Ecosystem biomimicry guide

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Abstract

Biomimicry, bridging biology and design, offers promising regenerative solutions, yet its systemic application remains underexplored. This study combines a literature review, case study analysis, and expert interviews to investigate effective ecosystem biomimicry implementation. It advocates for integrating ecosystem-level biomimicry into developmental projects from the outset. Key challenges identified include the complexity of urban systems, the need to contextualize ecosystem services, and the fragmented ecological knowledge among practitioners. The research highlights the necessity of comprehensive ecological understanding and practical tools, such as user-friendly guides and visualization software, to broaden biomimicry's accessibility. Additionally, the creation of a detailed project database is essential for knowledge sharing and standardizing practices. The study developed and validated an initial biomimicry process and online guide, incorporating user feedback to refine the tool. Future research should focus on advanced ecological processes, predictive modelling, and long-term monitoring to customize biomimetic solutions for specific local contexts. These efforts aim to foster resilient, regenerative solutions that promote long-term ecological health and functional ecosystems.

Summary

Biomimicry is the practice of designing solutions by learning from nature, and it has the potential to make our cities more sustainable and resilient. However, applying these nature-inspired ideas to complex urban environments is still a challenge. This research looked at how we can better use biomimicry at the ecosystem level, which means understanding how entire natural systems work together rather than just copying individual aspects of nature.

One of the main findings is that to make biomimicry more accessible to designers, urban planners, and others, we need to develop easy-to-use tools and resources. These might include clear guides, visual aids, and interactive workshops that help people understand and apply biomimicry in their projects. Additionally, creating a detailed database of successful examples can support professionals by showing them how biomimicry has been effectively used in other projects.

A first version of an ecosystem biomimicry process and guide has been designed. The guide has been designed with a wide range of users in mind helping people apply the process. To test if the process and guide are practical and effective a round of tests has been performed. Points for improvement have been collected and used to design an improved version of the guide. This version is a good starting point, but it will be important for the guide to be tested and improved further in the future.

The study also identified some challenges, such as the complexity of any system and the need for better knowledge about local ecosystems. To address these, the research suggests that future efforts should focus on improving our understanding of how ecosystems work and developing tools that can predict how nature-inspired designs will perform in real-world settings. This also means making sure that biomimicry solutions are customized to fit the specific needs of local environments and communities.

Finally, it's important to monitor these designs over time to see how well they work and make necessary adjustments. By focusing on these areas, we can create solutions that give back to the local environment, are well prepared for potential changes, are healthy, and deeply connected to the natural world around them. This approach could lead to systems that are better for both people and the planet.

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1. Introduction & background

Biomimicry is at the cross-disciplinary boundary between biology and design and offers great potential for more sustainable solutions. It is one of the three most commonly used bio-inspired design methods but is considered to be the most sustainable of the three (Jatsch et al., 2023; Landrum & Mead, 2022).
However, so far, there is limited research into biomimicry at the system level. Most publications detail the imitation of a single organism or even part of a particular organism to extract a relatively narrow design strategy. What is important for system-level biomimicry is to see that everything must work in complex, interconnected systems. It is believed that expanding the field to combine academic literary research, laboratory research and field observation could move the practice from individual abstraction to a more systemic approach (Jatsch et al., 2023; Hayes, Desha & Baumeister, 2020).

Biomimicry could translate ecosystem knowledge into concrete learning points, such as effective ecosystem services generation in urban areas. To date, however, systems-level biomimicry research has been limited. In their literature study Hayes et al (2020), found that only 4 of the 75 examined documents focussed on whole-system or partial-system-level biomimicry. In most publications, mimicry is performed on a single organism or even just part of a particular organism. Mimicking aspects of living organisms may produce innovations that address sustainability issues. Without a deep understanding of the ecological context, such innovations have a high risk of becoming just a novel more efficient technology (Pedersen Zari & Hecht, 2020).

Most important for system-level biomimicry, is a recognition that ecological systems cannot simply be copy-pasted into human systems. While both can be seen as complex systems, each system has a distinct set of unique characteristics related to external influences, such as human interference (Blanco et al., 2021a). The challenge lies in implementing systems-level biomimicry within complex socio-eco-technological systems that differ from their natural context (Hayes, Desha & Gibbs, 2019). The current lack of integrated knowledge on ecosystem functioning and the generation of services prevents the effective application of ecosystem-level biomimicry (Blanco et al., 2021a).

It is essential to understand which ecological information and concepts are relevant to urban designers to better study and translate ecosystem functioning and promote ecosystem services (Blanco et al., 2021a). Chayaamor-Heil. (2023), emphasizes the need for further research on how to incorporate biological knowledge into other practices (such as design, planning and policy).

Gibbons (2020), states that the target moving forward should be on realising regenerative projects. Thriving living systems provide a great example of regenerative functions, addressing the root causes of current exploitative practices. Biomimicry at the systems level can be addressed by exploring ecosystem literature and research. Biomimicry could help to bridge the understanding of ecosystems at a systemic level and harness their inherent capabilities as a blueprint for regenerative design.

Main research question:
The main question asked will be: How can research support the effective implementation of ecosystem biomimicry?

Sub questions:

- What kinds of research support the implementation of ecosystem biomimicry?
- How can scientific research be used to inform a more practical approach to ecosystem biomimicry by non-biomimicry professionals?
- In what ways can academic research contribute to identifying and mitigating potential challenges in implementing ecosystem biomimicry?

2. Materials and Methods

The study was designed to analyse how ecosystem biomimicry could be developed further and adapted to be more practically applicable to a broader user base. The research process involved an extensive literature review, selection and analysis of relevant case studies, expert interviews, and user validation of the designed guide.

Literature Research

A comprehensive literature review was conducted to gather existing knowledge on ecosystem biomimicry. The databases used included Web of Science, Google Scholar, and ScienceDirect. The keywords for the search included "ecosystem biomimicry," "biomimetic design," "systems thinking," "biomimicry challenges" and "biomimicry process."

- Articles were selected based on their relevance to the principles of biomimicry, their inclusion of challenges or lessons, and the presence of practical examples or case studies.
- A total of 28 articles passed the selection and have been read fully. Information was extracted on the fundamental principles of biomimicry and systems thinking, successful applications, challenges, and best practices.

Case Studies

Five case studies were selected from Web of Science, Google Scholar, and ScienceDirect databases to provide concrete examples of biomimicry in practice. The keywords for the search included "ecosystem biomimicry," "biomimicry case studies," "biomimicry projects," "biomimicry challenges" and "biomimicry analysis."
The selection criteria included diversity in cases, geographical location, and the scale of implementation. Each case study was thoroughly read and analysed to extract key insights and practical lessons.

- Detailed notes were taken on the objectives, methodologies, outcomes, and lessons learned from each case study. This analysis informed the development of the biomimicry guide.

Expert interviews

To deepen the understanding of ecosystem biomimicry and its practical applications, a series of expert interviews were conducted. These interviews aimed to gather insights from professionals with extensive experience in fields related to biomimicry, urban planning, ecology, and sustainable design. Experts were selected based on their professional background, contributions to the field of biomimicry, their involvement in relevant projects, and location of work.

- A semi-structured interview protocol was developed to guide the discussions. The protocol included open-ended questions designed to explore the experts' views on the challenges faced during the implementation of biomimicry principles and practising biomimicry with new practitioners.

Guide design

Because of the limited website coding skills of the researcher, the choice was made to create an online guide using WordPress. This tool allows for simple webpage creation while still providing lots of customisation flexibility. Design choices were made based on the findings from the research, personal preferences, restrictions from WordPress and using the biomimicry toolbox as a reference.

User Validation

User validation was conducted to assess the designed guide's practicality. A mock-up case study was given to participants along with a questionnaire to evaluate the guide's usability and effectiveness, see appendix III. A subset of participants with a base knowledge of biomimicry were selected for the validation. The validation focussed on qualitative results. In the first instance, users were asked if they could provide a project of their own. For the instances where users did not have any large projects at the time an example case was devised. Structured questions were used to assess the understanding, and usability, discuss potential challenges, and perceived value of the guide. Most feedback was given in virtual meetings to lower the barrier to entry**.**

3. Findings

A. Academic literature review on Biomimicry

Integrating (Eco)system-level biomimicry into urban design still holds significant challenges. Hayes et al (2019) suggest that the current barriers may be due to the complexity of urban systems. Blanco (2021a) further underscores this complexity, noting that urban environments have unique characteristics, such as human activity and infrastructure, making it impossible to simply copy and paste effective strategies from ecological systems. (This realisation will help to effectively advance the practice of ecosystem biomimicry).

An increasingly popular strategy that could fall under ecosystem biomimicry is ecosystem services (ESs). However, integrating ESs is currently not an intrinsic part of the urban planning process (Marques, Alvim & Schröder, 2022). A lack of understanding of integrating ESs into urban development prevents the strategy from being widely used. Recent literature argues that integration can be achieved by contextualising ESs within the local environment. While simultaneously aligning with the higher objectives of urban planning (Pedersen Zari et al, 2020; Semeraro, Scarano & Pandey, 2022). The ecosystem services concept is a good start, but only estimating ecosystem services provision represents an overly simplistic view of ecosystems. Limiting the practice to ESs limits the potential regenerative impact that ecosystem biomimicry can have (Blanco et al., 2021a; Toner et al., 2023). A true ecosystem-level biomimetic approach should focus on biophysical structures and processes governing ecosystems. An improved understanding of ecology can then guide urban design processes (Blanco et al., 2021a; Graeff et al., 2021). So, the challenge becomes twofold. Firstly, there needs to be a better understanding of ecology and how to translate this knowledge. Secondly, knowledge needs to be put into local context and goals.

<u>Challenges and barriers:</u>
To advance the practice and make it more practically applicable, it is important to know and understand the greatest challenges and barriers to its use and adoption.

Urban planning at the neighbourhood scale can have a role in aggregating all stakeholders by developing a unique vision of landscape development. Currently, individuals could develop heterogeneous actions leading to a worsening of the situation, or even decide not to act, due to the low economic interest in the investment of money (Semeraro et al., 2022). On a professional level, there are multiple barriers to biomimicry adoption and implementation. The list includes; a lack of awareness, a lack of professional knowledge, a lack of training/education, and a lack of information/ database (Oguntona & Aigbavboa, 2019). Graeff et al. (2021) identified the needs that potential adopters have through a survey. Their study found that the three biggest needs were the need for better risk management, the need for biological expertise and the need for clear guidance during the biomimicry process.

Few built environment professionals have the requisite knowledge and skills to undertake regenerative design and development, including, for example, understanding how living systems function and how they are attuned and responsive to place (Toner et al., 2023).

Furthermore, the development of processes and methodologies has also run into the challenges of accessing information and the limited availability of prior project examples. Academia could help to tackle some of these challenges (Hayes et al., 2019).

Supportive research:

Different forms of research might hold the keys to solving and overcoming some of these barriers and challenges.

Research can support the effective implementation of ecosystem biomimicry at the neighbourhood level by developing theoretical foundations (Hayes et al., 2019; Semeraro et al., 2022). However, there is a need for further research to integrate knowledge of ecosystem functioning and services generation, which is crucial for the success of ecosystem-level biomimicry in urban design. This research should focus on the design of nature-based solutions and the role of ecosystem services in urban planning. At the same time, case studies can provide valuable insights into applying these concepts in real-world scenarios (Blanco et al., 2021a).

Ecological research can significantly advance system-level biomimicry by providing a foundation for sustainable and regenerative design. Furthering knowledge of ecological processes and niche strategies can lead to successful models to follow when devising how systems should be put together and how they should work (Pedersen Zari, & Hecht, 2020). Hayes et al (2020) and Hayes et al (2019) both emphasize the need for further exploration of system-level biomimicry in infrastructure and urban design. Hinkelman, Yang & Zuo (2023) reviewed design methodologies for ecosystem biomimicry, their work highlights the potential that interdisciplinary research and teams hold to advance the field.

A better regenerative practice can be achieved by connecting the domains of ecological knowing and systems thinking. Systems thinking can be seen as an abstraction of ecosystems. By having ecosystems as a model, systems thinking explores concepts such as nested hierarchies. Linking form to function is so fundamental to ecology that its abstraction into nested orders for use in systems thinking should be central. Understanding ecosystems better would thus lead to improved systems thinking. Nested hierarchies could lead to a hierarchy of leverage points. By integrating even more ecological knowledge systems thinking could evolve into living systems thinking (Davelaar, 2021).

More theoretical development, in conjunction with case studies, design experiments and adaptive design are necessary to continue improving ecosystem biomimicry. Especially how to bridge the discipline gap (Gibbons, 2020).
Biomimicry tools need to be devised with industry professionals' needs in mind (Haselsteiner et al., 2021; Hayes et al., 2019).

How can scientific research be used to inform a more practical approach to ecosystem biomimicry by non-professionals?

This leads us to the most important point. How might scientific research inform and aid a practical approach that is repeatable and accessible to a wide range of practitioners?

The most important aspect of more practically applicable biomimicry is context. There are multiple types of contexts to consider. Firstly, the context of the practitioners is key for everyone to understand. This involves any educational, socio-cultural, and professional background which informs a person's worldviews, thinking patterns, ways of working and potential biases (MacKinnon, Oomen & Pedersen Zari, 2020). The second and third types of contexts go very much hand in hand. The second type is the unique local context surrounding the problem or project. Decision-makers must work from an intricate understanding of a project's unique place. This requires understanding and conceptualising how a place sustains and self-organizes within a specified geographical area (Craft, Ding & Prasad, 2021). This leads us to the intimately tied third type of context, local ecological knowledge. Applying biomimicry will be most successful if the knowledge is as local as possible. This means understanding the biome, climate region and ecological processes of the location (Pedersen Zari, & Hecht, 2020). The preferred manner of obtaining this knowledge would be to combine scientific knowledge with place-specific knowledge by engaging local/indigenous communities (Toner et al., 2023).

The second important aspect of more practically applicable biomimicry is practice. Like any other craft, the more someone practices biomimicry, the better practitioners will learn to master the art. Biomimicry presents itself somewhere between a practice and a scientific discipline (Davelaar, 2021). To practice biomimicry more effectively there are several key concepts that practitioners will need to get some familiarity with. Which will help to engage deeper with biomimicry.
This leads to the third important aspect: helping practitioners think about and visualise their problems and systems. Particularly, aiding professionals from different disciplines to think about and engage with ecosystem biomimicry on an equal level.
One of the most challenging aspects of ecosystem biomimicry is dealing with abstract concepts. However, emulating processes in ecosystems provides designers with successful models for devising how systems should be constructed and operated (Pedersen Zari, & Hecht, 2020).

Humans are always performing abstraction. However, there is confusion surrounding this term, as many disciplines have used it in varying interpretations. Therefore, a general set of abstraction levels has been formulated (see Figure 2.1). There are three practically useful levels of abstraction. Firstly, the low level. Which ranges from its low-end literal physical mimicry to its upper-end Specific traits. Secondly, the intermediate level. Ranging from its low-end Generic traits to its upper-end Dynamic patterns. Third and last, is the high level. Ranging from causal loop models to Generic system models. For ecosystem biomimicry you ideally would beat the level of dynamic patterns and higher (Graeff et al., 2021. The abstraction levels can be seen as ranging between direct and indirect. Direct abstraction can be on any scale but must be explicit. Oppositely, the indirect approach uses generalised principles from nature. The abstraction here is on known processes, lessons learned, and best practices from successful organisms and ecosystems on Earth (Hinkelman et al., 2023).

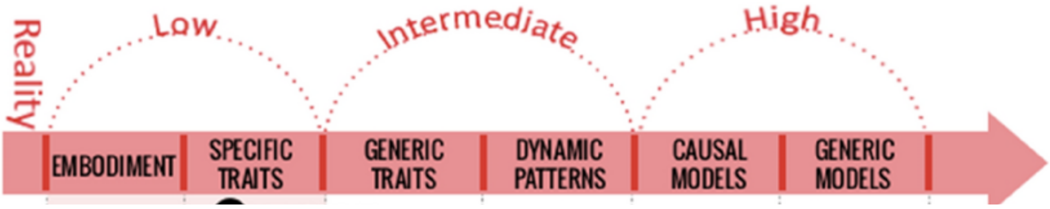


Figure 2.1, Levels of abstraction from Graeff et al., 2021).

To best deal with abstract meanings practitioners should be using a guide or tool that allows multiple representation systems (Zdrazilova et al., 2018). Making a map of the system in question is a useful tool, and storytelling is a way of communicating the map more effectively. Especially as it gets more abstract. With larger systems, complexity mapping might be the best tool to use (Suoheimo & Miettinen, 2018). Analogies and metaphors are other tools that can be used to explain abstract concepts, particularly in the context of systems (Nisar, Ali & Zuhaib, 2022; Zdrazilova, Sidhu & Pexman, 2018). To advance ecosystem biomimicry, designers should keep an open mind to scale when seeking nature-inspired solutions to complex system problems. Divergent ideation has a heightened value in ecosystem biomimicry (Hinkelman et al., 2023).

By analysing previous literature, Apul (2010) devised a list of common themes that were found in other frameworks and could inform bio-inspired design projects. The three main themes are the human dimension, learning from nature (biomimicry), and integrating nature. The biomimicry theme on its own is very large and broad in potential, therefore a set of seven sub-themes can aid in the practicality of this theme: (1) complex system properties, (2) energy source, (3) structure (4) function, (5) scale, (6) mass and energy flows, and (7) diversity and cooperation. By considering these themes and sub-themes, practitioners will ensure a certain base level of learning from ecosystems.

Leverage points are places in the system where a small change could lead to a large shift. Before you disturb the system in any way, you need to understand the rhythms, flows, history, and the (local) context. Acquiring or generating objective quantitative data is a plus. However, anecdotal, and qualitative data is also valuable (Wright & Meadows, 2008). Leverage points might better be seen as areas with the greatest potential for change (Birney, 2021). Understanding that patterns of living systems are self-similar at different scales (Capra & Luisi, 2014:p117), implies that a change at the smaller level can affect changing the dynamics on a larger scale. If we place new dynamics and patterns at one scale it can have an effect at wider levels. This is important when we start to understand the potential for intervention, as we do not have to change the whole system but choose where energy goes. Just like how there are ecosystem engineers for example. (Birney, 2021).

To evaluate projects, it is important to understand that ecosystems are made up of non-linear and interconnected processes. However, the things that connect these processes are cycles. Energy and materials are constantly transformed but never destroyed. For living beings, everything has costs and benefits. So, to learn from ecosystems, project evaluation should incorporate cycle and cost-benefit analyses (Pedersen Zari, M. (2018).

More formalised communities of practice and knowledge-sharing mechanisms must be established. Such networks would benefit from the involvement of industry, academic and public sectors (Hayes et al., 2019).

In summary:
Ecosystem biomimicry holds promise for sustainable and regenerative design, but several challenges and knowledge gaps must be addressed. Every system has its complexities, therefore understanding the local context is crucial. A deeper understanding of ecosystem functioning, structures and processes is critical for advancing the field and achieving meaningful impact. Barriers for potential practitioners include a lack of awareness and training. Research should focus on theoretical foundations, case studies, and practical guidance to bridge gaps and support adoption.

Most Important Factors for Ecosystem Biomimicry:

1. **Local Knowledge Integration:** Biomimicry themes should incorporate local ecological knowledge and engage indigenous communities to merge scientific and place-based knowledge effectively.
2. **Ecosystem-Level Biomimetic Approach:** A better understanding of ecological structures and processes in the local context is essential for ecosystem biomimicry. Effective biomimicry relies on understanding and translating biophysical structures and processes governing ecosystems.
3. **Interdisciplinary Collaboration:** Collaboration between academia, industry, and public sectors is essential for developing and applying biomimetic tools. Addressing the lack of awareness, training, and guidance among professionals is crucial for the broader adoption and implementation of ecosystem biomimicry.
4. **Understanding Complexity:** Urban systems are complex and unique, requiring tailored biomimicry strategies rather than simply copying and pasting ideas.

Most Pressing Knowledge Gaps and Future Research Directions:

1. **Lack of Integrated Knowledge:** There is a need for integrated knowledge of ecosystem functioning and services production to enhance the effectiveness of ecosystem-level biomimicry in local contexts.
2. **Educational Needs:** Future research should focus on identifying educational needs for consultants, contractors, and other stakeholders to implement regenerative principles effectively.
3. **Barriers to Implementation:** There is a need to identify and address the barriers to implementing system-level biomimicry.
4. **Lack of Formalized knowledge platforms and tools:** The absence of formalized communities of practice and knowledge-sharing mechanisms hinders the advancement of biomimetic design in the built environment.

B. Case studies

Multiple case study articles have been analysed. 4 out of 5 of the articles read examined multiple case studies in their studies. The most important lessons learned are described below.

Addressing the local ecosystem's biophysical structure and state needs to gain a central place in choosing sustainable urban solutions. The use of diagnostics at the start of any project must become a wider practice. Diagnostics could even be used to define project priorities and find the key pain points (Blanco, Raskin, & Clergeau, 2022).
Ecological knowledge needs to be integrated more into projects. Ecological knowledge encompasses understanding local ecosystems, species interactions, and biodiversity, which are essential for creating sustainable and resilient solutions. By incorporating this knowledge, natural processes can be mimicked more effectively. Integrating local ecological principles ensures that development is effective in the local context, does not come at the expense of environmental health but rather works in harmony with it and promotes long-term benefits (Blanco et al., 2022; Hayes et al., 2019).

Utilizing the concept of ecosystem services to formulate solutions can be a practical way to mimic natural systems. By developing solutions that enhance ES, planners can ensure that systems function more like natural ecosystems. The approach has been found to help urban designers understand and emulate natural processes. ES simultaneously help to improve the resilience and flexibility of solutions concerning environmental changes. (Blanco et al., 2022; MacKinnon et al., 2022).
Recent French urban design projects have seen an increase in biomimicry interest or applications. The solutions were mostly developed using macroscopic models from plants, animals and in some cases even ecosystems. The projects highlighted two main challenges to applying biomimicry in systemic projects: A lack of knowledge among urban stakeholders about biomimicry and gaps between research and design practice (Blanco et al., 2021b).

One way to mitigate some of the challenges could be adopting a holistic approach. When applied to urban design and by extension larger projects in any discipline, holistic thinking will ensure that more factors are considered. The holistic perspective recognizes that any environment is a complex system where various factors are interdependent. Approaches that integrate natural factors into the project will ensure more thought-out and resilient results (Blanco et al., 2022; Frantzeskaki, 2019). Besides a more holistic view, developers also need to develop a regenerative view. To realize projects that reconnect with natural ecosystems it will be crucial to adopt strategies aiming to regenerate ecosystems. Unlike traditional sustainability approaches that focus on minimizing harm, regenerative design aims to restore and enhance ecosystems. This means going beyond reducing negative impacts to actively improving the ecological health of urban areas (Blanco et al., 2022).

To address the second main challenge a combination of considerations will work best. Firstly, development should be done by multi-disciplinary teams and span across sectors. For instance, implementing successful nature-based solutions would need collaboration from developers, urban planners, designers, biologists, and policymakers. (Frantzeskaki, 2019; Hayes et al., 2019; MacKinnon et al., 2022). Secondly, as stated before, incorporating local knowledge is crucial. This ensures that adaptation strategies are relevant and effective at the local level. (Blanco et al., 2022; Frantzeskaki, 2019; Hayes et al., 2019).

Thirdly, testing, running simulations and accurate data acquisition are essential for effective novel solutions (Frantzeskaki, 2019; MacKinnon et al., 2022). More importantly, there is a need for platforms that can empower communication and knowledge transfer within the field (Frantzeskaki, 2019). Interdisciplinary communication and understanding have often been found to be lacking in projects. Disseminating knowledge and best practices is vital for effectively implementing biomimicry projects. A knowledge-sharing platform that includes best practices can help in replicating successful strategies in different contexts (Hayes et al., 2019). Biomimicry projects will also require continuous monitoring which will better allow for adjusting strategies to changing contexts (MacKinnon et al., 2022).
Lastly, because the field is quite new tools and guides need to be developed that can help train people and make the practice more practical (Blanco et al., 2022; MacKinnon et al., 2022).

In summary:
Ecosystem biomimicry is slowly becoming more known and practised. However, A lack of knowledge about biomimicry and gaps between research and design practice are still challenges that remain. Key lessons for sustainable urban solutions include integrating local ecological knowledge, utilizing ecosystem services to mimic natural systems, and adopting holistic and regenerative approaches. Developing practical tools and guides will help train practitioners and make biomimicry more accessible and effective.

Most Important Factors for Ecosystem Biomimicry:

1. **Ecological Knowledge**: Integrating ecological knowledge into projects is essential. This includes understanding local ecosystems, species interactions, and biodiversity to create sustainable and resilient solutions.
2. **Ecosystem Services**: Utilizing ecosystem services (ES) to formulate solutions can help mimic natural systems. This approach ensures systems function more like natural ecosystems.
3. **Holistic and Regenerative Approaches**: Adopting holistic and regenerative perspectives is vital. Holistic thinking considers the environment as a complex system with interdependent factors, ensuring more resilient results. Regenerative design goes beyond minimizing harm to actively improving ecological health, aiming to restore and enhance ecosystems.
4. **Interdisciplinary Collaboration**: Effective development requires collaboration across disciplines and sectors. Creating platforms for communication and knowledge transfer can help disseminate best practices and replicate successful strategies in different contexts.
5. **Training and Practical Tools**: Developing tools and guides are necessary to train practitioners and make the practice of ecosystem biomimicry more practical and accessible.

C. In-depth interviews with biomimicry practitioners.

This section will feature the key takeaways from the interviews. For more detailed answers please see appendices I & II.

Interview with Jess Berliner, Learn Biomimicry

Jess Berliner emphasises that understanding the user's context is crucial when introducing biomimicry concepts. It's about identifying the aspects of biomimicry that are most relevant to the user and ensuring they see its value. People need to get in the mindset of approaching biomimicry with curiosity rather than expecting an immediate, definitive answer. This means fostering an environment where users can explore and discover how biomimicry can be applied to their specific needs and challenges.

Berliner states that most people who approach their organisation are initially just curious about biomimicry. Therefore, introducing the concepts gradually and grounding them in the users' reality is essential, otherwise you overload them with too much information at once. Biomimicry must be made relatable and easy to understand, ensuring that the users can see the practical applications in their lives and work.

One significant challenge highlighted by Berliner is the time-consuming nature of accurately and fully applying biomimetic principles. Many initial users underestimate the time and effort required to perform biomimicry properly, which can lead to superficial applications and potential greenwashing. She feels it is important to recognise and address this factor subtly.

Berliner is convinced that successful biomimicry projects are not only about the principles themselves but the people applying them are just as important. Relatability and local connection are key to effective biomimicry. Therefore, it's essential to focus on the practitioner's perspective, environment, and ensure they can connect with the concepts on a personal level.

Finally, Berliner acknowledges the difficulty in creating new databases of biomimicry knowledge. However, she notes that initiatives aimed at sharing knowledge and fostering collaboration are always welcome and appreciated. Such efforts are needed to help build a more robust and accessible body of knowledge that benefits all practitioners.

Interview with Milan Master, Ecolution Consulting

Milan Master highlights the importance of always asking why a problem is occurring. By understanding the root causes, practitioners can develop more effective and sustainable solutions. Master advises that it's crucial to prompt people to look beyond the immediate problem. They should consider the broader context, including the local ecosystem and similar ecosystems in other locations. By examining both the macro and micro scales, practitioners can ensure that local context informs larger and smaller-scale solutions, leading to more holistic and integrated outcomes. A significant point raised by Master is the financial aspect of projects. Money often limits what can be achieved, but biomimicry has the potential to be more cost-effective in the long term. Practitioners need to gain ways of showcasing this potential to stakeholders. Master highlights the challenge of biologizing concepts for people who have not spent much time in nature. Providing relevant examples that resonate with the specific individual can help bridge this gap. He believes that encouraging interaction with nature is also vital. Practical exercises that engage all the senses and foster a connection with the natural world can be very effective in helping people understand and apply biomimicry principles.

Master suggests providing a clear framework for identifying leverage points and understanding different perspectives, including behavioural aspects. This distilled approach is needed to make the process more manageable. Understanding that processes take time is another critical point. Master used the analogy that a forest does not grow overnight to highlight the need for patience and long-term thinking in biomimicry. Practitioners should be encouraged to consider the time scales and process nature of the practice rather than seeking immediate solutions. He also thought out loud about how providing a condensed version of the process can help people see the value quickly. Making them more interested in investing the time needed.

Finally, Master stresses the importance of customising biomimicry examples and processes to fit the specific user. This can be done for instance through categorising based on discipline, industry, or personal interests. Identifying a common entry point that appeals to the most people can also facilitate broader acceptance and implementation of biomimicry principles.

In summary: Jess Berliner emphasizes the importance of understanding the user’s context when introducing biomimicry concepts, advocating for a gradual, relatable introduction to avoid information overload and ensure practical application. Berliner also underscores the significance of local connection and practitioner relatability, as well as the need for collaborative knowledge-sharing initiatives to build a robust biomimicry knowledge base. Milan Master stresses the importance of understanding root causes and broader contexts to develop sustainable solutions. Master advocates for practical exercises to connect users with nature, a clear framework for identifying leverage points and a distilled stepwise process

Most Important Factors for Ecosystem Biomimicry:

1. **Contextual Understanding:** Biomimicry should be relevant to the user's specific needs, encouraging exploration rather than expecting immediate answers. Practical exercises that engage the senses and foster a natural connection are crucial.
2. **Gradual Introduction:** Concepts should be introduced gradually, grounded in users' realities to prevent overload.
3. **Relatability:** Making biomimicry relatable and easy to understand helps users see its practical applications.
4. **Time and Effort:** Proper application of biomimicry is time-consuming, and users must recognize the effort required to avoid superficial implementations.
5. **Local Connection:** Successful projects hinge on the practitioner's connection to their environment and personal level.
6. **Financial Benefits:** Biomimicry can be cost-effective long-term, but this needs to be demonstrated to stakeholders.

4. Guide development

A. Process divided into steps

Based on the findings from the previous chapter a novel ecosystem biomimicry process has been devised. Consisting of 8 steps, this process touches on the most important factors for effective ecosystem biomimicry while being provided understandably and gradually. This process along with templates, tools and resources form the basis of the ecomimicry guide.

1. **System Analysis:**
    - Make a map of your situation and the surrounding system to try and understand the structure, function, and dynamics of the system.
    - Identify key components, relationships, and feedback loops.
    - Map out cause-and-effect relationships and identify visible and non-physical aspects.
    - Use systems archetypes (e.g., Limits to Growth, Fixes that Fail) to understand system dynamics.
    - Now define the local context on different levels. Ecologically (biomes and climate zone), socially, technologically, geographically etc.
    - Utilize this information to create a complexity map and write a concise 5-sentence story of the place/problem statement.
2. **Identify Leverage Points:**
    - Identify areas where small changes can lead to significant impacts.
    - Consider diverse relationships, scales, and potential for intervention.
    - Look for common causes, intervener-influenced factors, and root causes.
    - Explore areas with broken information flows or invisible influences.
    - Use systems thinking models, such as nonlinear causal loop diagrams, to identify bottlenecks, feedback loops, and system interdependencies.
3. **Apply Biomimicry Thinking/ biologize:**
    - Biologize your problem, and key components.
    - Go out and explore nature. Connect with local ecosystems.
    - Investigate how natural systems solve similar challenges, focusing first on locally relevant biological system models (biomes, climate zones, ecosystems), and then looking at similar models in other regions and ecotones.
    - Make abstractions at different levels & try to make analogies.
    - Brainstorm nature-inspired solutions and innovative approaches.
    - Assess the costs and benefits of natural models and evaluate their applicability to your solution.
4. **Promote Holistic Thinking:**
    - Consider the entire system and its interactions.
    - Think about the broader context and implications.
    - Think beyond isolated solutions and assess costs, benefits, and energy/material flows. Consider broader implications.
5. **Embrace Regenerative Design:**
    - Consider ecological context and embrace regenerative design principles.
    - Map the ecosystem services that could be generated.

- Aim to restore ecosystem functions and enhance resilience.
- Foster coevolution with natural systems and optimise resource flows.

6. **Practical Application:**
    - Use case studies and examples to illustrate concepts in action.
    - Develop design principles and concepts based on selected biological strategies.
    - Engage in rapid prototyping or simulation.
    - Conduct research, small tests, pilot projects and validation moments to assess feasibility and effectiveness.
7. **Evaluate & Continuous Improvement:**
    - Evaluate using the Life's principles or Natures unifying patterns from the biomimicry institute.
    - Conduct cost-benefit analyses.
    - Gather feedback and iterate on solutions over time.
    - Stay updated with the latest research and resources in ecosystem biomimicry.
8. **Collaborate and Share Knowledge:**
    - Foster a community of practitioners interested in regenerative design.
    - Share experiences, collaborate on projects, and amplify impact through collective action.

By following these steps, project leaders can apply ecosystem biomimicry principles effectively, leading to more successful, regenerative, and ecologically attuned outcomes.

B. Guide design

An online guide has been designed and developed to make the process more practically useable and be able to test its effectiveness. This is purely a first version of the guide, created to validate the steps of the ecosystem biomimicry process. The guide can be found at the following domain: **https://ecomimicryguide.com**

The design of the guide has been informed by the findings of this research project. The front page emphasises that the practice is not about finding the right answer but rather about improving the process of generating solutions, see Figure 4.1. It also shows that the guide features a shorter version, an overview, and a detailed version. The short version is created for those wanting to get a sense of what the process is about and which steps they can expect to perform. The short version features a few of the key images from the guide and a few lines of text from each step. This choice was made mainly from the recommendations of the experts interviewed. They highlighted that a lot of times people have limited time to assess if something will be worth more of their precious time and effort. So, a sorter summarised version can help them quickly assess the value of the guide and whether they want to invest more into using it.
The overview will link people to see the names of all the detailed steps and allows navigation to whichever step is preferred. Indicating that while there is a recommended order, practitioners are free to explore and practice non-linearly. It also allows for ease of getting back into a step of the process if someone left the website. Lastly, the detailed version button immediately links to the first step of the ecosystem biomimicry process in full detail.

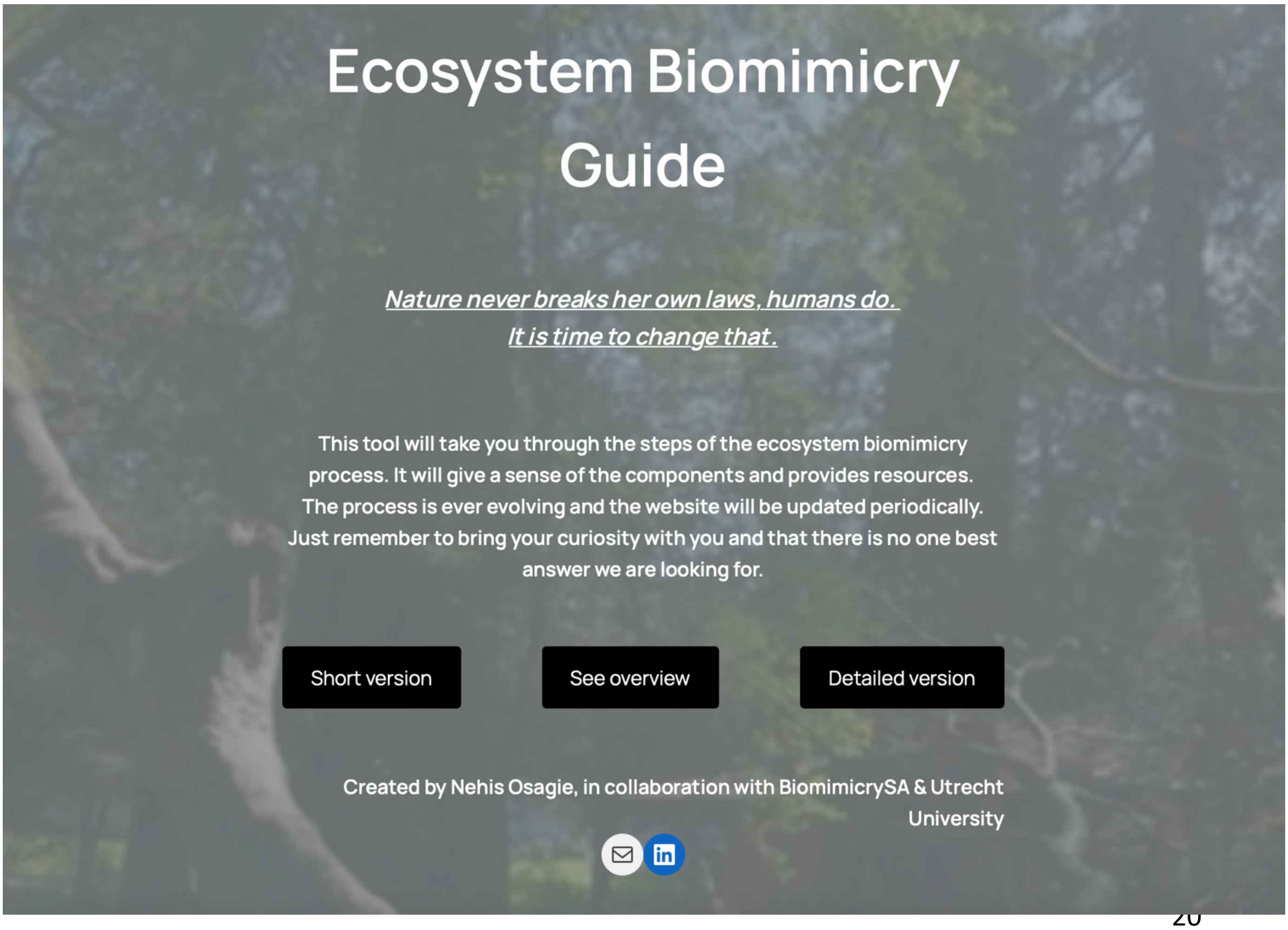
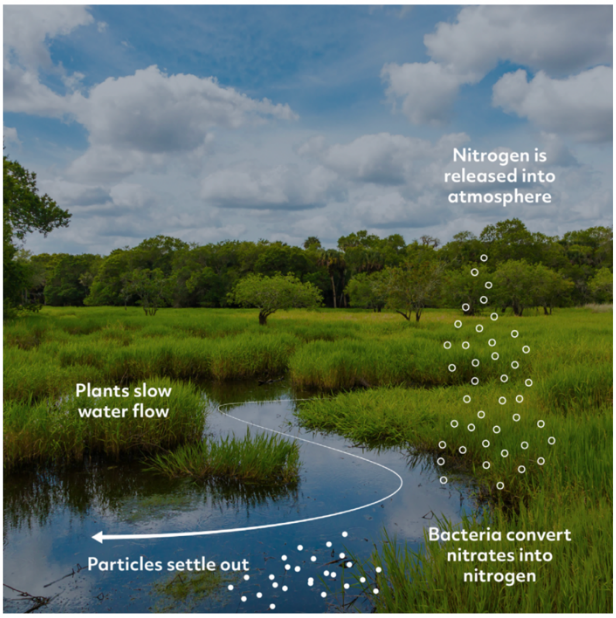


Figure 4.1, front page of the ecosystem biomimicry guide website.

Each page has a combination of three main elements. Firstly, each page has a few images that relay key concepts or help with explaining information from the descriptive text, see Figure 4.2. Secondly, there are grey blocks that contain the body of text. These blocks contain a combination of information, instructions and hyperlinks to websites and resources, see Figure 4.3. To not clutter the guide itself too much and have users slug through long web pages, the choice has been made to keep the pages themselves concise and practical, while allowing users the flexibility to open more detailed information, tools, and templates. Finally, each page contains a key takeaway and call to action.

Step 3 Biologize/ apply biomimicry thinking

> "All our knowledge has its origins in our perceptions."
>
> *-Leonardo Da Vinci*



Instead of only looking at the visual beauty of nature we can peer deeper into the intricate systems and processes that are happening in a balanced manner.

Image from Asknature.

Figure 4.2, Example of the start of each detailed step and images used in the ecosystem biomimicry guide website.

Biologize your problem and key components. It's about seeing things as functions and processes. That way you can search for similarities in the natural world.

It is also important to go out into nature yourself. Nature is everywhere, even in the city. Take a walk in a park, wander some streets, find a pond/stream or take a longer outing into a natural area outside the city.
First, be sure to just observe and be in nature. Take some time to experience and explore without any set goal. Be sure to take a notebook with you for any ideas and inspiration. You can observe an area with all 5 senses for example, and describe the same thing from each sensory experience. For more exercises see here.

Explore how natural systems solve similar challenges.
-First, look at the locally relevant ecological system models. Both in terms of biomes, climate zones, and ecosystems.
Find habitats that have similar environmental conditions and challenges. Identify the natural processes within that ecosystem and determine how these processes are managed and influenced.
For example, if dealing with water management, look at ecosystems that naturally handle large volumes of water, such as wetlands or riparian zones.
(Use sources like Asknature, panorama, scientific journal databases or Ecomimicry database(still to come).

-Next, if necessary you can look at similar biomes and climate zones in other regions.

-Lastly, you can look at ecotones at the border of your local context and the adjacent biomes and climate zones.

Try to come up with a minimum of 5 ideas/solutions to proceed with that pass an initial cost-benefit analysis. This does not have to be in depth but is mainly initial calculations and general gut feeling. Aim to have solutions that range between all 3 levels of abstraction.

The most important thing to envision is the feedback loop(s) that would be created/altered.
Do these keep themselves in balance (negative feedback) or would they spiral out of control (positive feedback)?

Write your ideas down or even better try and visualise them in whichever manner works best. Make sure to save them for the next steps in the process.

Next: Step 4.

Previous: Step 2.

Figure 4.3, Example of the grey information blocks and key message in the detailed steps in the ecosystem biomimicry guide website.

The final step also contains a form that can provide the base for a more detailed biomimicry database, see Figure 4.4. Creating such a database fell outside the scope of this project. However, to assess which categorisations can be made and which information about projects could be important, the choice has been made to include this first version of a form to stimulate knowledge-sharing down the line.

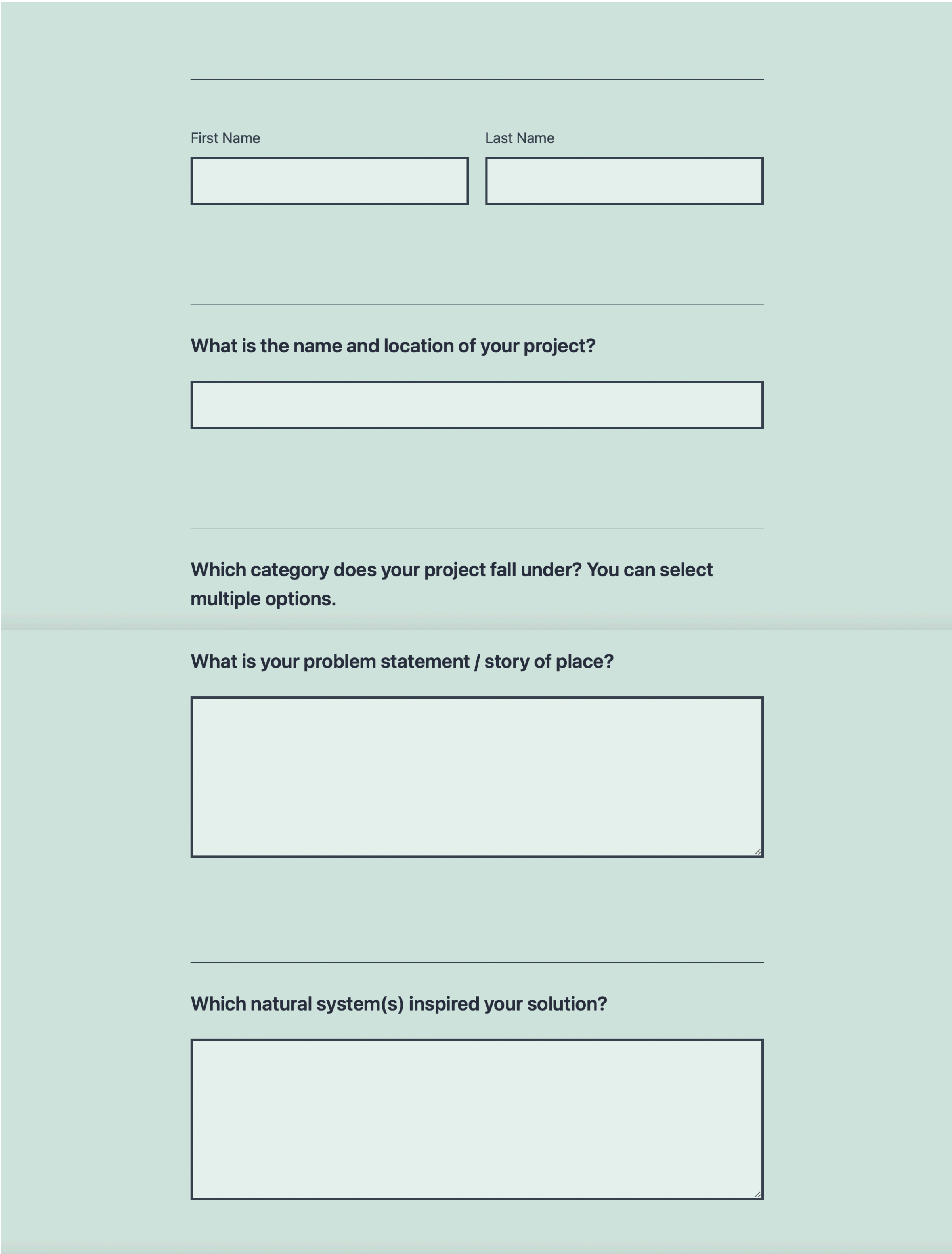


Figure 4.4, Example of the start of each detailed step and images used in the ecosystem biomimicry guide website.

C. Validation

Expert validation with Stefano Semprini, BiomimicrySA

To refine and validate the guide, it is crucial to incorporate expert feedback and practical testing. The information currently given is solid but could be a little hard to comprehend for users with no previous experience in Biomimicry. A suggestion has been given to expand the information presented in the grey blocks further. It was also advised to provide more detailed descriptions and practical directions for the sub-steps within each larger step of the process, to ensure that new users have comprehensive information to follow.
As currently constructed the guide should be primarily marketed towards existing biomimicry practitioners and systems thinkers who wish to use the guide themselves or utilize it in collaborative projects or client work. Further development of the guide should also see a dedicated page compiling all relevant resources in an organised manner, possibly including additional materials for further reference. As well as incorporating an example. Recommended future developmental steps, after this project is finished includes; creating a more detailed PDF that guides users through the steps and provides templates for filling in, And conducting workshops with test users to gather first-hand insights and feedback. This could be done physically or remotely. Finally, the project could be improved further by collaborating with actual clients and practitioners who are interested in biomimicry and have their own cases. This hands-on approach will help fine-tune the guide, making it more effective and user-friendly for a broader audience.

User Validation

To ask guided and semi-structured feedback from a group of test users a set of questions was devised. An example case was created to use for participants who were not working on a systemic project themselves. This example case has been adapted from a systemic project performed in the BII master, see Appendix III for the questions and example case. This user validation aimed to answer two main questions. 1. Does the system do what I hope it does? And 2. Can users perform the steps independently with the information currently presented?

In general, the information provided in Step 1 gave a good description of the expected results. Most users felt that it allowed them to make their own system map. However, a lot of users also noted not to be entirely sure what should all be in a system map or that they would forget certain aspects. Therefore, the ask was for one or multiple filled-in examples and a few even for templates.
In Step 2 the main leverage point identified by users was some form of convincing stakeholders/decision-makers. Especially convincing stakeholders of long-term benefits was an interesting answer.

For Step 3, the metaphor got a lot of positive feedback and users reported that they liked the use of metaphors. One user even came up with a metaphor for their specific project: 'Soil is the womb and vegetation is the midwife'. However, on the more technical side of things, users reported that more information was needed about ecosystem biomimicry. As for some, the information was still hard to distinguish from other biomimicry sources. Information was desired on: How to choose good models like looking at habitats or natural processes, figuring out which similarities in their system to look for, and what type of 'lens' you need to use for ecosystem biomimicry.

In Step 4 the relationship between the identified elements and the vision of the client was evident for the users, both for the users working with the example case or their own cases. While the information on the page was generally found to be sufficient, additions to the page could drive the message home harder. The importance of an integrative approach that considers ecological, social, and economic aspects could be stressed more. Some noted the desire for checklists or the like to ensure that all factors are considered. A sentiment that was shared is that holistic thinking may require experiential learning, but nature is the ultimate source of inspiration. Nature also provides the best examples of holism, which could be highlighted even more on the page.

All users were able to identify at least a few Ecosystem Services (ES) on campus or in their projects. Most users felt that listing ESs helps illustrate the benefits of the project or solution and provides a good comparison for choosing between multiple solutions. Some even noted that it could help showcase the benefits of your solution when presenting to a stakeholder. Overall, the feeling was that adding more ES can make a system more regenerative by enhancing ecological health. It was also proposed that Step 5 could benefit from providing clear guidelines on integrating these principles and seeing potential examples.

Step 6 generally provided sufficient information for brainstorming ways to test concepts. Mainly pilot projects and living lab tests were devised. Some users did question the necessity of including go/no-go moments for all future practitioners.
Life's principles were seen as effective tools that remain memorable after use, especially when used as a checklist. Users stated that checking more boxes would mean a higher chance of being holistic and regenerative and that what is lacking is proof of concept or practical examples of solutions. It was also suggested a few times that methods for gathering and analysing feedback and tracking the progress of implemented projects could be beneficial to the activity being performed.

In summary, while the guide is comprehensive and informative, it would benefit from more detailed examples, practical applications, and a focus on experiential learning to fully engage users and aid in the successful implementation of sustainable urban projects.

5. Discussion

A combination of a literature review, case study analysis and expert interviews have been performed to advance the field of ecosystem biomimicry, making the implementation more effective. The research findings have also been used as input for the first version of an ecosystem biomimicry process guide. This guide has been incorporated into a website for ease of reference and practicality. Having a tangible product enabled the guide to undergo a round of user validation.

Research
To effectively implement ecosystem biomimicry, diverse types of research are essential. Ecological research offers insights into local ecosystems and natural processes, while systems thinking helps map dynamics and identify leverage points. Economic analysis underscores the long-term financial benefits of biomimicry, helping to get the participation of stakeholders. Case studies provide practical examples and implementation insights, documenting successful projects, and highlighting best practices.

This multidisciplinary research underscores the need for a holistic understanding of ecosystem functioning and its integration into various fields. However, that is also where the biggest challenge lies. Interdisciplinarity requires professionals from different fields to have a certain base understanding of concepts and terms to effectively communicate. Ecosystem-level biomimicry emphasises the interconnectedness of ecological systems, which requires a profound understanding of local ecosystems. It therefore becomes the role of biologists to translate this ecological knowledge into digestible and understandable information for people outside the field.

Practicality for broad user base
Scientific research can inform a practical approach to ecosystem biomimicry for non-professionals by translating complex concepts into accessible, actionable steps. Clear examples, templates, and case studies from research illustrate successful applications and provide educational resources that simplify the biomimicry process. This makes it easier for non-professionals to identify and apply relevant natural models. Emphasising tangible benefits and cost-effectiveness encourages broader adoption. The case studies analysed were all performed by a team of researchers. It seems to be the best way moving forward to have this be done for novel ecosystem biomimicry projects as well. To minimize a single person's biases in the dissemination of best practices.
In addition, biomimicry must be contextualised within specific environmental, cultural and socioeconomic settings, integrating local ecological knowledge and collaborating with indigenous communities. This research did not dive much deeper into how to collaborate with indigenous communities. While believed to be important in the future, new research by socio-cultural experts should be performed.

Practical tools and guides that facilitate visualisation and abstraction are essential, supporting divergent ideation and system dynamics thinking, thereby making biomimicry more accessible and actionable. With the design of any visualisations and abstractions, you are reliant on the designers themselves. Meaning that the design and by definition good design will always be somewhat subjective. This is also the case in the resulting ecomimicry guide in this project. Which ultimately was designed by a single person making all the design choices. However, by performing rigorous user testing, the effectiveness of the design choices can at least be validated. The ultimate goal is not how pretty something looks or how sound the design considerations are but rather, how effective is the design in aiding practitioners to perform ecosystem biomimicry.

Barriers to implementation

Several barriers hinder the implementation of biomimicry at the systems level, particularly in urban planning. These barriers include a lack of awareness, professional knowledge, training, and accessible information. Addressing these challenges requires targeted educational initiatives and the development of comprehensive databases and tools that provide clear guidance and practical examples of biomimicry in action. Professional training programmes should be designed to equip urban planners, designers, and other stakeholders with the necessary skills and knowledge to apply biomimicry principles effectively. Moreover, interdisciplinary collaboration and knowledge-sharing platforms are crucial for fostering innovation and overcoming these barriers. By addressing these obstacles, the field of biomimicry can advance towards more widespread and effective implementation. I and the experts interviewed do acknowledge the difficulty of developing such a knowledge-sharing platform. Therefore, it will be crucial to have an interdisciplinary team working on such a tool from the start.

Validation

The user validation process provided valuable insights into two main questions: whether the system functions as intended and whether users can independently follow the steps with the provided information. Overall, I felt that users were able to follow most of the parts in each step independently. There were a few questions about some aspects but mostly the users required minimal help. It should be noted that the test users possessed some prior knowledge and experience with the key topics of biomimicry. Therefore, further testing is still required. Although this initial user test shows the promise of the guide and validates that the initial foundation is something that can be built upon. Testing to see if the system functioned as intended and specifically, if users acted and understood the steps as expected went well for a first run. Some parts did not go as intended, which were great lessons. By testing with users that have some biomimicry experience, targeted feedback could be requested. This helped to refine the website and guide to a 1.1 version as it were.

In Step 2 the main leverage point that was identified by users was some form of convincing stakeholders. I initially set out to have key leverage points be physically alterable things or processes. So, the frequency of users identifying other people came a little as a surprise. However, this was a good surprise. As in systems thinking, it is often believed that the highest leverage points are tied to beliefs and ways of seeing and thinking about the world. Therefore, focussing on changing the views of other people about things to align with your project ideas could be very valuable. Unfortunately, trying to change mental models is always the hardest thing to do. With practicality being one of the main objectives of the guide, mental models as leverage points were not intended to be the focus. This focus on people could be attributed to the nature of the example case and the projects on which users were working at the time of testing. It is good to keep in mind that users in this test saw decision-makers as the greatest leverage points for future development.

For Step 3, it was interesting to see that using a metaphor got positive results and even encouraged people to think more in metaphors themselves. Although not outlined in the guide itself, the users did come up with metaphors themselves. This leads me to believe that in this instance providing an example is more valuable than a description of how to perform making metaphors. The wish for more specific information on the ecosystem aspect of the biomimicry approach was great to hear about. Some users noted that things like encouraging a certain way of looking at their system and then finding inspiration for this in nature could be clearly outlined in more detail. Elements such as natural processes, trophic chains for energy transport and even habitat types could all inform solutions. Upon looking at the website as constructed at the time it was also fair feedback. This was one lesson that was immediately implemented and improved in the guide.

Most users struggled a bit with the go/no-go moment in Step 6. One user even remarked that he understood the idea but questioned whether it was necessary for a wide range of users. Upon reviewing this part myself using multiple example scenarios, the conclusion was that this part could lead to unnecessary confusion. Therefore, it has now been removed from the current version. However, the element should be explored in further tests to validate its usefulness and clarity. Perhaps prompting a return to the guide.

Moving forward
This study suggests several areas for future research. First, A guide such as this should be continuously improved with user testing and advances in ecological understanding. Developing practical tools and training programs are essential for making biomimicry accessible to a wider audience. These tools should include user-friendly guides, visualisation software, and interactive workshops that help practitioners apply biomimicry principles effectively. The continuous improvement should be paired with user validation. The validation rounds should ideally include different types of people in terms of age, professional discipline, work sector, cultural background and the case studies used. While also validating the guide more completely with the inclusion of steps 1 and 8 from the beginning.

Secondly, the development of a user-centric project database, that allows for searching based on sector, keywords and more must be explored. Creating and maintaining comprehensive databases that catalogue successful biomimetic strategies and case studies can significantly aid practitioners. These databases should include detailed descriptions of the natural models, the context of their application, and the outcomes achieved. Such resources would facilitate knowledge sharing and help standardize biomimicry practices across different regions and sectors

Thirdly, future research should delve deeper into the complexities of ecosystem dynamics. Particularly understanding the broader ecological processes that sustain the systems. Advanced ecosystem understanding can inform modelling and simulation tools to predict the outcomes of implementing biomimetic solutions in various contexts, considering both short-term and long-term impacts. Researchers and designers should focus on developing frameworks and methodologies that allow for the customization of biomimetic solutions to specific local contexts. This includes understanding the unique environmental, cultural, and socio-economic factors that influence the success of these solutions.

Finally, future research should emphasize the importance of long-term monitoring and adaptive management of biomimetic solutions. This involves tracking the performance of implemented strategies over time, evaluating their effectiveness, making necessary adjustments, and uncovering and sharing best practices.

I believe that this future research could improve the guide and process further. Which in turn will lead to the practice being more practically applicable for a large user base. Hopefully, this will result in successful long-term projects that are rooted in local knowledge, regenerative to the ecosystem and resilient.

Conclusion

My primary goal with this study was to uncover how research can support the effective implementation of ecosystem biomimicry. This study reveals that research supports the effective implementation of ecosystem biomimicry by providing a comprehensive understanding of ecosystem functioning. Each system's unique characteristics and complexities necessitate a deep understanding of local dynamics and processes. Research can also present successful biomimicry projects and extract best practices. Furthermore, a lack of knowledge about biomimicry and a gap between research and design practice are challenges that must be addressed. Research can aid in designing and developing guides and tools that bridge these gaps and support adoption by making the practice more accessible and effective for a broad user base. Guides must consider the context of the practitioner and introduce the practice gradually in a stepwise manner. Most importantly, an emphasis should be placed on a clear process that can be followed, which includes practical exercises that engage users with the topics and the natural world. Moving forward, collaborative knowledge-sharing and developing a robust biomimicry knowledge base will further support effective implementation.

Future research and development can build upon these findings as well as the first version of the guide.
This study underscores the importance of continuous improvement in biomimicry guides through user testing and advances in ecological understanding. Future research should focus on developing practical tools and training programs, creating comprehensive databases of successful biomimetic strategies, and deepening the understanding of ecosystem dynamics. Customization of solutions to local contexts and long-term monitoring of biomimetic projects are essential. By addressing these areas, the guide can become more accessible and effective, promoting successful, resilient, and regenerative projects rooted in local knowledge.

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Appendices

Appendix I, Interview Jess Berliner, Learnbiomimicry.

- What do you believe are the biggest needs or hurdles for new practitioners to successfully engage with biomimicry?
    - User Context is everything. Its about the pull that people will need to have. Which aspects of Biomimicry are relevant to them? Why should they want to use it. People needing to have a curious approach, not immediately finding the one right answer.
    - Understanding which aspects of biomimicry are relevant to them - Understanding why they want / need it - Needing to be curious, not “right” (initially) - Interdisciplinary
- How do you approach making biomimicry principles and processes understandable to a broad audience with on occasion little to no experience?
    - Find context of users again, most people just curious about Biomimicry. Introducing things bit by bit and grounded in their reality.
- What are some of the biggest challenges or concerns you have heard from people on using biomimicry approaches?
    - Biology - Time consuming. Underestimate how long things take to do properly. Maybe some greenwashing concerns.
- What is your approach to making a biomimicry database?
    - It snot about the biomimicry, but the person who is doing it. Relatability.
- How do they think about community engagement and bottom up sharing of projects/ knowledge?
- There could also be the potential to use Learnbiomimicry’s network for finding test users, to further develop the guide. And eventually market the guide to interested users.

Appendix II, Interview Milan Master,

-Always important to ask why a problem is happening. A chain of why questions. (first step)
-Prompt people to look bigger, place is spot on. Then look bigger at the whole area and then the same biome in other places. Look at the macro and micro scale. Local context should inform the bigger and smaller. (Localized context)
-Money is always a limiting factor. People must think beyond this limiting factor. Biomimicry could be more cost-effective long term. Question assumptions and push people on their comfort level about limiting factors.
-Difficult to biologize when people have not been in nature. Examples are good, but especially examples that speak to the specific person. (Customizable examples based on industry/sector? Think about categories and always have an other tab) have it be easier and better for people to connect with and to nature.
-Give a framework for identifying/prompting leverage points and mental models from different perspectives to also look at the behavioural side of things. Distil it down to a single point to address.
-People must understand it needs a process. Not just jump to the easiest solution right away. Because the process is designed to get the best solution. Just like evolution and the time it takes. (nice analogy) a termite mound is not build in a day. A forest does not grow overnight. We need to look more at the process and time scales. The consumer is not just going to change their behaviour it takes the developers/producers. No blame on consumers/users.
-Encourage going into and interacting with nature. Really look at some natural thing and understand that in its own way it's a living organism or part of living cycles. Have one or multiple actual exercises that people should do to connect. And then brainstorm with biomimicry. It is engaging all senses with the natural world.
-(tip for practicality and useability) Making it customizable to their situation. Either work/sector/industry or even interests. Make and provide also a very condensed version of the process. A simple test version for people to see the value. Find the entry point (commonality) that appeals to the most people.

Appendix III, user validation test case and questionnaire

Heidelwerfpark information designed by Connor Brennan, Cato Freie, Josh Hauser & Nehis Osagie

Problem Statement and Analysis for Heidelberglaan at Utrecht Science Park (USP)
Problem Statement
Heidelberglaan, a central street at the Utrecht Science Park (USP), presents an interplay of issues impacting its usability and environmental quality. The current state of Heidelberglaan presents several issues. A lack of pleasant gathering spaces diminishes the social functionality of the area, discouraging informal interactions. This issue is compounded by pervasive noise pollution, which stems from multiple sources including public transport lines, concentrated pedestrians, and ongoing construction. The hard surfaces of surrounding buildings amplify this noise, making the area uncomfortable for pedestrians. The minimal presence of vegetation exacerbates these problems by failing to provide natural sound barriers or contribute to air quality improvement and temperature regulation. Additionally, the stagnant body of water starting at the Genevelaan crossing under the Heidelberglaan fails to support a thriving ecosystem. The scarcity of green spaces also leaves the area visually unappealing and less adaptable to weather variations, which will increase in frequency. The Heidelberglaan and surrounding space suffer from Urban heat stress, small floods because the water cannot escape, poorer air quality and the wind tunnel effect. Furthermore, the absence of sheltered or semi-enclosed areas limits the functionality of outdoor spaces, particularly during adverse weather conditions, thereby reducing the overall usability of Heidelberglaan.

5 problems of the USP

Lack of pleasant gathering space

Excess noise pollution

Minimal ecosystem services

Lack of green/natural spaces

No sheltered/semi enclosed areas

Instructions: **Please read the information provided for each step. At the end of each step, answer the questions provided.**

-For step 2 an example leverage point can be the direction board of the campus, or ecological literacy of the employees that work on development.
-For step 3, A metaphor of seeing the Heidelberglaan can be as a blood system. The square next to the library is the heart, other buildings and key locations are organs, and all the paths function like arteries. For the ecological analysis focus on a specific part of Heidelberglaan (e.g., a building or street section).
-For step 4, one of the visions of the UU is to become the most sustainable university in NL.
-For step 5 an example of a regenerative concept is bioreceptive walls for moss growth.
-For step 6, Give an example of a biomimicry product and ask what needs to be done to get it into a working product. (DeLight lamp)
-Step 7 Choose one concept you find the most promising and use the life's principles as a checklist. Does it align with the strategies in Life's Principles?

Step 1: System Analysis

1. Do you feel the information gives enough of a description of what the result should be?
    1. Can you imagine what a good result would look like?
2. What additional information, if any, do you need to better understand the system?

Step 2: Identifying Leverage Points

1. What areas in the Heidelberglaan system do you think small changes can lead to significant impacts?

Step 3: Applying Biomimicry Thinking

1. Does the metaphor help you understand or look differently at the Heidelberglaan?
2. What functions can you identify in your focused building/area?
3. What processes can you identify in your focused building/area?
4. Do these functions and processes relate to the broader ecological context?
    1. If yes, in what ways?

Step 4: Promoting Holistic Thinking

1. How are the elements identified in Step 3 related to the vision of Utrecht University?
2. Based on your knowledge and experience, is the information on the page sufficient to understand and apply holistic thinking? If not, what is missing?

Step 5: Embracing Regenerative Design

1. Which ecosystem services (ES) currently exist on the campus?
2. Which ES do you think could be added?
3. Do you feel that if you add more ES's, does the system become more regenerative? If yes, please explain how.
4. How could these concepts be integrated into the existing campus environment?

Step 6: Practical Application

1. Can you use the information provided so far to brainstorm a way to test your concepts? If not, what is missing? If yes, how would you do it?
2. Looking at the roadmap, can you identify crucial go/no-go moments?

Step 7: Evaluating & Continuous Improvement

1. Use the life's principles as a checklist to see which strategies have been incorporated.
2. Do you feel with the incorporation of strategies, that you have created a regenerative holistic product? If not, what is lacking?

What feedback do you have on the overall process of using the Ecomimicry Guide?
How do participants go through the guide? Do they all go through all the steps?
Which step(s) were most valuable?
After completion, do you believe the guide as is can help users with getting more complex and regenerative solutions? If yes, what convinces you of this?