such as biology, design, engineering, and sustainability [39]. Hence, educators need to collaborate with experts from different fields so that students are exposed to a wide range of perspectives and knowledge, enhancing their understanding. Similarly, implementing biomimicry for T&L in HE requires a shift in pedagogical approaches. Instead of relying on traditional lecture-based methods, educators need to adopt interactive and experiential teaching strategies. These strategies engage students in hands-on activities and real-world scenarios that encourage them to explore and apply biomimicry principles. Another challenge of implementing biomimicry for T&L in HE is the paucity of resources and access to relevant information [40]. Educators face difficulties in finding appropriate materials, case studies, and examples of biomimicry in action that the learners will find resourceful.

Limited understanding and awareness of biomimicry principles among educators is another major challenge [41]. Many teachers and HEI administrators may not be familiar with the concept or its potential benefits for enriching the learning experience of the learners. Without adequate knowledge and a rich biomimicry thinking capacity on the part of educators, it becomes challenging to integrate biomimicry effectively

into the curriculum. The lack of professional development and training for educators is another barrier. To effectively implement biomimicry for T&L in HE, teachers need to be equipped with the necessary knowledge and skills to apply biomimicry principles in their classrooms. However, specialised training and professional development opportunities focusing on biomimicry are scarce or inaccessible for many educators considering the novelty of this concept thereby hindering its widespread adoption [38,41]. Constraints attached to most curriculum is another challenge. This is because HEIs often have rigid curriculum structures and standardised assessment requirements, leaving limited room for the incorporation of innovative approaches like biomimicry. Integrating novel teaching methods and content into existing curricula can therefore be challenging without disrupting the established conventional framework adopted by the majority of HEIs.

Time and resource constraints also hinder the adoption of biomimicry for T&L in HE. The implementation of biomimicry requires additional materials, resources, and time for research, design, and experimentation. Financial and budgetary limitations and time constraints in educational settings could deter educators from fully exploring and applying biomimicry principles in their teaching practices. Limited access to biodiversity and natural environments also constitutes hindrances to applying biomimicry for T&L in HE [42]. Biomimicry thrives heavily on rapt observations of nature and its patterns, which can be challenging for educators and students in urban or non-nature-rich environments. Access to natural spaces and outdoor learning opportunities is essential for fully engaging with biomimicry principles. This is however continually disrupted due to the disruption of natural environments by human industrialisation and infrastructural developments. Resistance to change within educational institutions can impede the adoption of new pedagogical approaches like biomimicry. Some stakeholders and educators may be hesitant to deviate from traditional teaching methods or may perceive biomimicry as a passing trend rather than a viable educational strategy. Similarly, encouraging biomimicry thinking among learners requires a shift in mindset, to promote curiosity, creativity, and problem-solving inspired by nature's solutions [18,38,41]. Nurturing these cognitive skills may take time and deliberate effort. While some HEIs and educators may successfully integrate biomimicry into their classrooms, scaling up these initiatives and ensuring their sustainability across entire educational systems can be a daunting task, requiring long-term commitment and support.

5 Benefits of Incorporating Biomimicry for Teaching and Learning

Despite the challenges hindering the implementation of biomimicry for T&L in HE, the potential benefits make it a promising approach worth pursuing and embracing through collaborative efforts, policy support, and dedicated resources. At the heart of biomimicry lies a deep appreciation for nature's sustainable designs thereby nurturing sustainability consciousness among educators and learners. By learning from and respecting the ecological balance found in natural systems, learners develop a strong-

er sense of environmental stewardship and are more likely to adopt sustainable practices in their personal and professional lives [43]. Biomimicry also encourages students to engage directly with the natural world resulting in a deep connection with nature. Through outdoor learning experiences and observation of ecosystems, learners develop a deeper connection with nature, fostering a sense of wonder, awe, and respect for the natural environment. Another benefit is that biomimicry empowers educators and learners for real-world application and relevance [44]. Biomimicry principles emphasise the practical application of knowledge. By examining nature's solutions and translating them into tangible innovations, students see the real-world relevance of their learning, leading to a more meaningful and impactful educational experience.

Biomimicry also promotes interdisciplinary learning among educators and learners. Biomimicry inherently bridges disciplines, connecting biology, engineering, design, and other subjects. It encourages an interdisciplinary approach to problem-solving, helping learners to recognise the interconnectedness of knowledge and the importance of collaboration across diverse fields. It also enhances problem-solving skills and critical thinking [24]. Integrating biomimicry principles for T&L in HE requires learners to analyse and adapt biological strategies to day-to-day human contexts. This process enhances critical thinking skills as learners evaluate the efficiency and effectiveness of natural models and apply them to various fields, such as technology, engineering, and design. Biomimicry encourages learners to explore nature's diverse solutions to complex problems which in turn fosters innovation and creativity [45]. By observing and understanding natural systems, learners are inspired to think creatively and develop innovative approaches to real-world challenges. This process of drawing inspiration from nature's designs fosters a culture of curiosity and inventive thinking among learners.

Biomimicry encourages lifelong learning as it instills a persisting learning mindset by fostering an appreciation for the wealth of knowledge available in nature. Students are encouraged to continue exploring and drawing inspiration from the natural world long after formal education, driving a continuous pursuit of knowledge and innovation. Furthermore, biomimicry supports diversity and inclusivity exemplified by the incredible diversity of life on earth, with each organism playing a unique role in the ecosystem [46]. This principle can be integrated into HE to promote inclusivity and celebrate the diverse strengths and talents of all learners which is key to achieving the sustainable development goals (SDGs). In a world facing complex environmental and societal issues, biomimicry prepares learners for future challenges as it equips them with the necessary skills and mindset to tackle these challenges creatively and sustainably. By learning from nature's time-tested strategies and processes, learners are better prepared to contribute to a more harmonious and resilient future [47]. Finally, biomimicry integration for T&L in HE enhances adaptability and resilience among educators and learners. The development of natural systems over time has led to their capacity for resilience and adaptation to changing educational conditions. A major and recent example is the COVID-19 pandemic which disrupted the global educational terrain. By studying the adaptive capabilities of organisms in nature, learners learn

valuable lessons about resilience and adaptability in their own lives, equipping them to face challenges with confidence and flexibility.

6 Conclusion

Conclusively, implementing biomimicry for T&L in HE offers a multitude of benefits in the short and long term. By embracing biomimicry in the realm of T&L, we have an opportunity to foster a new generation of environmentally conscious and creative thinkers who can draw inspiration from nature's wisdom to address the pressing challenges of the 21st century. The exploration of biomimicry's transformative potential in HE can unlock its profound lessons for a more sustainable and prosperous future. Incorporating biomimicry principles into T&L can transform traditional educational practices into dynamic, forward-thinking approaches that encourage learners to engage with nature and develop sustainable solutions for a better future. The study identified and examined how biomimicry principles can enhance T&L in higher education (HE). It was discovered that biomimicry has the potential to optimise collaborative and interdisciplinary T&L, sustainable and regenerative T&L, and outdoor and experiential T&L for both learners and educators in the HE spheres. Similarly, a few hindrances to the effective adoption and implementation of biomimicry were examined as they pertain to T&L. Major among these barriers are lack of interdisciplinary and integrative biomimicry approach, resistance to change of stakeholders, lack of biomimicry awareness, and lack of biomimicry education and knowledge among others. While the barriers may be a stumbling block to biomimicry adoption, the overwhelming benefits serve as necessary encouragement to ensure massive patronage and implementation. The major benefit that biomimicry offers to the HE through T&L is the promise of sustainability. The study revealed that educators and learners have the opportunity to be saturated with the requisite knowledge and information to make sustainable decisions and interventions when required. Also, the study informed of the potential of biomimicry to foster interdisciplinary collaboration, inclusion, and equality among learners, educators, and relevant stakeholders toward the realisation of the 2030 United Nations' sustainable development goals.

References

1. Goldschmid, M. L. Teaching and learning in higher education: Recent trends. *Higher Education*, *5*, 437-456 (1976).
2. Popenici, S. A., & Kerr, S. Exploring the impact of artificial intelligence on teaching and learning in higher education. *Research and Practice in Technology Enhanced Learning*, *12*(1), 1-13 (2017).
3. Crompton, H., Bernacki, M., & Greene, J. A. Psychological foundations of emerging technologies for teaching and learning in higher education. *Current Opinion in Psychology*, *36*, 101-105 (2020).
4. Kirkwood, A., & Price, L. Examining some assumptions and limitations of research on the effects of emerging technologies for teaching and learning in higher education. *British Journal of Educational Technology*, *44*(4), 536-543 (2013).

5. Price, L., & Kirkwood, A. Using technology for teaching and learning in higher education: A critical review of the role of evidence in informing practice. *Higher Education Research & Development*, *33*(3), 549-564 (2014).
6. Lai, K. W. Digital technology and the culture of teaching and learning in higher education. *Australasian Journal of Educational Technology*, *27*(8) (2011).
7. Kümmel, E., & Kimmerle, J. The effects of a university's self-presentation and applicants' regulatory focus on emotional, behavioral, and cognitive student engagement. *Sustainability*, *12*(23), 10045 (2020).
8. MacKinnon, R. B., Oomen, J., & Pedersen Zari, M. Promises and presuppositions of biomimicry. *Biomimetics*, *5*(3), 33 (2020).
9. Anderberg, E., Nordén, B., & Hansson, B. Global learning for sustainable development in higher education: recent trends and a critique. *International Journal of Sustainability in Higher Education*, *10*(4), 368-378 (2009).
10. Bidwell, D., & Smirnoff, D. Nature as Mentor: Catalyzing First-Year Liberal Arts and Sciences Undergraduate Transition through a Biomimicry First-Year Seminar. *International Journal of Teaching and Learning in Higher Education*, *34*(1), 124-143 (2022).
11. Giorgdze, M., & Dgebuadze, M. Interactive teaching methods: challenges and perspectives. *International E-Journal of Advances in Education*, *3*(9), 544-548 (2017).
12. Shahmoradi, L., Changizi, V., Mehraeen, E., Bashiri, A., Jannat, B., & Hosseini, M. The challenges of E-learning system: Higher educational institutions perspective. *Journal of Education and Health Promotion*, *7* (2018).
13. Lurie-Luke, E. Product and technology innovation: What can biomimicry inspire? *Biotechnology Advances*, *32*(8), 1494-1505 (2014).
14. Eadie, L., & Ghosh, T. K. Biomimicry in textiles: past, present and potential. An overview. *Journal of the Royal Society Interface*, *8*(59), 761-775 (2011).
15. Coban, M., & Coştu, B. Integration of biomimicry into science education: biomimicry teaching approach. *Journal of Biological Education*, *57*(1), 145-169 (2023).
16. Snyder, H. Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, *104*, 333-339 (2019).
17. Jácome Pólit, C. D. Regreening Nature: Turning negative externalities into opportunities (2014).
18. Benyus, J. M. *Biomimicry: Innovation inspired by nature* (p. 320). New York: Morrow (1997).
19. Hargroves, K., & Smith, M. H. Innovation inspired by nature Biomimicry. *Ecos*, (129), 27-30 (2006).
20. Oguntona, O. A., & Aigbavboa, C. O. Nature inspiration, imitation, and emulation: Biomimicry thinking path to sustainability in the construction industry. *Frontiers in Built Environment*, *9*, 1085979 (2023).
21. Yeter, I. H., Tan, V. S. Q., & Le Ferrand, H. Conceptualization of Biomimicry in Engineering Context among Undergraduate and High School Students: An International Interdisciplinary Exploration. *Biomimetics*, *8*(1), 125 (2023).
22. Legge, M. M., & Robinson, M. Animals in Indigenous spiritualities: Implications for critical social work. *Journal of Indigenous Social Development*, *6*(1) (2017).
23. Dyer, M., Gleeson, D., & Grey, T. Framework for collaborative urbanism. *Citizen Empowerment and Innovation in the Data-Rich City*, 19-30 (2017).
24. Blok, V., & Gremmen, B. Ecological innovation: Biomimicry as a new way of thinking and acting ecologically. *Journal of Agricultural and Environmental Ethics*, *29*, 203-217 (2016).

25. Bianciardi, A., Credi, C., Levi, M., Rosa, F., & Zecca, A. Biomimicry thinking: methodological improvements and practical implementation. *Bioinspired, Biomimetic and Nanobiomaterials*, *6*(2), 87-101 (2017).
26. Speck, T., Luchsinger, R., Busch, S., Rüggeberg, M., & Speck, O. Self-healing Processes in Nature and Engineering: Self-repairing Biomimetic Membranes For Pneumatic Structures. *WIT Transactions on Ecology and the Environment*, *87* (2006).
27. Speck, T., Mülhaupt, R., & Speck, O. Self-healing in plants as bio-inspiration for self-repairing polymers. *Self-Healing Polymers: From Principles to Applications*, 61-89 (2013).
28. Pedersen Zari, M., & Hecht, K. Biomimicry for regenerative built environments: Mapping design strategies for producing ecosystem services. *Biomimetics*, *5*(2), 18 (2020).
29. Lebdioui, A. Nature-inspired innovation policy: Biomimicry as a pathway to leverage biodiversity for economic development. *Ecological Economics*, *202*, 107585 (2022).
30. Deliman, A., & Lott, K. Inquiry-Based Learning on Biomimicry. *Science and Children*, *60*(6) (2023).
31. Zhang, M., Gu, Z. Y., Bosch, M., Perry, Z., & Zhou, H. C. Biomimicry in metal–organic materials. *Coordination Chemistry Reviews*, *293*, 327-356 (2015).
32. Ahamed, M. K., Wang, H., & Hazell, P. J. From biology to biomimicry: Using nature to build better structures–A review. *Construction and Building Materials*, *320*, 126195 (2022).
33. Silk, M., & Mauer, A. Connected Curiosity. In *Handbook of Mathematical Science Communication*, 205-230 (2023).
34. La, S., Joe, W. Y., Akbar, M., & Alsaidi, B. Surveys on skin design for morphing wing aircraft: Status and challenges. In the *2018 AIAA aerospace sciences meeting*, 03-15, (2018).
35. Boston, D. M., Phillips, F. R., Henry, T. C., & Arrieta, A. F. Spanwise wing morphing using multistable cellular metastructures. *Extreme Mechanics Letters*, *53*, 101706 (2022).
36. Altieri, M. A. Agroecological principles for sustainable agriculture. In *Agroecological Innovations* (pp. 40-46). Routledge (2013).
37. Lin, T., Gibson, V., Cui, S., Yu, C. P., Chen, S., Ye, Z., & Zhu, Y. G. Managing urban nutrient biogeochemistry for sustainable urbanization. *Environmental Pollution*, *192*, 244-250 (2014).
38. Oguntona, O. A., & Aigbavboa, C. O. Barriers militating against the adoption of biomimicry as a sustainable construction practice. In *MATEC web of conferences* (Vol. 266, p. 03010). EDP Sciences (2019).
39. Blanco, E., Cruz, E., Lequette, C., Raskin, K., & Clergeau, P. Biomimicry in French urban projects: Trends and perspectives from the practice. *Biomimetics*, *6*(2), 27 (2021).
40. Volstad, N. L., & Boks, C. On the use of Biomimicry as a Useful Tool for the Industrial Designer. *Sustainable Development*, *20*(3), 189-199 (2012).
41. Oguntona, O. A., & Aigbavboa, C. O. Barriers hindering biomimicry adoption and application in the construction industry. In *Engineering Design and Mathematical Modelling* (pp. 19-27). Routledge (2020).
42. Evangelopoulos, M., Parodi, A., Martinez, J. O., & Tasciotti, E. Trends towards biomimicry in theranostics. *Nanomaterials*, *8*(9), 637 (2018).
43. Ilieva, L., Ursano, I., Traista, L., Hoffmann, B., & Dahy, H. Biomimicry as a sustainable design methodology—Introducing the 'Biomimicry for Sustainability framework. *Biomimetics*, *7*(2), 37 (2022).
44. Nkandu, M. I., & Alibaba, H. Z. Biomimicry as an alternative approach to sustainability. *Architecture Research*, *8*(1), 1-11 (2018).

45. Mejía-Villa, A., Torres-Guevara, L. E., Prieto-Sandoval, V., Cabra, J., & Jaca, C. Training for Sustainability through Biomimicry and Creative Problem-Solving Processes. *Thinking Skills and Creativity*, 101359 (2023).
46. Helmrich, A. M., Chester, M. V., Hayes, S., Markolf, S. A., Desha, C., & Grimm, N. B. Using biomimicry to support resilient infrastructure design. *Earth's Future*, *8*(12), e2020EF001653 (2020).
47. McGuigan, N., Haustein, E., Kern, T., & Lorson, P. Thinking through the integration of corporate reporting: exploring the interplay between integrative and integrated thinking. *Meditari Accountancy Research*, *29*(4), 775-804 (2021).