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A Biophilic Design Guide to Environmentally Sustainable Design Studios

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Chapter 1
Introduction

Abstract Architectural education has openly embraced environmentally sustainable design (ESD) in studios. Differing from convention design studios, they use green design frameworks to guide the design, as well as showcase sustainability. These frameworks are developed based on green building certification schemes, used extensively in the industry. In most cases, these industry certification schemes are introduced to students as tools that form an integral part of the design process. In current practice, sustainable design solutions focus on energy and resource conservation, using new technologies and scientific advances that address environmental sustainability issues through the improvement of building performance. In contrast, biophilic design (BD) focuses on designing for human sensory experiences. It is grounded in strategies that bring humans closer to nature, fostering the concept of biophilia: a psychological orientation of humans with a desire to connect to nature and environment. However, the design approaches of BD and ESD are very different, and currently, BD principles are rarely used in ESD studios. This book attempts to bridge these two design approaches, proposing an innovative educational approach for incorporating BD in ESD studios. The ultimate aim is to empower students to develop BD frameworks that can bridge the gap between sensory experiences and sustainable building performance.

1.1 Background

Buildings have a significant impact on the environment (Dib & Adamo-Villani, 2014), consuming 40% of natural resources globally (Ness & Xing, 2017). To mitigate the negative impact of buildings, the architectural response has been to direct design toward more sustainable outcomes. This approach is distinguished from conventional design techniques by the explicit use of predetermined sustainability targets. Various Green Building Rating Tools (GBRTs) have been developed and used extensively for this purpose (Yudelson, 2008).

Existing rating tools vary in terms of their objectives, criteria, and methods for certifying building designs (Gou & Xie, 2017; Xue et al., 2019); however, they are

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all based on the same principle: providing a list of criteria for evaluating building performance (Yeang & Spector, 2011). Currently, GBRTs primarily focus on building design's technical aspects, such as construction materials and consumption of energy, but often fall short to support a holistic approach to design (Xue et al., 2019). As a result, sustainable buildings often feature a highly sophisticated technical expression but lack human-nature connectedness (Kayihan et al., 2018; Kellert, 2016).

Biophilia is an inherent human affinity to nature (Wilson, 1984). Biophilic design aims to support this innate human tendency by designing buildings that support human-nature connectedness (Kellert, 2008). Research indicates that this connectedness with nature can improve psychological wellbeing, nurture positive emotions, and elevate pro-environmental behaviour (Wijesooriya & Brambilla, 2020; Wilson, 1984). The technical expression of contemporary sustainable buildings has more potential to disconnect occupants from nature rather than foster biophilia; biophilic design, therefore, is a critical missing link in contemporary ESD. In the last two decades, biophilic design has been popularised extensively by Kellert (2008), Kellert and Calabrese (2015) and others. Browning et al.'s (2014) book "14 patterns of biophilic design" has contributed significantly to the emergence of design frameworks for BD, and the consequent recognition from the industry that modern sustainable buildings lack human–nature connectedness. The industry responded with the addition of awarding credits for biophilic design in certain building certification schemes, such as LEED and BREEAM (BRE, 2013; USGBC, 2013).

Green building technology and ESD have become fundamental parts of architectural education (Lee & Huang, 2011), leading to the emergence of unique pedagogical practices, known as sustainable design studios (De Gaulmyn & Dupre, 2019). While sustainable design studios share some features with conventional design studios, they have several distinct characteristics, such as engaging deeply with the notion of sustainability, dealing with multi-faceted and complex problems of sustainable design, adopting an interdisciplinary approach to design, drawing extensively on research when making design decisions, using a set of predetermined criteria for assessing the sustainable performance of buildings and asking students to provide evidence that their building design achieves these criteria (Wijesooriya et al., 2020). To fulfil all these requirements, sustainable design studios use design frameworks similar to those developed by the industry, often using various GBRTs, such as LEED (Dib & Adamo-Villani, 2014) or STAR (Drapella-Hermansdorfer, 2018).

Nevertheless, ESD educational settings are constrained by the lack of focus on the human experience. The need to enhance sustainable architectural design practices to nurture human-nature connectedness demands attention to the use of BD in ESD studios. However, the literature provides very few examples of how BD can systematically be incorporated into architectural education. A recent review shows that even in instances where design studios focused on BD, the key objective was the sensory experience of design, overlooking sustainability and missing the opportunity to integrate the two aspects (Wijesooriya & Brambilla, 2020).

Further, contrary to the abundance of ESD frameworks, only a handful of BD frameworks are found in the literature. The majority of these frameworks, such as those developed by Kellert (2008) and Browning et al. (2014), emphasise qualitative sensory experiences associated with human-nature connectedness. However, they rarely relate the sensory aspects of biophilic design to quantifiable measures of sustainable building performance. For this reason, these frameworks are inadequate for teaching students sustainable biophilic design in ESD studios, where students learn to assess the sustainability of their designs using a set of criteria similar to those found in the building industry (Wijesooriya et al., 2020). There is a crucial need to facilitate students' capabilities to create and use BD frameworks that are compatible with ESD and support both qualitative and quantitative design responses.

Addressing this need, the authors have conducted an educational design research study in an ESD studio during which they developed and investigated an educational innovation for teaching BD (Wijesooriya et al., 2020). This educational innovation focuses on empowering students to develop their BD frameworks compatible with the ESD or adapt existing BD frameworks for ESD studio projects. As a part of this work, authors, in a previous study, have developed an educational design approach for systematically designing and researching educational innovations in ESD studios (Wijesooriya et al., 2020). This approach is based on a Reflective Action Conjecture Map (RACOM), introduced briefly in the next section.

1.2 A Reflective Action Conjecture Map for Educational Design

Schön's (1987) work on reflective action is highly influential in architectural educational research. However, reflective action does not detail the components of an educational design and how they are interrelated. Sandoval (2014), recognizing that this is also true in educational design research in general, proposed a conjecture map to address this gap. Combining these two approaches, the reflective action model based on Schön's (1987) work and the conjecture mapping approach for educational design research developed by Sandoval (2014), it is possible to derive a Reflective Action Conjecture Map (RACOM): a generic model for supporting educational design that has been primarily developed for ESD studios (Wijesooriya et al., 2020) (Fig. 1.1).

The RACOM illustrated in Fig. 1.1 has five main components adapted from the conjecture map proposed by Sandoval (2014). The high-level conjecture is the critical assumption made on how to support students' learning to grasp and practice sustainable design approach, i.e. sustainable biophilic design. This conjecture is usually identified in response to a particular encountered educational challenge (e.g., fostering biophilia in ESD). What is recognised as the embodiment in this map is the collection of all the educational design elements included in educational innovation to support the students, such as lectures, materials, and tools. The mediating processes are the different activities that students complete to achieve the learning outcomes, which are the objectives the educators set up in the education innovation.

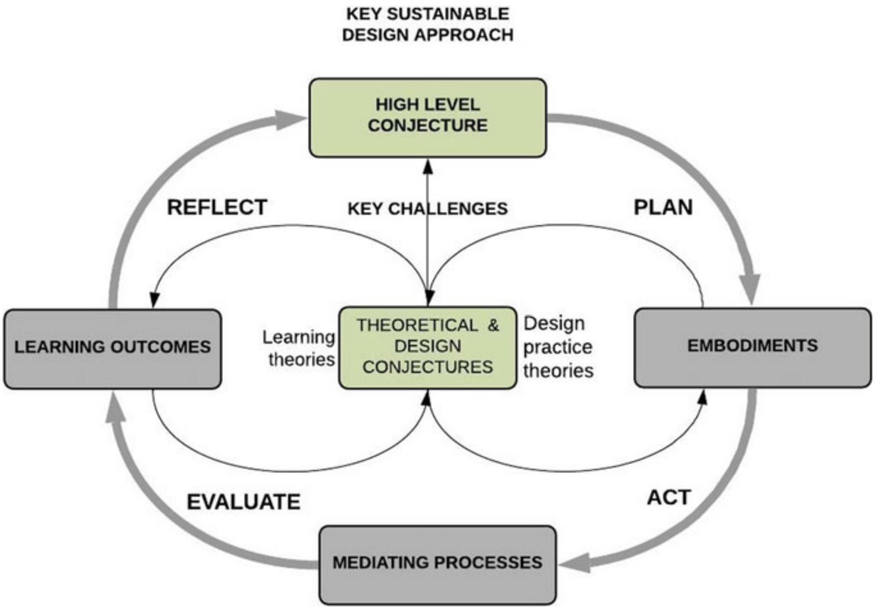

Fig. 1.1 Reflective Action Conjecture Map (RACOM) adapted from Wijesooriya et al. (2020)

Depending on each learning outcome, the mediating processes may vary. Sometimes one mediating process will help students to achieve multiple learning outcomes. Sandoval's conjecture map proposes that artefacts constructed by students and the observable interactions among students can be used to identify and assess these learning processes and outcomes.

This RACOM can be used and adapted based on the type of conjecture under examination. There are two main types of conjectures: theoretical conjectures and design conjectures. The main difference is that theoretical conjectures focus on how people learn, whereas design conjectures focus on how to teach within the educational innovation.

Theoretical conjectures are assumptions made by educators regarding the type of learning required to achieve the desired learning outcome. These are generally based on educational theories on learning. For example, if the educator expects a student to develop procedural knowledge, learning by doing would be an appropriate theoretical approach. Hence, the theoretical conjecture is that when students learn by doing the work, they can develop procedural knowledge. These learning theories usually point out the type of educational design elements that can be embodied in educational innovation.

Design conjectures, instead, are ideas that assist the educator in selecting concrete embodiments that support students' learning and engagement in the mediating processes. For example, if the student needs basic knowledge on a sustainable design approach, the educator may assume that a lecture will support the student learning of this knowledge. Hence, the lecture is the embodiment, and the assumption that direct teaching is a suitable approach is a design conjecture. If the student is asked to write a summary of the lecture, this summary is an artefact educator can use to assess the mediating process. And if the educator initiates a discussion and asks students to participate, then the mediating process can be observed with the student behaviour and responses. Design conjectures can be grounded on educational theory or can be identified by exploring relevant empirical studies.

There is a close relationship between the theoretical and design conjectures, and for this reason the RACOM model has included both as one component. For example, while developing the RACOM for BD, evaluative judgement was identified as a theory that guided the theoretical conjectures. When building further on this theory, self-assessment, peer-assessment and feedback were identified as possible embodiments to effectively support development of the evaluative judgment. Therefore, the evaluative judgement also contributed to the design conjectures.

The ideas about the relationships between the high-level conjecture, embodiments, mediating processes and learning outcomes are adapted from the conjecture mapping (Sandoval, 2014). In the RACOM, Sandoval's (2014) proposed the linear map is integrated with the reflective action model—plan, act, evaluate, and reflect—based on Schön (1987) that closely depicts the typical design activity facilitated by the teachers in the design studio. This integrated model showcases the components of a conjecture mapping and the cyclic process of a reflective action model in between the components.

Nevertheless, RACOM is a generic model for educational design in ESD studios. It could be applied not only for BD but for teaching other sustainable design approaches. In this case, each model's component requires a systematic exploration when developing a specific RACOM for teaching other sustainable design approaches. In our case, a comprehensive study was conducted to explore the key challenges and characteristics within ESD studios to derive a high-level conjecture for educational innovation. Further, the current research literature on ESD studios was reviewed, and embodiments used within the reported studies were identified to select the most appropriate educational design elements for the RACOM developed for BD. Similarly, learning theories and underpinning theory of design practices were identified to support the premise of using theoretical and design conjectures in the RACOM for BD. The same literature review was used to identify typical learning outcomes in ESD studios and the student artefacts associated with the mediating processes. The themes derived out of the extensive literature survey on ESD studios (Wijesooriya et al., 2022) are presented in Fig. 1.2, with an extended version given as Appendix A.

While conducting an extensive literature survey on design studio projects, only a few studies explored biophilic design and none of them was on ESD studios. Hence the themes given in Fig. 1.2 are from ESD studios in general and can be helpful when developing a RACOM for any sustainable design approach. The RACOM for BD framework development process is discussed in detail in Chap. 2.

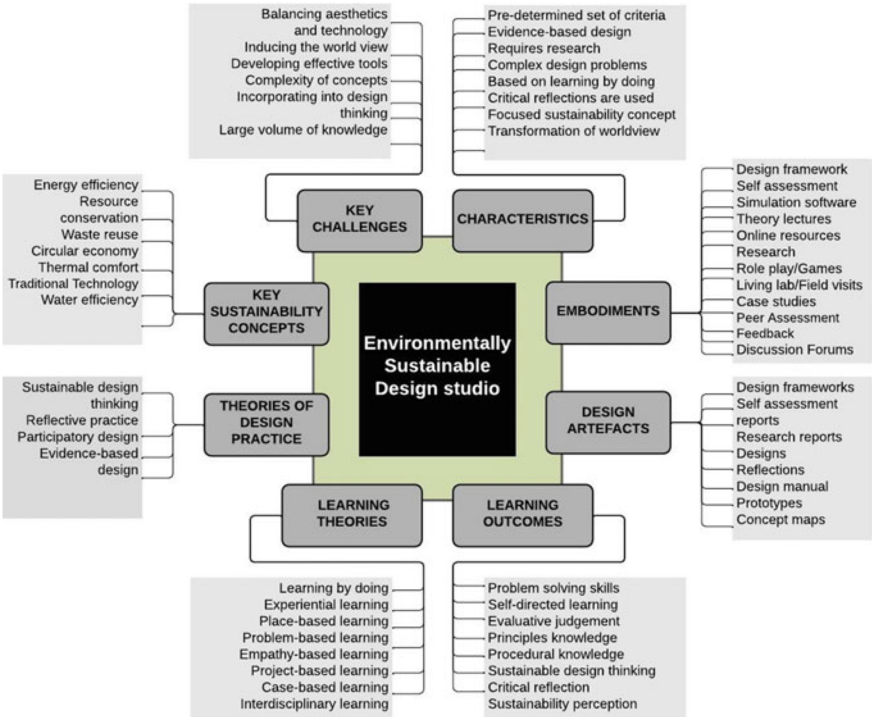

Fig. 1.2 Pedagogical framework for ESD studio adapted from Wijesooriya et al. (2022)

This book illustrates the RACOM development process and reflects upon the results of this educational innovation, providing a useful guide for educators interested in systematically developing education innovations and implementing BD within ESD studios.

1.3 Navigating the Book

This book presents a guide for educators, and it assists them in incorporating BD in ESD studios. Simultaneously, it also offers a guide for students for developing and adopting BD frameworks. Therefore, the structure of the book reflects this dual purpose. Figure 1.3 shows this structure and the links between different chapters.

This chapter describes the background, the need for this book, its structure and how readers could navigate it. Chapter 2 describes the proposed educational design approach. Chapters 3–6 present the practical guides for incorporating BD in ESD. These chapters can be used by students who want to learn how to develop and adopt BD frameworks. Chapter 7 discusses implications for practice when implementing this design approach in studios. It also provides directions for further development

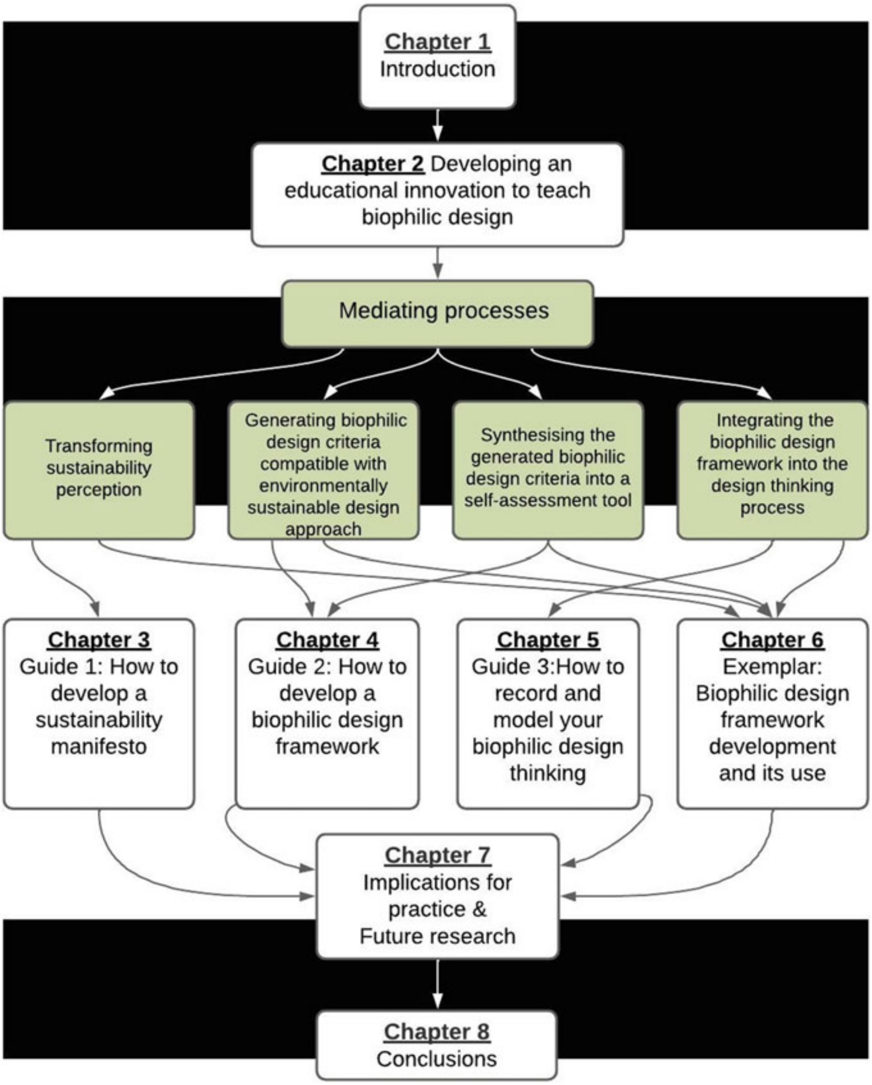

Fig. 1.3 Structure of the book

and research of pedagogical innovations for ESD studios. More detailed outlines of each chapter are provided in the next section.

Educators may refer to this guidebook either to teach students BD in an ESD studio or develop a RACOM for another sustainable design approach. To teach BD within an ESD studio using the proposed RACOM for BD framework, educators could read through the RACOM development process outlined in Chap. 2 and then use the three guides provided within Chaps. 3–5 and the exemplar in Chap. 6 for developing and implementing their educational innovation into their own studio. By reading Chap. 7, educators can get some insights on arranging tasks within the studio, discursive practices, and assessment of learning outcomes. Educators interested in BD and looking for research can refer to further study directions in Chap. 7.

Students who want to develop a BD framework may start from Chap. 3 and then move to 4 and 5. Chapter 3 guides to establish a sustainability perception or "sustainability manifesto" that focuses on BD principles. It also includes a definition of nature that guides the criteria categorisation in Chap. 4, which presents a systematic technique to develop a BD framework. Chapter 5 guides on the use of the design framework and identifying the design thinking process. Chapter 6 has an exemplar of a sustainable design project that showcases the use of a BD framework.

1.4 Chapter Outlines

Chapter 1: Introduction

This chapter introduced the background while highlighting the need for this book. It also briefly outlined the educational innovation and educational design approach undertaken by the authors to integrate BD within an ESD studio. This chapter includes a brief outline of the components of the generic model used for the educational intervention.

Chapter 2: Developing an educational innovation to teach biophilic design

This chapter demonstrates the development process of the RACOM for BD, accounting for the lessons learnt during the implementation and iterative refinement of this framework in a sustainable studio. The high-level conjecture discusses the critical challenges identified to support students developing and using a BD framework within an ESD studio. Theoretical and design conjectures explain fundamental learning and design practice theories concerning the use of design frameworks within ESD studio. Each learning outcome is elaborated with the mediating processes and the educational design's embodiments to support those processes.

Chapter 3: Student Guide 1: How to develop a nature-centric perception for a sustainable built environment

Chapter 3 guides students in developing a perception of the sustainable built environment that encompasses biophilia. The chapter presents how sustainability is perceived across its three dimensions—human-centric, nature-centric and built-centric—within a sustainable design. The discussion demonstrates how BD falls within the nature-centric perception, encouraging a focus on that dimension to bring BD into a typical ESD design. Highlighting the global environmental movement's concerns, theoretical ideas around deep ecology and ecological thought, the chapter argues that nature is the pivotal point in sustainability. This chapter can be used by educators as an embodiment in their unit of study.

Chapter 4: *Student Guide 2: How to develop a biophilic design framework*

This chapter presents a technique to develop BD frameworks. It initially discusses the main difference between ESD and BD approaches to design. Then, it overviews the techniques for BD framework development, drawing upon the analysis of different biophilic design frameworks currently in use. It proposes the *process bridging technique* to generate BD criteria compatible with ESD approach, and it demonstrates its use with examples. This chapter is grounded on the common categorisation presented in Chap. 3. This guide is for students also provides clear instructions to synthesise the developed BD framework into a tool for self-assessment of their BD.

Chapter 5: *Student Guide 3: How to record and model your Biophilic design thinking*

This chapter provides a practical guide for students, and it can be used by educators as a component of their unit of study development. It outlines how students can use their BD framework within the design thinking process by showcasing some typical models currently adopted by students. The various design activities required to use the design framework in the ESD project are then illustrated and explained in detail. Further, this chapter provides instructions and suggestions on how to record the biophilic design thinking process.

Chapter 6: *Exemplar: Biophilic design framework development and its use*

This chapter provides an example that illustrates how to use the process bridging technique, presented in Chap. 4, to develop a BD framework and synthesise the derived BD criteria into the self-assessment guide. It further demonstrates the use of a biophilic design thinking model that was introduced in Chap. 5, to design a building and assess it using the self-assessment protocol.

Chapter 7: *Implications for practice and future research*

This chapter discusses some of the practical challenges educators may encounter while implementing this guide. The use of task structures, discursive practice, and assessment artefacts are discussed, with insights from the authors' experience in conducting educational innovations within ESD studios. Directions for the future research and development are given by highlighting areas for educators to conduct research.

Chapter 8: *Conclusions*

Conclusions chapter summarises the key features of the educational design with brief outlines of each Student guide. A reflective account is given on the experiences from the studio with potential future uses of the guide.

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Chapter 2
Developing an Educational Innovation for Biophilic Design

Abstract Teaching students to practice biophilic design (BD) in an environmentally sustainable design (ESD) studio may enhance human–nature connectedness in their future design outcomes. However, integrating BD within ESD requires the development of a framework that is compatible with both approaches. Hence, a systematic teaching approach is critical to guide students in developing such a design framework. Reflective Action Conjecture Map (RACOM), an educational design approach for the ESD studio is developed that can guide educational designs to teach different sustainable design approaches. An educational innovation based on RACOM that facilitates students to develop BD frameworks is presented demonstrating the development process. This educational innovation aims to support students in overcoming three challenges: (1) shifting the sustainability view to derive common categorisations for criteria, (2) a systematic method to bridge ESD and BD, and (3) integrating the BD framework into the design thinking process. Three embodied educational design elements, namely, sustainability manifesto, success matrix and reflective portfolio are identified could support students to develop and use BD frameworks in sustainable designs.

2.1 Introduction

The previous chapter introduced a generic Reflective Action Conjecture Map (RACOM), an educational design approach for the ESD studio. Building on that approach, this chapter demonstrates how a RACOM for BD was systematically developed to support students in the development of a BD framework within a typical ESD studio. The RACOM for BD frameworks is presented first (see Fig. 2.1) followed by detailed descriptions of each component.

High-level conjecture is outlined by showcasing how a unique characteristic of the ESD studio and the identified challenges were used in the process. The three challenges are discussed pointing out the current debate on ESD studio education. A further mind-mapping exercise is shown (see Fig. 2.2) where the pedagogical

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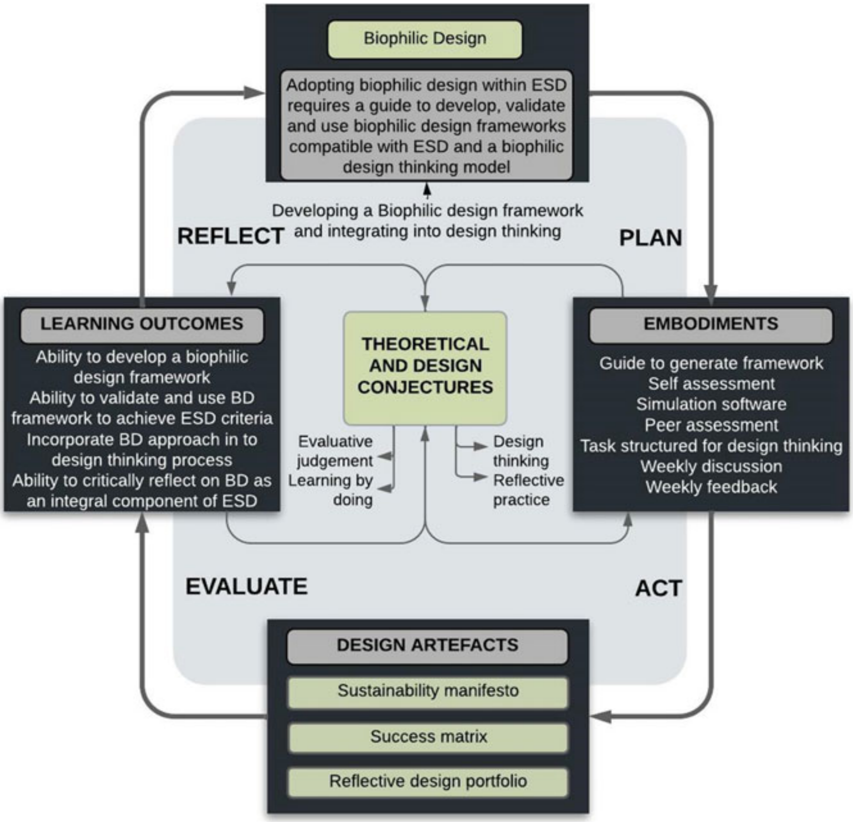

Fig. 2.1 A reflective action conjecture map for biophilic design frameworks

ideas that could potentially assist in overcoming the challenges are given. Thereafter the theoretical and design conjectures are outlined showcasing how they link embodiments, design artefacts and learning outcomes (see Fig. 2.3).

Each of the design artefact is detailed with a conjecture map showing how it can support to achieve learning outcomes through mediating learning processes. Finally, the develop process is shown in steps allowing the educators to replicate the same process for distinct purposes.

This chapter is intended for educators where the developed RACOM for BD frameworks can be directly adapted in a sustainable design studio.

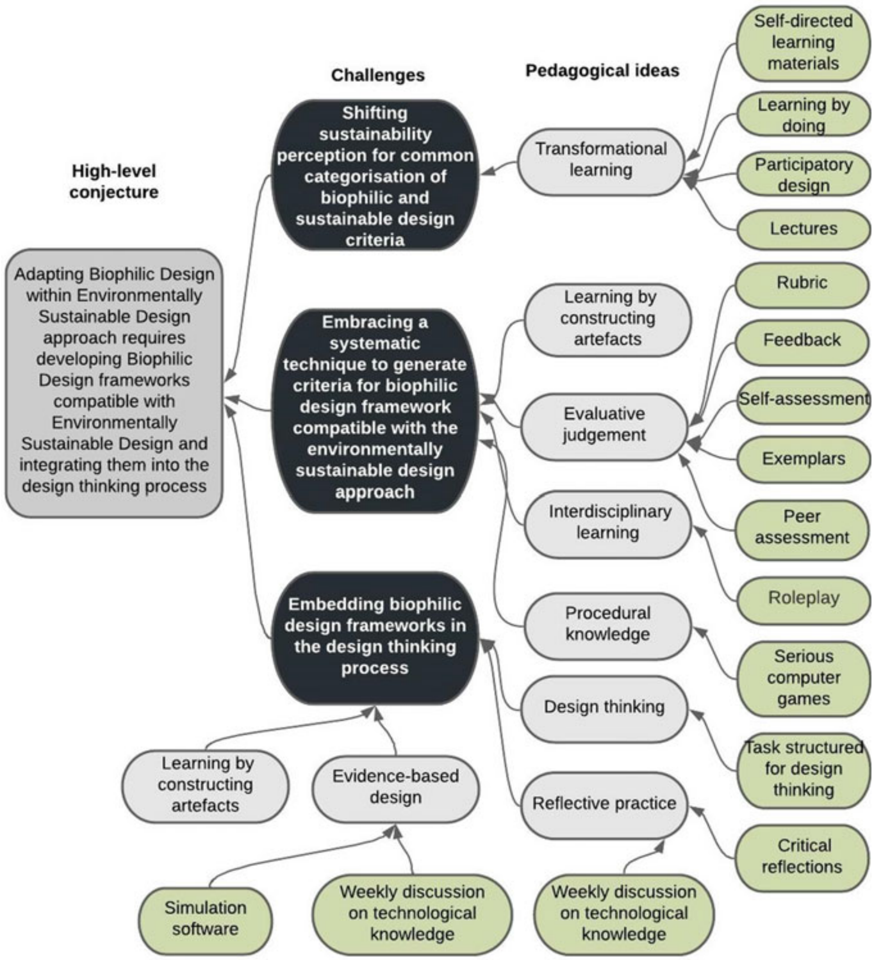

Fig. 2.2 Mind map deriving the high-level conjecture

2.2 A Reflective Action Conjecture Map for Biophilic Design

A Reflective Action Conjecture Map (RACOM) is an educational design approach that can be used in an environmentally sustainable design studio. RACOM can support educators in developing an educational innovation to teach various sustainable design approaches, such as energy-efficient design, passive solar design and biophilic design.

The development process for one such educational innovation is described in this chapter, and the RACOM development process for BD is described in Sect. 2.5.

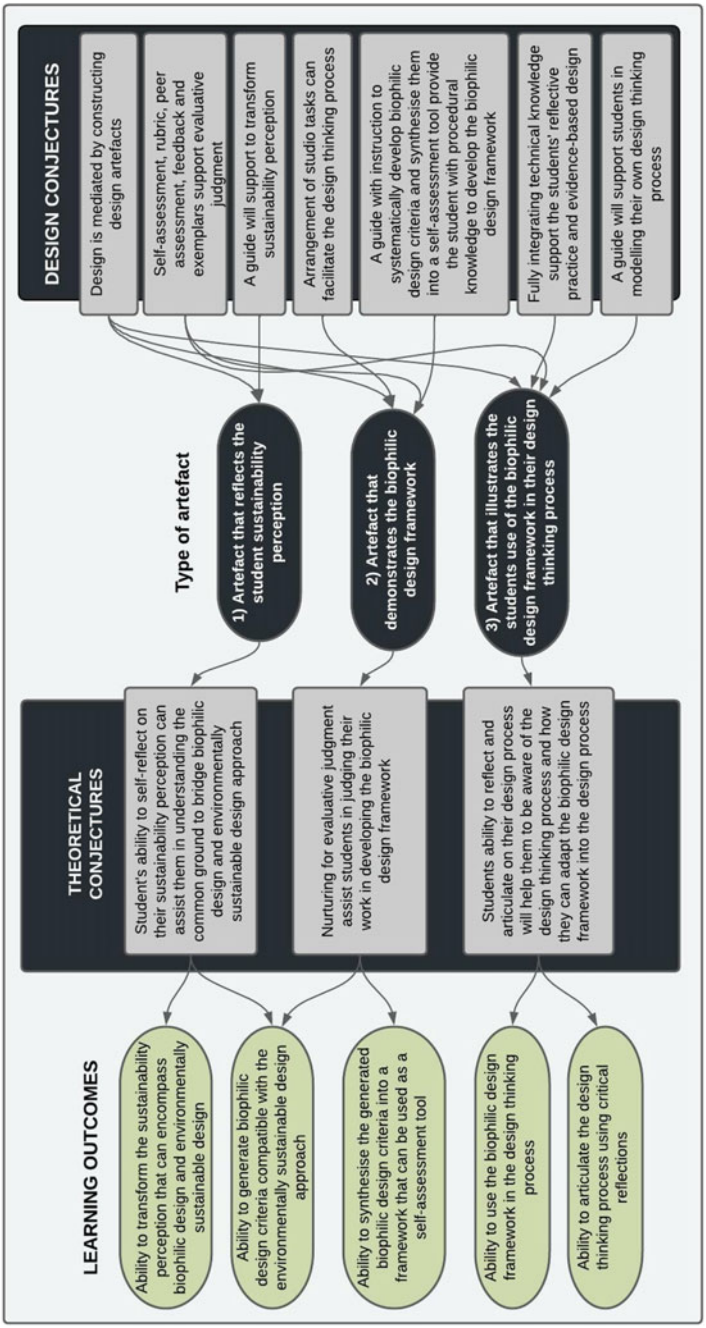

Fig. 2.3 Associating theoretical and design conjectures with design artefacts and learning outcomes

Using the abovementioned process, a RACOM for BD (Wijesooriya et al., 2020) was developed and implemented in an ESD studio. After evaluating the student responses and reflecting on the authors' experience in conducting the studio, the model was refined and further developed (Fig. 2.1).

As Fig. 2.1 illustrates, the RACOM for BD is focused on the BD framework development. This RACOM is a comprehensive model that includes all the pedagogical ideas that support students in developing BD frameworks and using them in a sustainable design studio. Educators can use the model by adapting its specific elements to suit their design studio project.

The high-level conjecture for BD framework development is discussed below to show how the different pedagogical ideas are connected to the key challenges. The theoretical and design conjectures are presented, highlighting their relevance in developing educational innovation. Mediating processes, learning outcomes and embodied educational design elements demonstrate themes used in developing educational innovation.

2.3 High-Level Conjecture

Identifying the high-level conjecture will shape other components in this educational innovation and require careful attention. This starts with looking at both the ESD studio's characteristics and the sustainable design approach that should be introduced. The previous chapter highlighted that developing a BD framework compatible with the ESD approach is the key strategy in bridging BD and ESD. Three challenges faced in developing a BD framework are identified thereafter and explored in detail in this section: (1) shifting the sustainability view to derive common categorisations for criteria, (2) a systematic method to bridge ESD and BD, and (3) integrating the BD framework into the design thinking process. Further, the support required to overcome these challenges in terms of learning theory and educational design elements are also outlined.

2.3.1 Shifting the Perception of Sustainability to Bridge Environmentally Sustainable Design and Biophilic Design

It is evident that an educational approach to facilitate BD requires developing a BD framework compatible with current ESD practice, however, the difference in the criteria used in BD and ESD frameworks contributes highly to their incompatibility. BD criteria focus on sensory place-making, while ESD criteria focus on building performance. These two categorisations of criteria for assessing designs make the integration of BD and ESD frameworks challenging.

Current green building rating tools (GBRTs), commonly employed as design frameworks in ESD, categorise criteria into the following groups: energy, water efficiency, resource use, site management and air quality (Building Research Establishment, 2013; U.S. Green Building Council, 2013). They also include aspects around the management of sites and construction, the engagement of professionals and innovation. These categories are focused on building performance. Each criterion is linked to concrete, quantifiable indicators that are used for awarding credits during certification. This provides transparency, and the design strategies can be easily replicated and adapted for other buildings.

In contrast, the available BD frameworks reference natural elements—such as the use of natural processes, nature in space, nature in place, direct experience of nature, the indirect experience of nature and evolved human–nature relationships (Browning et al., 2014; Kellert, 2008; Kellert & Calabrese, 2015)—to categorise criteria. These categories are focused on sensory place-making aspects and their criteria are highly qualitative and not easily measurable. Therefore, it is harder to provide firm evidence showing how well a particular criterion has been achieved. Further, BD is experienced as sensory stimuli, which, unlike ESD, is not always directly sensed or visible.

In short, sustainable design focuses on a building's technical characteristics, whereas BD focuses on sensory, spatial qualities. There is an epistemological gap between these two approaches: not only in their pragmatic application but also in the associated fundamental perception of sustainability. This gap is reflected in both education and practice. Creating a common categorisation for criteria that combines BD and ESD is a challenge. Adopting a new way of thinking about sustainability and the sustainable design can overcome this challenge.

A student's own perception of a sustainability is a critical factor for practising ESD. For example, Donovan (2018) emphasised the importance of students' critical reflections and active engagement for finding sustainable architecture theory relatable to their design practice. Further, Karol and Mackintosh (2011) stated that students' philosophical and personal positions on the principles and application of sustainability need to be developed if sustainable design is to become an integral part of their design practice. Luley (2020) noted that sustainability should begin from a philosophical, ethical and social perspective.

The perception of a sustainable built environment depends on how a person perceives the relationship between the built environment, nature and humans. Three orientations in a triangular relationship are identified by investigating how students develop their sustainability perception within the ESD studio: the built-centric view, the human-centric view and the nature-centric view. The built-centric view approaches sustainable design in terms of bringing benefits to building performance by merely mitigating environmental impacts. The human-centric approach focuses on achieving human comfort. The nature-centric view is premised on the built and the human being encompassed by nature and supports common criteria applicable to both BD and ESD. In promoting the adaption of BD within the current sustainable studio, a student's understanding of their orientation is a starting point for triggering their thought processes and developing their philosophy. This new way of thinking is further discussed in Chap. 3.

This type of learning wherein changes to students' attitudes are expected, falls into transformational learning (Munro & Grierson, 2018). Typical educational design elements that support transformational learning are the use of self-directed learning materials, lectures, participatory design and learning by doing. Research has revealed that hands-on experience, along with knowledge, can improve the transformation of thinking (Dabaieh et al., 2017). For recording a student's transformational learning process, critical reflections play a significant role (Berg et al., 2014).

2.3.2 Embracing a Systematic Technique to Generate Criteria for a Biophilic Design Framework Compatible with an Environmentally Sustainable Design Approach

To generate criteria that integrate BD and ESD and then use those criteria to develop a framework that guides student self-assessment is not so simple. In a situation where this integrated framework provides quality and standard for design, students should assess the BD framework's compatibility with the ESD approach and use it as a self-assessment guide. Nurturing this ability to judge their own work has been identified as 'evaluative judgement' in educational design (Goodyear & Markauskaite, 2019; Tai et al., 2018). Pedagogical design ideas that support evaluative judgement include self-assessment, the use of rubrics, peer assessment, feedback and the use of exemplars (Tai et al., 2018).

An exploration of the current literature reveals that the process for developing design frameworks has not been adequately discussed. This issue is not specific to BD—it applies to ESD as well. There is a lack of both theory and robust accounts of practice. One can only analyse current frameworks and speculate about the techniques that were applied during their development. For example, an analysis of literature regarding the 14 patterns of BD (Browning et al., 2014) showed that this BD framework was developed by drawing upon an extensive review of the literature about the benefits of BD and synthesising these into a few criteria. How these criteria were generated has not been described, but careful consideration reveals the inspiration from the previous framework by Kellert (2008).

The only available guidebook where the method for developing the BD framework is clearly outlined is recommended for use with the Living Building Challenge and is published by the International Living Future Institute (2018). It proposes an interdisciplinary ideation process, whereby different stakeholders come together to create a comprehensive BD framework.

In an education setting, interdisciplinary learning is frequently seen in ESD studios. This type of learning can assist the development of the framework but has its limitations in a design studio. For example, the key pedagogical design that supports interdisciplinary learning is role-playing. However, in a studio context, students may not have the adequate professional expertise to generate ideas by assuming another disciplinary or professional role.

In an educational setting, where a design framework is the critical design artefact that supports student learning, a more systematic and replicable technique is suggested. The design framework is also an assessment artefact and the systematic technique for framework development provides a foundation for transparent assessment of learning outcomes. This framework development activity involves students learning by way of constructing artefacts, through which students are also expected to develop a procedural knowledge of using a systematic technique.

Design studios predominantly nurture students' learning by having them construct design artefacts through their design projects. An embodied educational element that explains the step-by-step technique could support students in overcoming the challenge of developing procedural knowledge. For example, Dib and Adamo-Villani (2014) used serious computer games to support the development of students' skills in designing with a GBRT. They highlighted the importance of interactive learning materials that teach students procedural knowledge. The process-bridging technique (PBT) detailed in Chap. 4 is an embodied educational element developed to serve this purpose. The PBT supports students in generating criteria for their BD frameworks, and the guide in Chap. 4 provides further assistance in using these criteria, including instructions for synthesising them into a self-assessment tool. The theory around learning and educational design elements underpinning this approach is further discussed in Sect. 2.3.

2.3.3 Embedding Biophilic Design Frameworks in the Design Thinking Process

Designing in the studio encourages students to adopt a systematic design thinking process. According to Braha and Reich (2003), the design process is characterised by being a cyclic and exploratory endeavour and is generally depicted as a model. Although several design thinking models have been proposed, most of them share four broad phases: information collection, analysis, synthesis and evaluation (Lawson, 2005). The development of a design framework that supports sustainable design should be incorporated into these models for design thinking. The conventional design thinking models allow for information gathering and research, but they are more focused on studying similar buildings and finding inspiration. This typical design thinking may not consider supplying evidence for design decisions as a prominent need.

Consequently, there has been a growing awareness that, in the ESD context, design thinking approaches should suit the demands of ESD (Berg et al., 2014). For example, Karol and Mackintosh (2011) pointed out that, to grapple with the complexity of sustainable thinking, students need to be aware of their own learning and transformation. Further, this design thinking process should facilitate the rigour of the ESD process while also embracing BD's creative principles. It is also important to remember that the ESD approach requires showing evidence of sustainability achievement, which therefore demands an evidence-based design approach. Generally, in ESD studio projects, students are exposed to simulation software, which they use to model their design solutions and provide evidence supporting the design's sustainability. Therefore, these simulation software training programs are embodiments of educational design elements. Teaching students the required technical knowledge is crucial in the ESD approach and is integrated into design studios in certain ways (Altomonte et al., 2014) that are further explained in Sect. 2.3.3.

The typical design thinking process adapted by students may change with the addition of a design framework and other tasks related to ESD approach. The teaching within the studio should showcase students to understand the differences in design thinking process and model their own process rather than supply them with a new model. This demonstration will allow the students to individualise and develop their design thinking process, enabling them to use a similar process flexibly in their future design work. Further, students should be given opportunity to develop their own individualised design thinking that could nurture evaluative judgement. Arrangement of studio tasks in a certain way can promote a specific design process (Berg et al., 2014). This pedagogical idea is discussed in Chap. 7.

Finally, critical reflections are used to report on a student's design thinking process. Berg et al. (2014) reported on a study that attempted to map students' design thinking in a sustainable design project. In the study, the studio was structured around regular discussions aimed at supporting the design process. Students' critical reflections on the design process were a significant design artefact used in the study to model design thinking.

2.3.4 Mind-Mapping the High-Level Conjecture

While trying to understand the challenges faced in developing a BD framework compatible with the ESD approach, various pedagogical design ideas that could support overcoming these challenges were identified through an extensive literature review. A mind map was used to synthesise these ideas and derive a detailed high-level conjecture (Fig. 2.2).

As illustrated in Fig. 2.2, the pedagogical ideas include themes for both theoretical and design conjectures. The aim was to gather as many pedagogical ideas for deriving the high-level conjecture as possible. This made it possible to include a range of pedagogical ideas into the RACOM for BD frameworks, allowing it to be used in different situations.

Important theoretical ideas around the proposed strategy to overcome the challenges were highlighted in the above discussion. These included transformational learning, evaluative judgement, learning by constructing artefacts, developing procedural knowledge through practice, design thinking and reflective practice. How these ideas shape educational innovation is further discussed in the next section.

2.4 Theoretical and Design Conjectures

After identifying the challenges, theoretical assumptions were made regarding the type of learning required to support students and the educational design that may suit the desired learning. Before detailing the theoretical and design conjectures, an attempt was made to briefly connect the underpinning theories to the entire design process envisaged in this educational innovation.

Students learn develop BD frameworks and design sustainable buildings by constructing various artefacts. The term ‘artefacts’ or ‘design artefacts’ is used to refer to multiple objects that are created as part of the learning process, including a BD framework, building design and self-assessment report. Some of these artefacts are used to assess student learning outcomes. In such instances, they are referred to as ‘assessment artefacts’ (Markauskaite & Goodyear, 2017). Therefore, the key design conjecture is that a student’s learning process is mediated by constructing various design artefacts.

Identification of pedagogical ideas to support students’ construction of various artefacts influences all the educational design elements embodied in the educational innovation. Close investigation of the challenges in developing a BD framework revealed three distinct design artefacts students should construct: (1) an artefact that reflects the student’s sustainability perception, (2) an artefact that demonstrates the BD framework and (3) an artefact that illustrates the student’s use of the BD framework in their design thinking process. Each of these artefacts relates to different types of learning and embodied educational design elements.

The key theoretical assumption is that a student’s developed BD framework will guide them to assess their sustainable building design, thereby facilitating their evaluative judgement. Evaluative judgement refers to the capability to judge the quality of one’s own work and is particularly important in professional work and learning (Goodyear & Markauskaite, 2019; Sadler, 1989). It is expected that the construction of a BD framework and its use in the design thinking process, result in a sustainable and biophilic building design and students’ capacity to make sound decisions about BD in future. This is the key theoretical conjecture. Further exploring evaluative judgement as a learning outcome, Tai et al. (2018) proposed five educational design elements that support evaluative judgement: self-assessment, rubric, peer assessment, feedback and the use of exemplars. Thus, the evaluative judgement also influences the selection of educational design elements. Figure 2.3 shows how theoretical and design conjectures are associated with design artefacts and learning outcomes.

The central ideas embedded in Fig. 2.3 are *learning by constructing artefacts* and *evaluative judgement*; they guide the key theoretical and design conjectures. The developed BD framework needs to be integrated into the design thinking process for students to generate an ESD outcome that also embraces BD principles. This takes the discussion towards *design thinking* that, again, underpins both theoretical and design conjectures. The underlying theoretical assumption is that students require design thinking to integrate the BD framework into the design. Structure of the design studio tasks encourages students to follow a particular design thinking process, and this can be supported by appropriately arranging studio tasks.

There are numerous design thinking process models available, and reflective practice model (Schön, 1987) is widely used within architectural design studio pedagogies. Particularly in the ESD approach, a design outcome is a reflective response to a design framework. Reflective practice also makes thinking more visible; and students' critical reflections help teachers get insight into both change in students' perception and design thinking process. Therefore, design thinking, and reflective practice can be combined together into *reflective design practice* in the ESD studio.

Interdisciplinary learning, transformational learning and support for procedural knowledge also surfaced in the previous section. These are learning processes that are considered when deciding on educational design elements to support students in constructing design artefacts.

The key ideas that underpin theoretical and design conjectures—constructing design artefacts, evaluative judgement, design thinking and reflective practice—are briefly explained below.

2.4.1 Learning by Constructing Artefacts

Learning in the design studio is primarily focused on students constructing a design. Bertelsen (2000) stressed that a new epistemological understanding for design-led pragmatic learning is required. He further discussed how design is mediated by design artefacts, which he believes are crucial for understanding design-oriented epistemology.

With multiple design artefacts constructed within a design project, their different relationships with the design activity and the types of knowledge involved in their construction must be clarified. Bertelsen (2000) used an example from computer software development and defined three relationship between the design artefact and the design activity: construction, cooperation and conception. *Construction* is the productive relationship between the designing subject and the object of design that includes artefacts directly representing part of the final outcome. *Cooperation* is the representational relationship between subjects involved in the design. This includes artefacts made to communicate with team members of different disciplines cooperating with each other. *Conception* is the dialectical relationship between the designing subjects and the historically developing activity. This refers to artefacts developed based on a concept or model that is used in the design discipline. Bertelsen (2000) further stated that design artefacts, in most cases, mediate all three relationships.

In an ESD, a BD framework also mediates all three kinds of relationships. For example, a BD framework has a constructive relationship with the design because it represents an essential design artefact. The framework also has a cooperative relation because it represents different ESD aspects—such as energy, water and indoor air quality—that require varied disciplinary expertise and is, consequently, a design artefact that mediates cooperation among disciplinary and professional experts and stakeholders. Finally, the BD framework also has a conceptual relationship because it mediates the conceptualisation of different ESD approaches already in use and students' perception of BD: in a design studio, students working in a group bring their own personal ESD knowledge into the BD framework. Thus, the design framework is a design artefact that mediates all three relationships in the design project: construction, cooperation and conception. These multiple relationships position design frameworks as crucial learning and assessment artefacts.

Further exploring assessment artefacts, Markauskaite and Goodyear (2017) pointed out three types of assessment artefacts often used in professional learning: *cultural*, *conceptual* and *epistemic*. *Cultural* artefacts are generally developed and used for day-to-day professional practice, such as design proposals, drawings and documentation of concrete building designs in architecture. *Conceptual* artefacts are products of deliberative knowledge work aimed at constructing explicit articulated professional knowledge for professional judgements and practice. Some examples include developed design syntaxes and success matrixes used in the ESD approach. Such artefacts may contain knowledge to address specific problems in professional practice. However, these artefacts can usually be applied to varied situations to solve problems arising out of similar circumstances. Finally, *epistemic* artefacts link conceptual and cultural aspects of professional knowledge. They embody principled practical knowledge (Bereiter & Scardamalia, 2014) that enables practitioners to create customised context-specific solutions. Typical examples are design pattern books, design guidelines and other practical professional artefacts that enable practitioners to make design decisions while accounting for the unique challenges and multiple constraints that are encountered. Students' work in developing, adapting and applying BD frameworks for their own designs and then reflecting on their work involves an ensemble of conceptual, cultural and epistemic artefacts. Such complex artefacts facilitate students' development of professional knowledge that can be adapted to varied situations in their practice (Markauskaite & Goodyear, 2017; Markauskaite & Patton, 2019).

2.4.2 Evaluative Judgement

A student's BD framework is a crucial design and assessment artefact. As such, it can play a critical role in developing students' evaluative judgement, particularly their ability to judge the quality of their own work (Goodyear & Markauskaite, 2019; Sadler, 1989). Evaluative judgement is increasingly recognised as a learning outcome in higher education (Sadler, 1989; Tai et al., 2018) and crucial to preparing students for professional careers (Goodyear & Markauskaite, 2019). This ability also helps students become independent from their teachers (Tai et al., 2018) as it does not merely support the students to succeed in one particular course but also contributes to developing lifelong professional skills (Boud & Soler, 2016). Therefore, assessments that involve evaluative judgement, as Boud (2010) described, meet 'the needs of the present and prepare students to meet their own future learning needs' (p. 151).

Tai et al. (2018) suggest five types of pedagogical designs that support evaluative judgement: self-assessment, peer review, feedback, rubrics and exemplars. However, they note that evaluative judgement has not been extensively researched or theorised within higher education studies.

There have been, some studies in architectural design premised on nurturing a student's evaluative judgement, even though the researchers did not explicitly use the term evaluative judgement. For example, Hengrasmee and Chansomsak (2016) described a study that developed activities within the design studio to develop self-awareness, self-evaluation and self-criticism. They conducted a series of workshops wherein students could bring their ESD project, identify a problem and improve it through the workshop. Each workshop covered an aspect of ESD, such as energy efficiency or water management. The study suggested that one of the key assumptions of the educational design was that a student's ability to judge sustainability in their work was crucial for transforming their professional practices towards sustainability. Therefore, focusing on evaluative judgement is pertinent in ESD studios.

There are two integral components in developing evaluative judgement: understanding work quality and applying standards to one's own and others' work (Tai et al., 2016). In the case of the ESD studio, students' work in creating and using their design frameworks involves both components. A framework's development requires an understanding of various industry GBRTs, technical standards and benchmarks for sustainability criteria. Additionally, the use of the framework to develop design solutions inevitably involves applying standards for judging one's work quality.

Evaluative judgement is specific to a context and a domain (Tai et al., 2018). Therefore, to scaffold learning to nurture evaluative judgement, it is necessary to consider the interactive relations between students, tutors, educators and evolving industry standards while, at the same time, having students produce professional design work.

2.4.3 Design Thinking and Reflective Practice

Razzouk and Shute (2012) defined design thinking as 'an analytical and creative process that engages a person in opportunities to experiment, create and prototype models, gather feedback, and redesign' (p. 330). Design thinking is crucial in contexts with complex problems, such as the current environmental and sustainability challenges (Fry, 2009). The literature provides several models of the design thinking process, but there are concerns regarding their suitability for the level of complexity required by the ESD (Berg et al., 2014).

By closely investigating the design process in ESD, it is possible to notice similarities between the fundamental activities of the ESD and those typical in the conventional design: a creative and technological response to a certain problem—that is, reflection-in-action. Schön (1987) argued that reflection-in-action is the main way to develop the knowledge needed for professional practice. Studio teaching involves coaching students to reflect, in action, on complex design problems and learning-by-doing activities. Education within design studios has undergone various phases and the reflective practice model has emerged as dominant in conventional design studios. ESD studios share similar structural arrangements as conventional studios but also have two main distinguishing features.

First, the demands for technical knowledge tend to be much higher in ESD studios than in conventional studios. Therefore, teaching and learning activities ranges from lectures on sustainability principles to learning to use simulation software in computing labs. These teaching and learning activities can be structured and integrated with the studio activities in different ways. For example, Altomonte et al. (2014) identified five models for this integration: parallel, partially integrated, fully integrated, iterative and elective. In a parallel model, technical units are offered parallel to the studio, but these subjects are not connected to each other. In the partially integrated model, some of the technical knowledge is integrated into the studio and others run parallel. In the fully integrated model, all technical knowledge is embedded into the studio. In the iterative model, technical knowledge is provided when needed, depending on the briefs. Finally, in the elective model, technical units are offered as optional electives that students may choose according to their preferences or requirements.

Second, design frameworks play a distinct role in reflection. Schön (1983) described the studio as a practicum that can be:

> reflective in two senses: it is intended to help students become proficient in a kind of reflection-in-action, and when it works well, it involves a dialogue of coach and student that takes the form of reciprocal reflection-in-action. (p. xii)

In ESD studios, the design framework sets the parameters for a sustainable response and inevitably shapes the reflection-in-action. In some ways, the framework plays the role of the 'coach', particularly when industry frameworks are used or when frameworks provide guidelines and strategies for achieving the desired outcome.

2.5 The Proposed Educational Design: Learning Outcomes, Mediating Processes and Embodiments

The educational innovation project proposed in this book aims at empowering students to autonomously develop a BD framework integrated within the more traditional ESD approach. It opted for a fully integrated model, where technical knowledge is embedded within the studio, and structured to focus on a success matrix that provides an artefact for both the tutor and the student to relate to and guide the self-assessment.

Identifying the learning outcomes, mediating processes and embodied educational design elements was an iterative process that required moving back and forth. The three artefacts that later mediate biophilic and sustainable building design are also

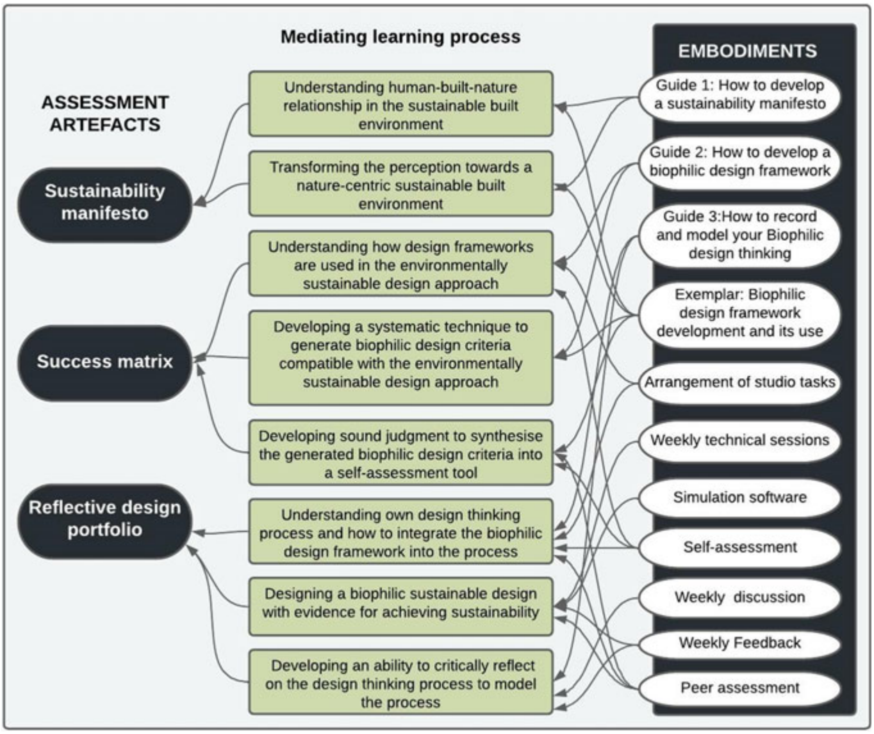

Fig. 2.4 Assessment artefacts and their associations with mediating processes and embodiments

used as assessment artefacts. Figure 2.4 shows the assessment artefacts and their relationships to mediating processes and embodiments.

As illustrated in Fig. 2.4, few mediating processes are reflected in the three assessment artefacts (sustainability manifesto, success matrix and reflective design portfolio).

Embodiments include following materials as guides: (i) guidelines and references to elaborate a sustainability manifesto, (ii) a systematic technique to develop a BD framework as a self-assessment tool, (iii) guidelines for the application of a sustainable and biophilic design thinking model and (iv) an exemplar showing the step-by-step process. Each guide supports students in transiting through the mediating processes and achieving learning outcomes by constructing an artefact. The guides are written as ready-to-use tools for students. The underlying idea is that educators can embed the BD teaching approach described in this book within their teaching practice by scaffolding student progression using the guides in the studio.

The three guides to the assessment artefacts are outlined in the remainder of this chapter; Chaps. 3–5 present the guides themselves. Chapter 6 presents the exemplar. Other embodiments are discussed as practical implications in Chap. 7.

Within the following subsections, specific conjecture maps for each of the three assessment artefacts are given, and a discussion is provided as to how embodied educational design elements support students in constructing assessment artefacts. Learning outcomes, and theoretical and design conjectures, are also included in these detailed conjecture maps of each assessment artefact.

2.5.1 Development of a Sustainability Manifesto

As outlined in Sect. 2.3.1, shifting the perception of sustainability is a challenge within ESD studios when BD approaches are integrated. A task that asks students to develop a sustainability manifesto responds to this challenge.

A sustainability manifesto helps students reflect on their perception of a sustainable built environment by rethinking the relationships between the *human*, the *bui*lt and *nature*. Producing this artefact also mediates the development of the BD framework. Figure 2.5 shows the association between theoretical and design conjectures of the assessment artefact with the learning outcomes and embodiments.

As illustrated in Fig. 2.5, two mediating learning processes are required to complete this assessment artefact. First, the students need to understand the relationship among—*human*, *built* and *nature* and how those interrelations assign different interpretations to the sustainable built environment. Second, students should shift their perception towards a nature-centric sustainable built environment. The assumption is that students with a nature-centric perception could produce sustainable designs with higher biophilic quality. The evaluation of the sustainability manifesto should demonstrate the achievement of two learning outcomes: (1) a perception of sustainability that encompasses BD within ESD, and (2) the ability to generate BD criteria compatible with the ESD approach. A practical guidance for students is given in Guide 1 (Chap. 3) and illustrated in the Exemplar (Chap. 6).

2.5.2 Development of a Biophilic Design Framework Within the Success Matrix

The term 'success matrix' is here used to identify the design framework that guides students' sustainable designs, traditionally employed in ESD studios. Students should be given the flexibility to develop their own success matrix, including design criteria, performance and evaluation rules, with the intent to give them an occasion and a tool to reflect upon their achievement of sustainability in the final design. Three mediating learning processes are required to successfully develop this artefact. Figure 2.6 illustrates how embodiments and learning outcomes are related to the design and theoretical conjectures.

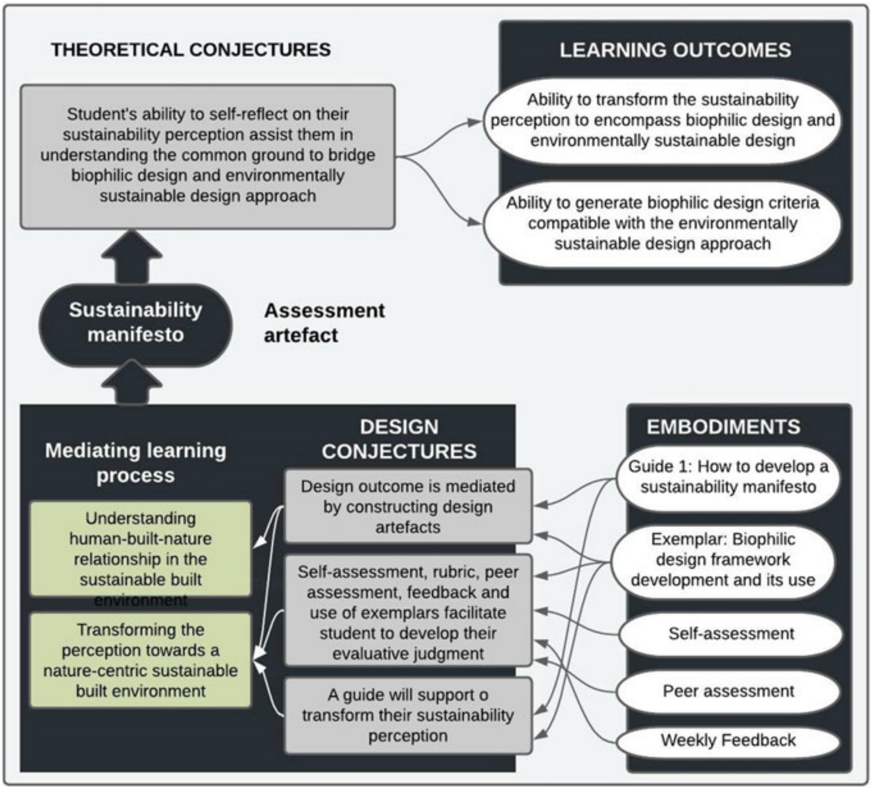

Fig. 2.5 Conjecture map for sustainability manifesto

There are three mediating learning processes necessary to construct this artefact. First, students need understand how design frameworks are used in ESD. A brief analysis of the current industry GBRTs and BD frameworks is included in Guide 2 (Chap. 4) that could be used to support this learning process.

Second, students are expected to learn a systematic technique to generate BD criteria compatible with the ESD approach. Guide 2 provides specific instructions on bridging the two approaches and generating compatible criteria. Peer assessment is an embodiment that can support students in this task through critical evaluation and discussion.

Third, students can use the generated BD criteria as:

- Integrated part of the success matrix, included as a separate category,
- Integrated into the success matrix where BD criteria are scattered across categories,
- BD framework is taken as the success matrix and further developed as a self-assessment tool to evaluate the biophilic response.

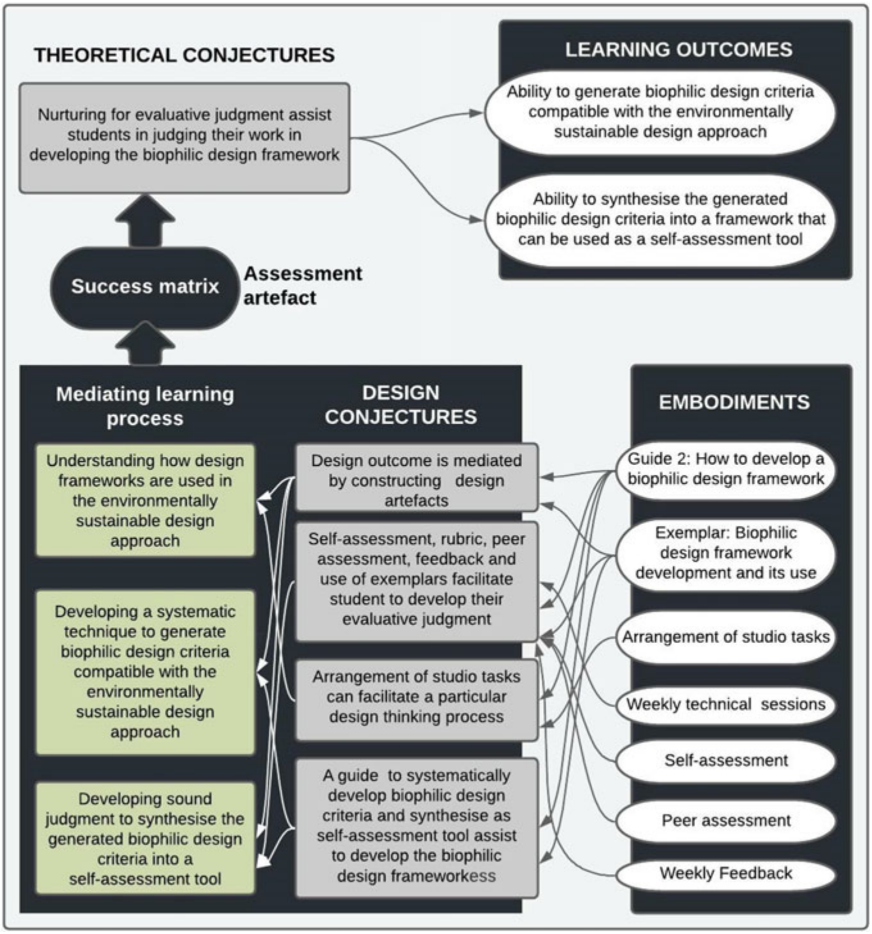

Fig. 2.6 Conjecture map for the success matrix

Guide 2 has instructions for the three approaches. It is suggested that the criteria are used as a self-assessment tool so that it will support nurturing evaluative judgement. By going through the exemplar provided in Chap. 6, students will learn the application of all three mediating learning processes.

Two learning outcomes are demonstrated by this assessment artefact: (1) the ability to generate BD criteria compatible with the ESD approach and (2) the ability to synthesise the generated BD criteria into a framework that can be used as a self-assessment tool.

2.5.3 *Use of the Biophilic Design Framework in the Design Thinking Process and Reflecting*

Once a BD framework is constructed, students use this framework in the design thinking process. A reflective design portfolio can be used as the key assessment artefact to demonstrate their design thinking process. In addition to be developed as a design portfolio it should include reflections on their design journey through the project. Four mediating learning processes are involved in the construction this artefact (Fig. 2.7).

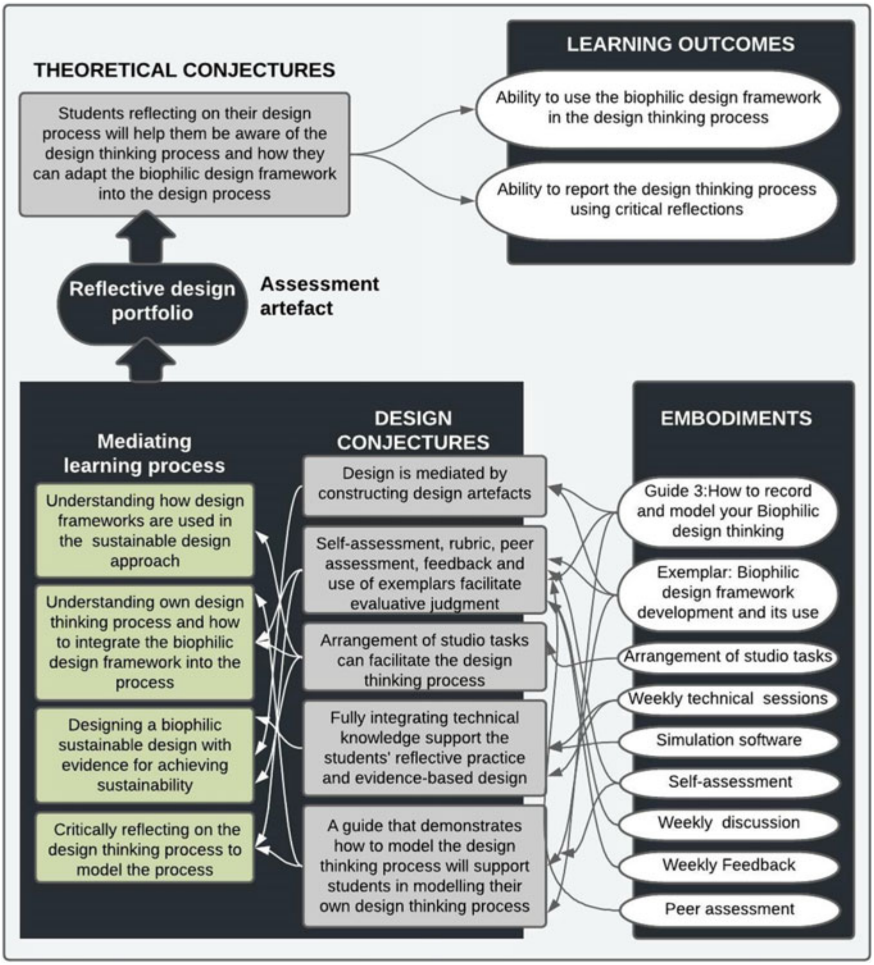

Fig. 2.7 Conjecture map for the reflective design portfolio

The first mediating learning process is understanding how design frameworks are used in the ESD approach. The second one requires students to understand their design thinking process and how to integrate the BD framework into that process. It introduces five design thinking models that students can use to explore and identify their own design process. The arrangements of studio tasks and peer assessments are also included as embodiments to support this mediating learning process.

The third mediating process engages students in the design of a biophilic and sustainable building, and provision of evidence of the achievement of sustainability. Within an ESD students are required to support their claim on sustainability with evidence-based design practice. Weekly technical knowledge teaching embedded in the studio will prepare the students for this.

The fourth mediating learning process is students' critical reflection on the design thinking process. Peer assessment—whereby students can critically look at how others are modelling their process—is also crucial for this mediating learning process. The purpose of Guide 3 (Chap. 5) is to support the students with above tasks.

The exemplar given in Chap. 6 shows a specific design thinking process that resulted in a sustainable design with high biophilic quality and also shows how to work through all the mediating learning processes discussed above.

By constructing this artefact, students can achieve two learning outcomes: (1) the ability to use the BD framework in the design thinking process and (2) the ability to articulate the design thinking process through critical reflection.

2.6 Reflective Action Conjecture Map Development Process

Figure 2.8 provides an outline of how the RACOM for BD frameworks was developed in this proposed educational innovation.

Step 1: The process started with deriving the high-level conjecture and identified key challenges in developing a BD framework, as well as the pedagogical ideas that can support overcoming these challenges. A mind map was created to derive the high-level conjecture with the supporting pedagogical ideas (Fig. 2.2).

Step 2: Then, pedagogical ideas were investigated in relation to the design artefacts that mediate the development of a BD framework. By doing this, the theoretical and design conjectures for educational innovation were identified (Fig. 2.3).

Step 3: Consequently, the assessment artefacts and mediating learning processes for each of those artefacts and the embodiments that could support the students in the learning processes were identified (Fig. 2.4). This step was an iterative process, comprising four sub-steps aimed at assisting in the generation of the themes of a RACOM for BD frameworks.

Clearly, mediating learning processes are agile. They depend on the design brief of the project and the context. Identifying the mediating learning processes assist in linking between the learning outcomes and embodiments through theoretical and design conjectures. The alignment of the learning outcomes, assessment artefacts,

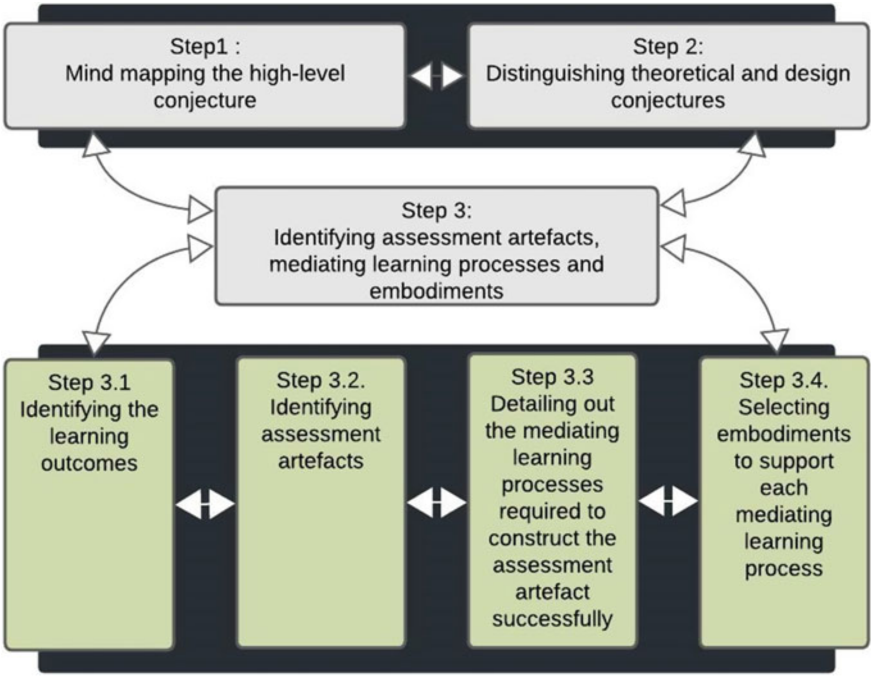

Fig. 2.8 Development of a reflective action conjecture map for biophilic design frameworks

mediating processes and embodiments is an iterative process that requires moving back and forth between these components.

2.7 Concluding Remarks

This chapter outlined the development of the educational design innovation for BD frameworks based upon RACOM, a systematic approach to develop educational innovations for sustainable design studios. Authors have implemented a similar RACOM for BD where the insights from it's evaluation and the reflections were taken into consideration whilst developing this version.

The RACOM developed for BD included three design artefacts that are also assessment artefacts, providing materials to support students in successfully transitioning and achieving learning outcomes. Each design artefact corresponds to mediating learning processes linking learning outcomes with necessary embodiments. These mediating learning processes were expanded connecting the theoretical and design conjectures providing educators with an ability to adapt them in similar situations. How these assessment artefacts could be evaluated is discussed in Chap. 7.

This guidebook includes three guides and the exemplar as the materials within the embodiments detailed out in following chapters. Each Student Guide was developed to support an identified challenge where the exemplar demonstrated the use of the introduced design approach. They are presented in a way that can be directed used in the studio to suit the learning outcomes used in the proposed educational innovation. Educators will need to adapt the given learning outcomes to their contexts, along with potential assessment artefacts and other components. The implications educators may face in implementation and embodiments other than materials are given in Chap. 7.

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Chapter 3
Student Guide 1—How to Develop a Nature-Centric Sustainability Manifesto

Abstract A foremost challenge in developing a biophilic design (BD) framework is uncovering a perception of sustainability that appreciates nature and fosters biophilia in the built environment. The sustainable built environment can be understood through the relationships among three dimensions: *the human*, *the built* and *nature*. Depending on the dimension in focus, the perception can drastically differ. This chapter provides a few directions for developing a nature-centric perception. Ecological thought and deep ecology are presented as the bases of the nature-centric perception. This perception has two functions in developing the BD framework: (i) it allows us to understand and interpret buildings and nature as two parts of the same metaphysical entity; (ii) it provides an opportunity for categorising the criteria found in current environmentally sustainable design and BD practices using a classification common to both approaches. One example of a common classification—based on defining nature as elements of earth, air, water, energy and habitat is elaborated, reflecting a verbal expression of the sustainability manifesto.

3.1 Introduction

This is a guide to support you in developing a sustainability manifesto. A sustainability manifesto is your own personal interpretation of sustainability, which will inform how you approach your design. This interpretation can be expressed through speech, a diagram, a video, an act or any other representation you deem appropriate and relevant.

This chapter presents a comprehensive framework that can guide you in building your manifesto through understanding the relationships between *the human*, *the built* and *nature*. We demonstrate, through one example, how we interpret sustainability; this can be taken as source of inspiration or even adapted for your manifesto. This example shows a sustainability manifesto that interprets building as an extension of the natural setting. We interpret both *the built* and *nature* as comprising the same elements of earth, air, water, energy and habitat. These elements provide a common categorisation for both an ESD and BD approaches.

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3.2 The Relationship Between Human, Built and Nature in the Perception of Sustainability

Sustainability is an ambiguous notion with diverse interpretations. In architecture, when we refer to a sustainable built environment, we usually mean a system that comprises three dimensions: *the human*, *the built* and *nature*. The evolution of a sustainability perception can be understood by the interrelationships among these dimensions (Fig. 3.1).

This triangular relationship between the dimensions can be understood through the built-centric, human-centric or nature-centric lens. Built-centric approach means that a primary objective of design is to bring benefits to the built environment, the human-centric approach attempts to bring benefits to humans, and the nature-centric approach brings benefits to nature. These dimensions are interrelated. The two-way relationships between *nature* and *the human* target the psychological wellbeing of building occupants; between *human* and *built*, physical comfort; and between *the built* and *nature*, minimising environmental impacts, which shifts attention from building occupants to the environment.

The resulting six relationships reflect various design approaches, which have different implications for sustainability. For ease of reference, we have termed these relationships as follows: *built-to-express*, *built-to-mitigate*, *human-built-comfort*, *human-nature-wellbeing*, *nature-for-wellbeing* and *nature-to-mitigate*.

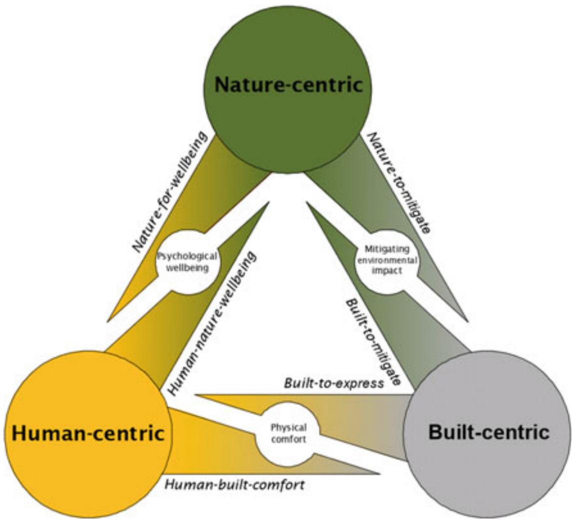

Fig. 3.1 Interrelationships among the human, the built and nature in sustainability perception

3.2.1 Built-Centric Design Approach

The relationships *built-to-express* and *built-to-mitigate* are part of the built-centric approach, in which design is focused on the built object. These are building-dominant views that maximise the benefits to the built program. When referring to the built-centric design approach in regard to *the human*, the *built-to-express* relation usually indicates a design approach with very little, if any, consideration for environmental impacts. For instance, classical architecture focuses on perfecting the shapes and forms of the building expression while providing a comfortable space for human activities. The same trend can be partially observed in modern buildings, which are intended to be functional and comfortable spaces for the occupants.

By contrast, a built-centric approach directed towards *nature* focuses on mitigating design impacts on the environment. This is the *built-to-mitigate* relation, which can be identified as the starting point of modern sustainability practice. In this approach, buildings are designed to mitigate environmental impacts, but they often overlook the implications on human psychological wellbeing. This dominates current ESD practice, in which sophisticated technology merely achieves mitigation targets. Research has shown that a building may achieve its sustainability and energy targets but fall behind in supporting healthy human–nature connectedness (Kellert, 2008). This is a different building expression, displayed in many technically advanced buildings and reflecting a new expression in modern buildings.

It must be noted that there exist exceptions in sustainable practices that can reflect other types of relationships. This is the case of architectures that draw upon vernacular practices, which demonstrate both built-centric and nature-centric sustainable practices.

3.2.2 Human-Centric Approach

In the human-centric approach, *human-built-comfort*—that is, the relationship between *human* and *the built*—reflects unique human-centred design within ESD practice and, in some instances, within conventional design. This approach established itself in opposition to the building-as-machine movement by supporting and appreciating human behaviour and thereby generating architecture that maximises comfort. The difference between this and *built-to-express* is that, even though both focus on comfort, the *human-built-comfort* approach is not dominated by building expression. Rather, forms are generated to support user comfort.

Another aspect of this design movement has focused on human behaviour—both individually and collectively—and has been advocated by scholars such as Alexander (1977) and Bill Hillier and Hanson (1989). However, buildings responding to human behaviour are also focused on psychological comfort, going beyond mere physical comfort. This highlights the fact that, when considering different design approaches, there are some relations with overlapping boundaries, and it is always up to you to reinterpret them to suit your view.

Within ESD practice, some GBRTs such as the WELL Building Standard are focused on physiological comfort, providing strong examples of a *human-built-comfort* approach.

The current BD practice is a human-centric towards *nature* that can be deduced as being a *human-nature-wellbeing* approach. This approach is based on the numerous benefits that nature can bring to humans (Wijesooriya & Brambilla, 2021); designs following this approach attempt to harness these potential benefits and make them an integral part of the conceptual phase of the design process. The BD approach developed by Xue et al. (2019), for example, claims to improve human performance in terms of enhancing productivity, cognition and creativity by incorporating nature into buildings.

This approach can be observed in the growing design trend of using natural elements in isolation—often within sophisticated interiors—as distinctive BD features. The Changi international airport in Singapore (Fig. 3.2) is the perfect case: featuring a giant indoor waterfall, it has been depicted in many forums as a successful BD. In this example, nature is used and re-created for the sole benefit of human psychological wellbeing, paying less attention to sustainability—that is, the environmental impact of such design elements. Therefore, this design brings benefits to humans and is focused on psychological wellbeing; consequently, it is a perfect example of the *human-nature-wellbeing* approach.

3.2.3 Nature-Centric Design Approach

The *nature-for-wellbeing* and *nature-to-mitigate* relationships belong to the nature-centric approach.

Nature-to-mitigate approaches—that is, nature-centric approaches towards *the built*—focus on the mitigation of environmental impact. Buildings designed through this lens bring benefits to nature while achieving building performance targets. Recent GBRTs, such as the Living Building Challenge (International Living Future Institute [ILFI], 2016), promote this holistic approach to architecture. Even in earlier ESD practice, you may come across building designs that have these characteristics. For example, Kandalama Hotel in Sri Lanka—by Geoffrey Bawa, a pioneer in modern regionalism architecture—is designed with a nature-centric approach (Fig. 3.3). It is the first LEED-rated hotel and also has a focus on mitigating environmental impact.

Paramit Factory, Malaysia designed by Design Unit Sdn. Bhd. is another example that demonstrates *Nature-to-mitigate* relationship within nature-centric approach. This building is a BD example practiced in an industrial architectural project showcasing the potential for varied building types. The building lies within an industrial zone with a recreated forest earning the name ‘factory in the forest’ (Fig. 3.4). In this project the factory building design has included sustainability

Fig. 3.2 Changi airport. *Source* Authors

Fig. 3.3 Kandalama Hotel, Sri Lanka, by Geoffrey Bawa. *Source* Authors

Fig. 3.4 Paramit factory, Malaysia designed by Design Unit Sdn. Bhd. *Photo credit* Lin Ho photography

initiatives with passive strategies and sophisticated climate controls allowing it to mitigate environmental impacts.

Nature-for-wellbeing—a nature-centric approach towards the *human* dimension—is identifiable with designs that bring benefits to nature while optimising human psychological wellbeing. This is the case with vernacular architecture—which is designed to minimise the effects on the natural environment—or with modern buildings that focus on minimising the destruction of nature, integrating existing landscape into the design.

An example from Mexico that demonstrate *Nature-for-wellbeing* in the nature-centric approach is IK LAB Gallery designed by Jorge Eduardo Neira Sterkel. The design uses organic forms and shapes blending with surrounding natural environment with greater potential to enhance HNC. Figure 3.5 a similar project from Malaysia that includes a meditation centre designed by Inchscape Sdn Bhd. Unlike the previous example of Kandalama Hotel, that focuses on mitigation of environmental impact through verified sustainability performance this design emphasises on connection to nature at every possible opportunity.

The selection of the dominant approach is a personal choice. A sustainability manifesto can integrate more than one approach, or, conversely, it can be focused solely on one aspect. There is no right or wrong choice; however, if your intention is to develop a BD framework compatible with ESD criteria, you should explore the nature-centric approach.

Fig. 3.5 Meditation centre, Malaysia by Inchscape Sdn Bhd. *Photo credit* Lin Ho photography

3.2.4 Identifying the Built-Centric, Human-Centric and Nature-Centric Design Approaches

Table 3.1 summarises the six relationships so that you can easily refer to them and understand the differences.

You may have also come across numerous approaches that are practised in sustainable design, such as climate-responsive design (Hyde, 2000), passive design (Belmonte et al., 2021), bioclimatic design (Watson, 2020), low-carbon design (Pan & Pan, 2021), and water-sensitive design (Fogarty et al., 2021), to name a few. All of these approaches can be categorised within the six abovementioned relationships by investigating the concepts and targets at the core of each approach. By analysing different approaches, you can learn how to recognise the relationships between *the human*, *the built* and *nature*, which characterise current ESD practices. The following section presents a decision-making tree (Fig. 3.6) that can be used to identify these relationships.

To use the decision tree, follow these steps:

- Step 1—Identify the focal point of the design. Refer to the explanation above and ascertain the primary objective of the design. How is the design approach perceived?
- Step 2—Think about the potential outcome of the design and the target criteria that are used to judge whether it is successful.

Table 3.1 Six human–nature–built relationships for a sustainability manifesto

Relation	Approach	Focus	Description
Built-to-express	Built-centric	Comfort	Conventional highly expressive building designs
Built-to Mitigate	Built-centric	Environmental impact	The current environmentally sustainable designs, which focus on mitigating environmental impact using sophisticated technology
Human-built- comfort	Human-centric	Comfort	Building designs maximising the human comfort for physical and behavioural found within both conventional and environmentally sustainable design practice
Human-nature-wellbeing	Human-centric	Psychological wellbeing	The current biophilic design practice, which focuses on improving psychological wellbeing by using natural elements within the building
Nature for-wellbeing	Nature-centric	Psychological wellbeing	Development within biophilic design that aims to bring benefits to nature while enhancing psychological wellbeing through human–nature connectedness
Nature-to-mitigate	Nature-centric	Environmental impact	Designs that are sustainable and biophilic, where natural processes can be used to achieve building performance

- Step 3—Now, look into the area that will most benefit from the design. This step is crucial to reaffirm the originally identified perception in step 1.

Now, let us delve into an example and analyse the climate-responsive design approach (Fig. 3.7).

Climate responsive design is an approach where 'building from and structure moderates the climate for human good and wellbeing' (Hyde, 2000, p. 3), thus attempt to expose the senses of the user to the climatic variations. The first impression may lead you to think that this approach is nature-centric, since it seems to be

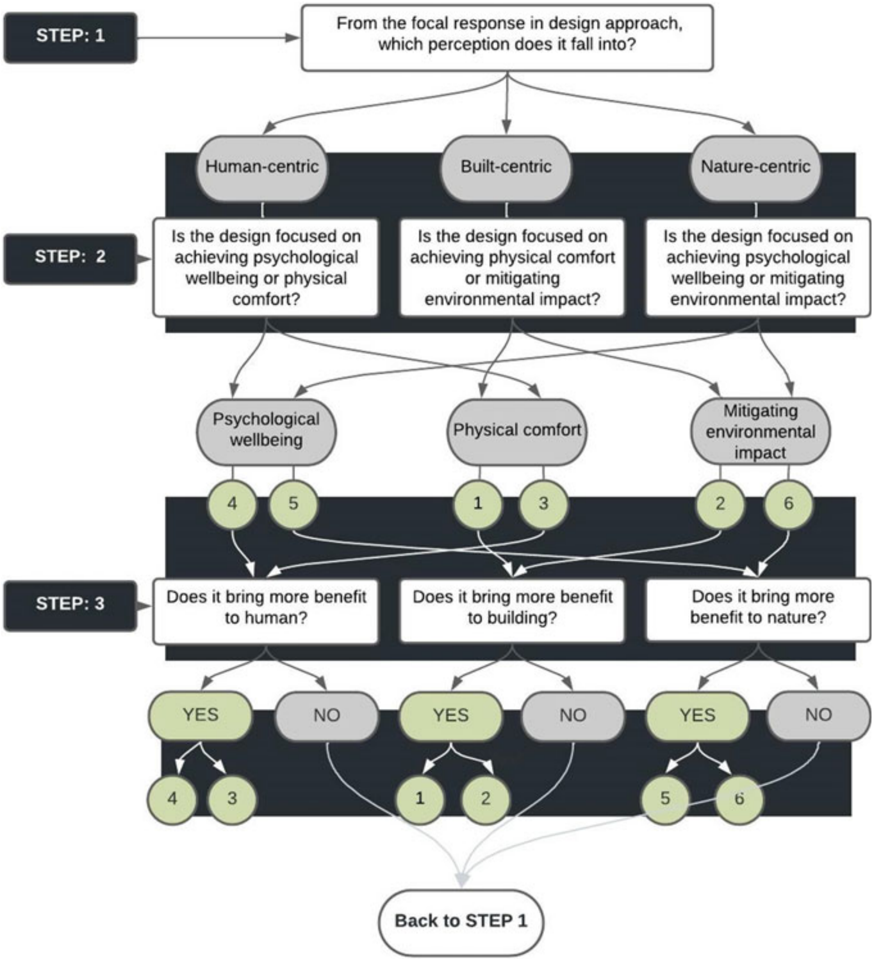

Fig. 3.6 Decision tree for identifying the dimensional interrelations in sustainable designs. *Note* Numbers refer to (1) *built-to-express*, (2) *built-to-mitigate*, (3) *human-built-comfort*, (4) *human-nature-wellbeing*, (5) *nature-for-wellbeing* and (6) *nature-to-mitigate*

dealing with climate. If this is the case, we will then ask the question of whether it is more focused towards mitigating environmental impacts or towards psychological wellbeing. Generally, climate-responsive design is focused on designing for a particular climate; hence, our interpretation shifts towards one of a focus on mitigating environmental impacts. It is important to remember that this is a personal interpretation and may differ from one person to another. One might even argue that climate-responsive design is, in fact, more focused on comfort. Selecting 'nature-centric', and 'mitigation of environmental impacts' as the focus, we are directed towards Relationship 6 (*nature-to-mitigate*). At this point, we have to double-check the relationship.

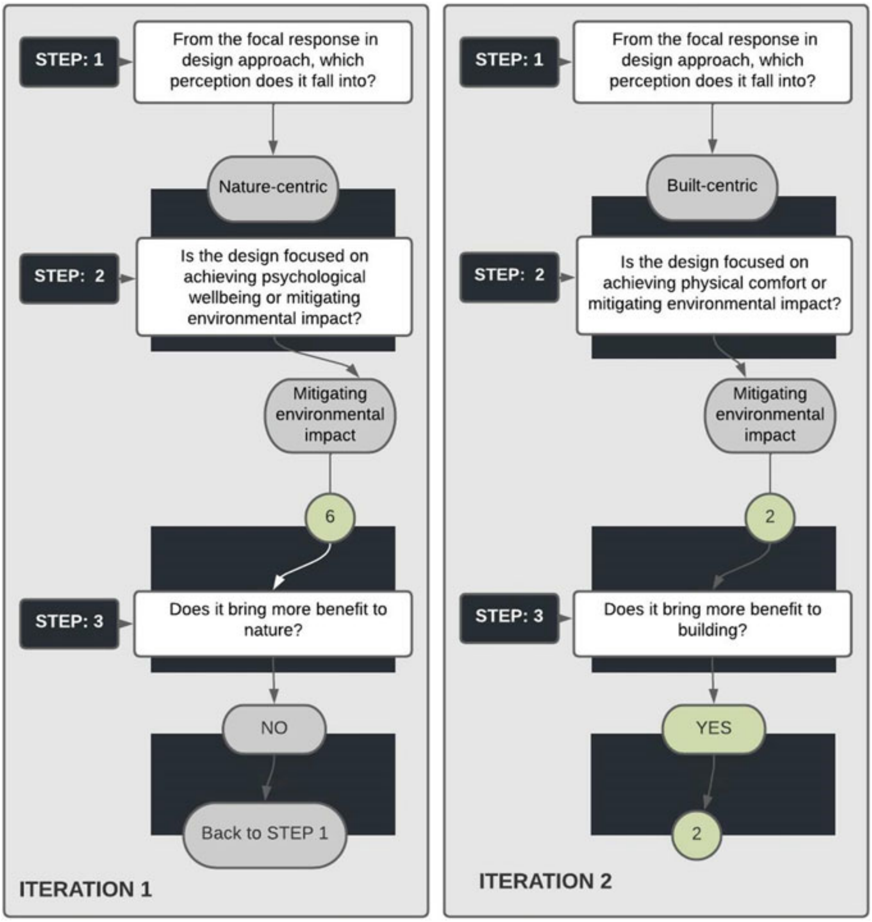

Fig. 3.7 Use of the decision tree to identify the dimensional interrelations for climate-responsive design. *Note* Numbers refer to (2) *built-to-mitigate* and (6) *nature-to-mitigate*

To do so, we might need to look at some examples (i.e., relevant case studies of developments following the design approach) and refer to the current debates on design. This step confirms that climate-responsive design seems to be more focused on using climatic conditions to achieve human physical comfort, reflecting a focus typical of Relationship 2 (*built-to-mitigate*). This is a typical ESD approach, which have lesser emphasis on psychological wellbeing.

Your conclusion may differ. Indeed, this analysis depends on your interpretation. We highly encourage you to try this decision tree as a group activity, wherein different interpretations can be elucidated, compared, and critically examined.

By completing this exercise, you will be able to understand what relationship is placed at the core of any sustainable approach, while building foundation and confidence for making informed choices. You will also notice that this exercise will progressively clarify what is important to you as a sustainable designer.

3.3 Biophilic Design: How to Develop Your Nature-Centric View

Approaching design with a nature-centric perception and developing a sustainability manifesto is a crucial step for constructing a BD framework compatible with an ESD approach. Applying a nature-centric approach is fundamental for identifying a common classification for both ESD and BD.

However, once you have clarified your own approach to sustainable design, you might find that it is not nature-centric. If this is the case, you may need spend some time exploring and understanding the biophilic view. Contemporary ecological thought argues that *human* and *the built* can be considered parts of the same metaphysical entity; hence, *the built* can be considered an extension of the natural setting.

In the following sections, we will provide you with some ideas, principles and evidence that support the nature-centric view. In particular, we will explain in detail how ESD and BD are two faces of the same coin: the first is focused on sustainability as mitigation of environmental impacts; the second, on its human emotional affinity. Further, we will present advanced notions of ecological thought (Morton, 2010) and deep ecology (Devall & Sessions, 1985), which are grounded on the idea that everything is interconnected through nature.

3.3.1 Understanding Nature Within a Global Environmental Movement

The effects of human actions on the environment are no longer negligible. Visible, catastrophic consequences have aroused a desire to protect nature in all its forms, resulting in a global environmental movement (Mol, 2000). The roots of the modern environmental movements date back to the Middle Ages (Istiadji et al., 2018). There are some key milestones in organised environmentalism: McCormick (1991) has argued that the Age of Discovery, Romanticism and Darwinism heavily influenced the rise of protectionists, wilderness preservationists and resource conservationists. The rise of the movement is apparent from the mid-nineteenth century, but revolutionary actions are visible only after 1945, with drastic momentum after the 1960s (McCormick, 1991).

Examining some of the key contributions that shaped the directions of the global environmental movement, it is apparent that the human relationship with nature is the pivotal point. The Age of Discovery is represented by advances in natural history that played a crucial role in exposing how human activities exploit nature. The foundations for modern botany and zoology were laid during this time, when being a naturalist and exploring natural sciences was quite popular during Victorian era. Studies into natural sciences awakened interest in studying, documenting and collecting specimens of nature. This new knowledge led people to explore and study nature from different viewpoints.

One viewpoint was Romanticism. *The Natural History of Selborne*, by Gilbert White (1788), was one of the texts advocating for people to restore the peaceful connection with nature as a way to appreciate its beauty. This text influenced many others to study natural history from a romantic viewpoint, focusing on beauty and emotional solace rather than scientific merit. While appreciating the beauty of nature, poets and painters bewailed the changes made to nature through agriculture. For example, Wordsworth (1882) claimed that agriculture violated the rights of nature, while Gilpin (1794) noted the shocking encroachments on the elegance of the natural landscape. In either case, nature was clearly the focus of concern.

The other viewpoint was to explore nature on scientific grounds. First naturalists emerged out of these scientific explorations of natural world. Their role was as scientific explorers, and their interests were in expanding the collection of animal and plant specimens through exotic expedition. The height of the exploration era was the rise of Darwinism, which drastically shaped environmentalism. At this time, Western thinking was premised on the belief that humans were superior to other species, and work by Darwin—with the subsequent publication of the *On the Origin of Species* (1852)—shattered this common belief. Darwin provided evidence for naturalists to realise that humans are evolved, much like any other species in nature, and it was by their own choice that humans have distance themselves from nature. This not only challenged the Western school of thought but also contributed immensely to the latter expansion of the environmental movement, which revealed that human dominance was leading to the unethical destruction of nature (Erdos, 2019).

Both Romanticism and Darwinism shaped the fundamental understanding of nature, and responses were broadly identified as either conservationist or protectionist. The conservationist approach aimed to conserve wilderness and natural landscapes. The establishment of nature reserves and parks was part of this response. The protectionist approach aimed to mitigate human impact and protect both animals and landscape. Both approaches had a common goal of raising environmental consciousness and constructing a healthy relationship with nature.

The environmental movement kept growing across the globe while expanding its focus. *A Sand Country Almanac* (1949), by Aldo Leopard, directed focus on ethical consciousness to protect nature. Conservation ethics is based on human intrinsic moral obligation to protect nature. This viewpoint also contained ideas around environmental justice that encompassed debate around equal participation in environmental policy, equal access to nature and justice for non-human environmental entities (Palmer et al., 2014). Thus, conservation ethics became embedded in the environmental movement (Rolston, 2012).

Drastic changes to legislation were seen after the 1960s. Seminal texts by Rachel Carson contributed immensely to strong policy frameworks for environmental protection. *The Sea Around Us* (1950), *The Edge of the Sea* (1955) and *Silent Spring* (1952) all presented vivid narratives of how people disturb the ecological equilibrium in nature in the name of development. These stories, with scientific evidence, reminded people of the origin of the environmental movement, the beauty of the natural environment and the tragedy of its loss.

The need for sustainable development was a broader response that attempts to encompass the many facets of the rising global environmental movement. This was evident from the United Nations Sustainable Development Goals, introduced in 2015, in which all social, environmental and economic aspects were incorporated into a very broad framework.

The response from the built environment focused on mitigating environmental impacts by introducing the new approach of ESD. ESD, from its inception, had more focus on policy and technological interventions than on the human–nature relationship. However, current ESD practice has a greater emphasis on nature and nurturing for healthy human–nature relationships (Africa et al., 2019).

It is clear that, throughout the rise and expansion of the global environmental movement, nature has held a focal position. Even though ESD originally focused on merely mitigating environmental impacts, there is currently a transition towards an approach that has enhanced human–nature connectedness. Thus, a nature-centric approach is crucial for shifting ESD to respond to the need for enhanced human–nature connectedness in the design outcome.

3.3.2 The Interconnected Mesh: Interplay of the Human, Nature and the Built

While literature on global environmental concerns presented in Sect. 3.3 above has emphasised the central position of nature in the global environmental movement, another crucial school of thought has evolved around the idea that all living entities are interconnected. This idea broadens the definition of what constitutes nature. This phenomenon was widely discussed in deep ecology and ecological thought (Morton, 2010), and highlights the criticality of achieving long-lasting sustainability.

The notion of the interconnectivity of all living things had its foundation in Eastern thinking. Erdos (2019) argued that Eastern philosophy has a high emphasis on enduring a close relationship with nature. Henning (2002) drew similarities between Buddhist philosophy and deep ecology. Buddhist philosophy was built upon this notion of interconnectivity to convince people to be more passionate towards nature. As Hennings (2002) pointed out:

> Buddhism views people as a part of nature. If the environment is destroyed or degraded, people cannot survive or have a quality life. By abusing the environment, people abuse themselves and their descendants as well as future generations of all life. (p. 9)

By contrast, early Western thinking placed humans above other living beings, which, in return, may have led to the exploitation of natural resources (Erdos, 2019). The idea of interconnectivity first appeared in Western thinking only after the rise of Darwinism. Darwin planted the seeds of the idea that all living beings are interconnected, and that human evolution was equal to any other species, which shattered the idea of human dominance over other species.

The idea of deep ecology was brought into the global environmental movement through the work of Norwegian philosopher and mountaineer Professor Arne Næss. He argued that there were two types of environmentalism (Naess, 1973), which were not compatible: the long-range deep ecology movement and the shallow ecology movement. He distinguished these two types by the level of inquiry. Deep ecology argues deeply into the purposes and values of environmental issues, breaking them down to their fundamentals, such as exploring the deeply rooted relationship between human and nature. Shallow ecology merely questioned at the surface level such as taking actions against pollution and resource depletion. Even though the term 'deep ecology' was coined in early 1970s, Rachel Carson's work with *Silent Spring* (1952) is recognised as the turning point that 'ushered in what appropriately can be called the Age of Ecology' (Sessions, 1987, p. 105).

Sessions (1987) conducted a comprehensive review of the deep ecology movement, pointing out its ideological nature and argued that:

> many environmental historians, ecophilosophers, and anthropologists now agree that primal societies throughout the world practiced a spiritual 'ecological' way of life in which everything was to be respected in its own right. This 'ecocentric' religious approach accounts for their cultural success for thousands of years and can provide modern humans with historical models for the human/nature relationship. (p. 107)

By assigning spiritual connotations to ecological views, Sessions (1987) also distinguished between the Eastern and Western religious philosophies and pointed out how Eastern religions were premised on the interconnectivity of all entities.

Snyder (2004) further expands this view by emphasising the need for nature to be considered from an ethical point of view, arguing that:

> a huge number of contemporary people we can no longer think that the fate of humanity and that of the natural world are independent of each other. A society that treats its natural surroundings in a harsh and exploitative way will do much 'other' people. Nature and human ethics are not unconnected expansion of ecological consciousness translates into a deeper un interconnectedness in both nature and history, and a far more grasp of cause-and-effect. (p. 21)

Snyder (2004) also stressed differences in the Western and Eastern philosophical debates in acknowledging the mutual connectivity of humans and nature. Snyder (2004) argued that, to establish this connection, we need to understand that 'I am part of your surroundings just as you are part of mine' where 'this sort of mutuality is acknowledged in Buddhist philosophy, and highly developed in ecological thought' (p. 23).

Deep ecology seemed to have its roots in Buddhist philosophy and that the idea of interconnectivity was been further explored with varying interpretations. Morton

(2010) used the term 'mesh' to represent the interconnectedness of all living and non-living things. In the mesh, he placed the built as an extension of the environment, arguing that:

> all the life forms are the mesh, and so are all dead ones, as are their habitats, which are also made up of living and non-living beings. We know even more now about how life forms have shaped Earth. We drive around using crushed dinosaur parts. Iron is mostly a by-product of bacterial metabolism. So is oxygen. Mountains can be made of shells and fossilised bacteria. (p. 29)

He specifically used the term 'ecological thought' to describe this way of thinking about an interconnected metaphysical world wherein we can consider the built as a part of nature itself.

The arguments around deep ecology and ecological thought support the idea that nature is a connecting factor in the world in which we live. Thus, shifting our sustainability perceptions towards a nature-centric approach will assist us to consider the built as an entity within nature and both are made from same elements. This means that the built is not a separate entity but rather an extension of nature. If nature is built with elements, then so is the human, and so is the building. Therefore, any definition we use for nature or natural things can be equally applied to the built or to humans.

3.4 Biophilic Thought: A Nature-Centric Sustainability Manifesto

We have argued that shifting the perception of sustainability towards a nature-centric view is also to accept that things are interrelated, that nature is the pivotal point, and that we can, therefore, define both nature and the built using common aspects.

With this biophilic thought, we developed our own sustainability manifesto. Drawing on the literature presented above, we used the elemental view of nature: that nature is a composition of *earth*, *air*, *water* and *fire*. This philosophical, elemental view of nature is common in both Eastern (Hardy, 1853; Kalupahana, 1976; Upham, 1829) and Western (Adler, 1952; Glacken, 1970) traditional cultures. *Earth*, *air*, *water* and *fire* are commonly used as grounding elements of the environment—or nature—bearing both physical and cultural meanings.

Buddhist philosophy provides an early revelation that matter is made of four elements: *prutav-dhatu* (earth), *vayu-dahthu* (air), *apa-dhatu* (water) and *theja-dhatu* (fire) (Karunadasa, 2020). In Hinduism, these elements are commonly termed *pancha boota* with an additional fifth element of space (Singh, 1992). The Chinese concept of *fengshui* similarly views *earth*, *air*, *water* and *fire* as elements of existence. In the practice of *fengshui*, functions of household are orientated to designated directions of the four elements (Parkes, 2003). The objective of this is to harmonise the elements and thereby attract universal energy for wealth and prosperity.

Mortimer Adler (1952) identified the elemental view as one of the hundred great ideas of Western thought. Traditionally, ancient Greek geography used the natural elements as guides to understand and interpret the environment and space (Glacken, 1970). They identified the elements of fire in the sun, air in the sky, earth in mountainous landscape and water in the sea. This view is reflected in Greek mythology, poetry and literature (Hesiod, 1973) as well as in Greek philosophy (Macauley, 2010).

However, with industrialisation and technological advances, this perception also took a shift. Hegel, in the *Philosophy of Nature* (1970), explained how science, with the advances of chemistry, deduced all materials into elementary chemical compounds, and the four elements were neglected. Hegel (1970) stated that 'the concept of the four elements, which has been commonplace since the time of Empedocles, had been rejected as puerile fantasy' (p. 34) and that 'no educated person is now permitted, under any circumstances, to mention (it)' (p. 34). It is highly likely that this vision influenced the ESD approach as well, which is focused on technological solutions to mitigate environmental impacts, rather than building expression for depicting cultural meanings, values or enhancing human–nature relationships.

By contrast, the elemental view underlines the importance of sensory experience as a means to bring humans closer to nature. Macauley (2010) explored the use of the four elements under elemental philosophy and argued that further inquiry into the four elements not only enriches philosophical debate but also actively contributes to environmental activism. Macauley (2010) believed that understanding nature through these elements serves two purposes: First, it supports a sensory experience, wherein physical entities touch the senses—for example, the earth beneath our feet, feeling a breeze on our face or touching a body of water. Establishing these sensory links makes it easier to understand nature and enhance human–nature connectedness based on a set of achievable and tangible targets. Second, this 're-rooting' of nature as elements gives an understanding of the use of natural elements and processes within buildings for everyday use as a 'domestication of elements' rather than a 'domination of nature'. For instance, water is domesticated through fountains, ponds and reservoirs, while fire, in the form of hearth, brings warmth to an interior space, lighting and electricity (Macauley, 2010). This conscious domestication helps us to appreciate the consumption of elements extracted from nature, rather than positioning them as scientific or chemical compounds.

Foster (2002), among many others who have advocated for the use of the four elements to perceive nature in overcoming the environmental crisis (Callicott et al., 2014; Light, 1995; Sallis, 2012), has argued that an elemental view could lead to a stronger environmental virtue ethics.

With this definition, we could create criteria in BD and ESD using the four elements of *earth*, *air*, *water* and *fire.* To use these elements for both nature and the built, we also needed to amend the terms in ways familiar to sustainable design. We used *earth*, *air* and *water* as they were, but changed *fire* to *energy*. This change facilitated a more sensible interpretation of current ESD criteria given under *energy*. We added another element, *habitat*, which reflects the inclusion of flora and fauna into the built environment, currently promoted in both BD and ESD. Thus, biophilic thought defines **"buildings as extensions of a natural setting and as made of *earth*, *air*, *water*, *energy* and *habitat*".** We further elaborated our biophilic thought by assigning definitions to each element:

- *Earth* is the materiality of the building that brings it into existence with colours and textures.
- *Air* is the space that is trapped within the building to allow for ventilation and air quality performance and which contributes to the sense of space and light.
- *Energy* is the power of the building that brings warmth, comfort and light into the building; the visual attributes of daylight; and the perceived heat in the building.
- *Water* is the fluidity within the building, serving aesthetic and utilitarian purposes.
- *Habitat* is the living forms in and around the building that interact with humans, including flora and fauna that connects the inside with the outside.

These definitions allow ESD criteria and BD criteria to be mapped onto the five elemental categories. These categories can not only be used to create comprehensive design principles that encompass both ESD and BD criteria, but they are also the expression of our sustainability manifesto. For us, sustainable design is the bridge between the built and nature; it represents the fundamental connection between performance, emotions and wellbeing. The built without nature is a mere construction; the built is an extension of nature, and both are composed of *earth*, *air*, *water*, *energy* and *habitat*. Architecture is the interconnected mesh that allows us to design truly sustainable buildings, allowing for a nourishing coexistence of the built, nature and the human.

Now you have seen how we built our manifesto by drawing upon the literature on ecology and sustainability; however, this manifesto is our interpretation of the concepts, principles and ideas. You can try to build your own manifesto by responding to these questions:

- What is the fundamental role of architecture for you? Why do we design?
- What is sustainability? How can you define it in fewer than 100 words?

In responding to these questions, try to think about what you have read and the different connecting relations illustrated in Fig. 3.1. It is important that you try to contextualise the manifesto within the framework. If you do this, it will be possible to develop a design framework based on your manifesto.

The written definition of biophilic thought above is an example of a sustainability manifesto given in verbal expression. You can also use a diagram to communicate your sustainability manifesto, as shown in Fig. 3.8.

3.5 Concluding Remarks

In this chapter, we have seen the fundamental interrelations between *the built*, *nature* and *the human*. We identified a method for analysing current ESD frameworks and identifying their fundamental relations. The literature on the human-centric approach development can guide us towards the creation of a sustainability manifesto grounded in the elemental view, wherein humans, buildings and nature are part of the same entity and interconnected in a unique mesh. Starting from this exercise, it is possible

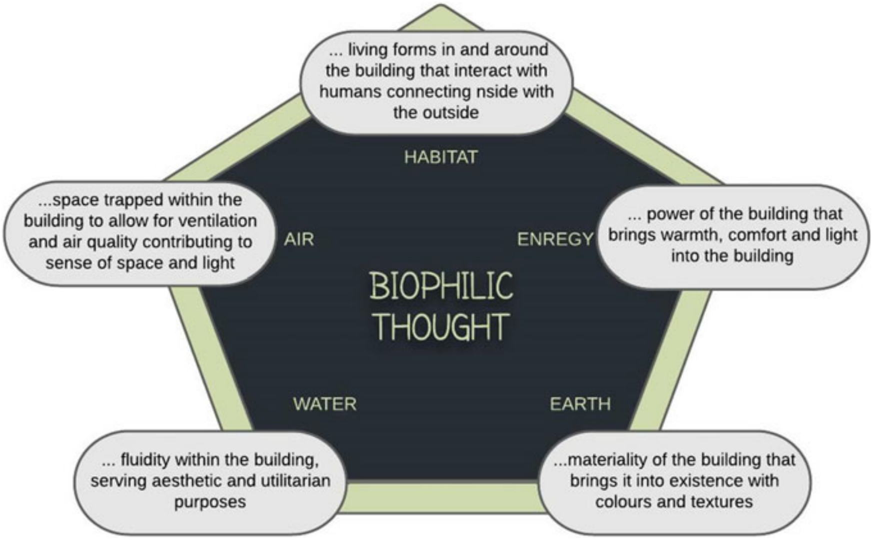

Fig. 3.8 Diagrammatic presentation of biophilic thought

to develop a personal manifesto, responding to these pressing questions: What is sustainability? What is the role of architecture?

Within sustainable studio, this represents a first step towards an informed approach to design. In the next chapters, we will provide evidence for the next steps that must be undertaken to integrate BD into ESD studios: Student Guide 2 (how to develop a BD framework) and Student Guide 3 (how to report and model your BD thinking), which contains an exemplar showing how to apply the framework to develop a design proposition.

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Chapter 4
Student Guide 2—How to Develop a Biophilic Design Framework

Abstract A biophilic design (BD) framework is a crucial component for using BD principles within an environmentally sustainable design (ESD) approach. One key challenge in developing a BD framework compatible with an ESD approach is the lack of systematic techniques with clear instructions to generate the criteria. To address this need, the process-bridging technique—a systematic method for developing biophilic criteria—is outlined in this chapter. The proposed system uses natural processes to bridge between biophilic and building performance criteria. The five elements—*earth*, *air*, *water*, *energy* and *habitat*—proposed in previous chapter are used to categorise the criteria. The process-bridging technique supports you in systematically generating biophilic criteria compatible with ESD approach We illustrate how a *place criteria* for BD and a *performance criteria* for ESD are generated using current BD and ESD frameworks respectively. These biophilic criteria can be used as a basis to develop and elaborate strategies for the architectural concept, geometrical model and building components and systems to be employed in the design. These, in turn, can then be integrated into your ESD framework, which we have termed as the 'success matrix'. There are two ways to integrate: (i) you can include them as a specific category in the matrix, hence your BD framework will become a sub-section of the overarching ESD framework, or (ii) they become the leading design targets in the matrix. We will give you some examples of each. Either way, you can synthesise the generated biophilic criteria, design strategies and building components into a self-assessment tool.

4.1 Introduction

This guide outlines a systematic method for developing a BD framework that you can use to enhance your biophilic response within an ESD project. To describe the development process, we use a number of specialised terms that we summarised in Table 4.1.

N. Wijesooriya et al., *A Biophilic Design Guide to Environmentally Sustainable Design Studios*, SpringerBriefs in Education,
https://doi.org/10.1007/978-981-19-4428-4_4

Table 4.1 Definition of process-bridging technique terms

Term	Definition
Design framework	A design framework is a set of predetermined criteria that outlines what you want to achieve in your building design. In the practice of environmentally sustainable design, green building rating tools are used for this purpose; they set the criteria you aim to achieve through your design. Some examples are Green Star certification and Leadership in Energy and Environmental Design (LEED) certification
Biophilic design (BD) framework	When a design framework is developed to practise biophilic design, we call it a biophilic design framework. The *14 Patterns of Biophilic Design* developed by Browning et al. (2014) is an example
Success matrix	A success matrix is a design framework used within a studio design project. Similar to a design framework, you can include a set of predetermined criteria that you intend to achieve within your sustainable design
Category	These are the high-level categories, covering different aspects, presented in a design framework. For example, the Leadership in Energy and Environmental Design standards comprise eight categories: site management, energy, water efficiency, air quality, materials and resources, innovation and regional priority
Criteria	Criteria are given under each category. They are aspects of what is to be achieved within the category. For example, under the 'water efficiency' category, 'reduction of potable water use' is a criterion
Place criteria	Place criteria consist of a list of criteria that support biophilic design and contribute to sensory place-making aspects of a design. They include criteria given in the current biophilic design frameworks found in industry practice
Performance criteria	Performance criteria consist of list of criteria that support building performance. They include criteria generally found in green building rating tools currently used in industry practice
Natural process inventory	A natural process inventory is a list of natural processes that can be used to achieve certain building performance. This is generated by reviewing current academic literature and building case studies
Process	'Process' is short for 'natural process' within the natural process inventory
Biophilic criteria	Biophilic criteria is a list of criteria that is generated through the proposed technique. The criteria in this list contribute towards place-making and sustainable performance of a building

(continued)

Table 4.1 (continued)

Term	Definition
Design strategy	A design strategy outlines how a certain criterion can be achieved through design. For example, if 'use of natural elements to reduce heat gain is a criterion', then 'use of vegetation to reduce heat gain' and 'use of water features to reduce heat gain' are two design strategies
Building components	A building component is used to adopt a design strategy in the building. For example, if the 'use of vegetation to reduce heat gain' is a design strategy, then 'vegetated vertical window shading' is a building component
Implementation steps	Implementation steps are further instructions given in a design framework to realise the design strategies or building components. For example, if 'vegetated vertical window shading' is the building component, then 'calculate the dimensions of shading device' and 'use a simulation model to calculate the reduction through window' are implementation steps

Figure 4.1 shows the structure of a typical BD framework. It is based on our pilot of BD framework development (Wijesooriya et al., 2021) and an extensive literature review of academic and industry references (Wijesooriya et al., 2022).

As illustrated in Fig. 4.1, *categories* are at highest level. Under each category is a list of *biophilic criteria*. Each criterion can be further detailed in terms of *design strategies*, which can each be achieved in the building through *building components*. Elaborating the *biophilic criteria* with *design strategies* and *building components*

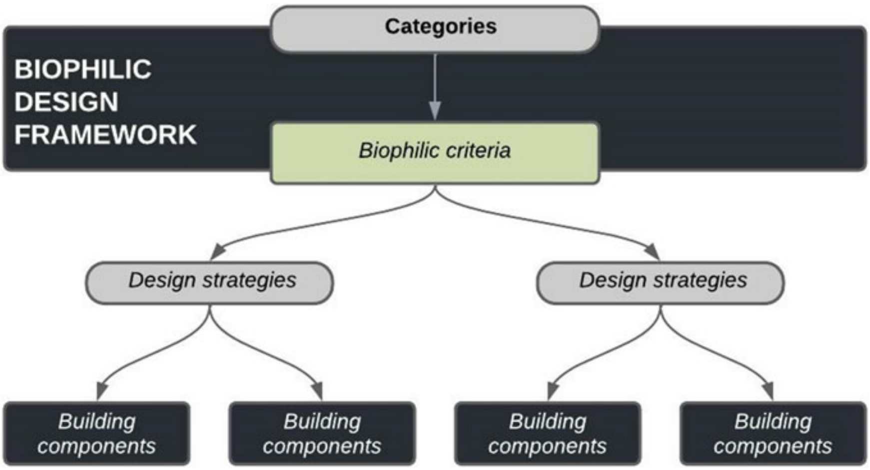

Fig. 4.1 Structure of a typical biophilic design framework

is an optional activity that improves the applicability of the BD framework. By investigating this structure and analysing current frameworks, we can identify the stages involved in developing a BD framework:

Stage I: deriving *categories* (Sects. 4.2 and 4.3)
Stage II: generating *biophilic criteria* compatible with the ESD approach (Sects. 4.2 and 4.3)
Stage III: identifying *design strategies* (Sect. 4.4)
Stage IV: proposing *building components* (Sect. 4.4)
Stage V: integrating the *biophilic criteria*, *design strategies* and *building components* into the success matrix (Sect. 4.5)
Stage VI: synthesising the BD framework into a self-assessment tool (Sect. 4.5).

The most challenging of these stages is generating *biophilic criteria* that are compatible with the ESD approach. We propose the Process Bridging Technique (PBT) for this purpose, which is more specifically detailed in Sect. 4.2. We have included an example of BD framework analysis (Wijesooriya et al., 2022) in Sect. 4.3, which may assist you understanding the process and generate your own framework.

We used the term 'success matrix' to identify the design framework in a studio setting. These generated *biophilic criteria*, *design strategies* and *building components* alone will not guide your design; instead, you need to integrate them into your success matrix. Instructions on how to integrate the BD criteria into your success matrix and further synthesise the framework as a self-assessment tool are given in Sect. 4.6.

Once the BD framework has been developed, it is necessary to validate its compatibility with the ESD approach. This step can be undertaken following the methodology used by Xue et al. (2019), presented in Sect. 4.5.

4.2 Stage 2–4: Process-Bridging Technique

The use of natural processes in building performance and ESD approaches is becoming increasingly popular. Identifying natural elements that support the sensory experience while contributing towards building performance is a strategic bridging point between ESD and BD. The PBT presented in this chapter is based on this concept. The PBT we outline here to generate the BD criteria comprises a few steps, as shown in Fig. 4.2.

As illustrated in Fig. 4.2, PBT requires additional steps expanding on the previously identified stage II:

Stage I: deriving *categories*
Stage II: generating *biophilic criteria* compatible with the ESD approach

II(a) develop the place criteria and performance criteria
II(b) develop a *natural process inventory* (NPI), meant as a list of natural processes that can be used for achieving building performance

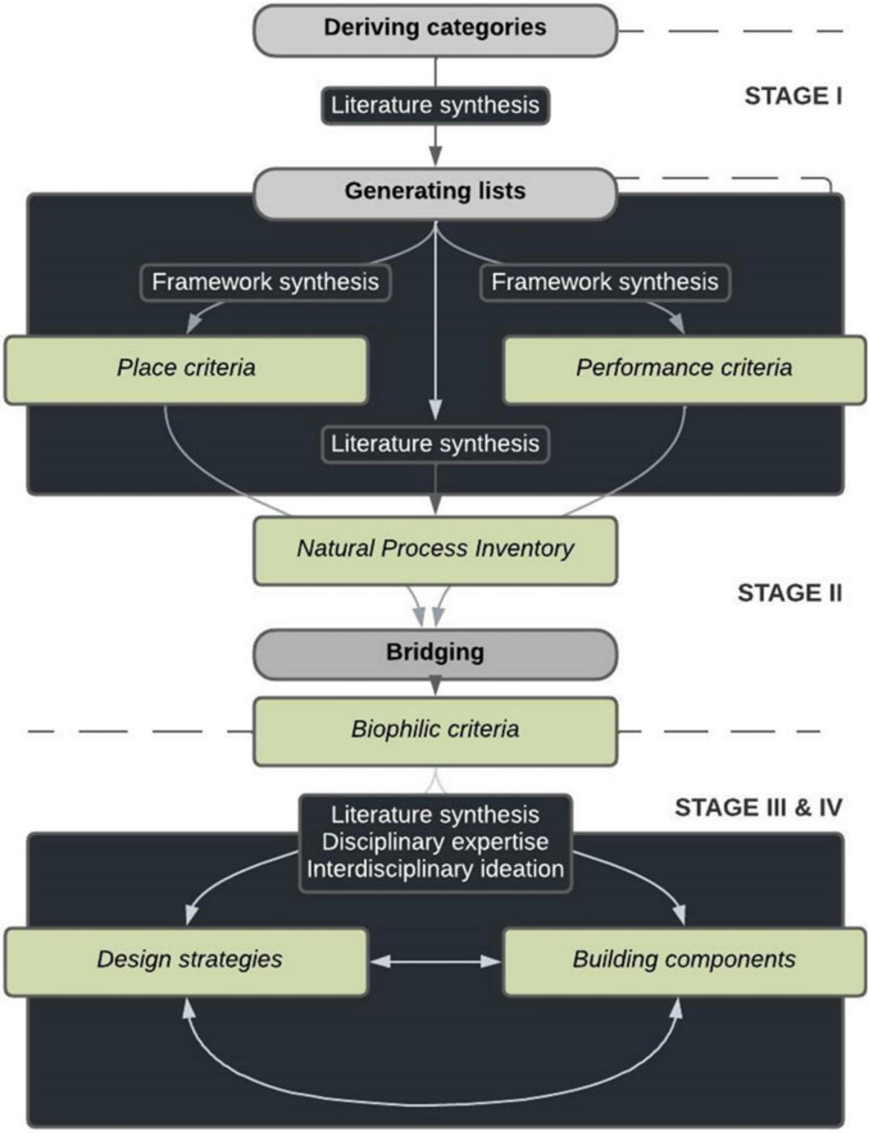

Fig. 4.2 Process-bridging technique steps

II(c) bridge between the *place* and *performance* criteria lists using the items from the NPI and develop the *biophilic criteria*.

Stage III: identifying *design strategies*
Stage IV: proposing *building components*

PBT has several stages, and, depending on the need and the scope of the project, this may differ. The figure provides the technique for development in between the steps and how these techniques are identified by analysing the exiting BD frameworks is reported in Sect. 4.2.1, while Sect. 4.3 provides a step-by-step guide to apply the PBT.

4.2.1 Techniques Used in the Stages of Biophilic Design Framework Development

To develop a systematic method for deriving BD frameworks it is important to refer to previous examples and applications. In literature, there are only a limited amount of BD frameworks that can be used at building level. All of them are outlined in following Table 4.2.

If we analyse each of these BD frameworks, we can notice that there are several common stages of BD. These stages include deriving *categories*, generating *criteria*, identifying *design strategies*, proposing *building components* and *outlining implementation steps*. Not all BD frameworks include all these stages, as these frameworks vary in terms on their aims, targets and expected outputs. However, it is possible to define four techniques common to BD frameworks at each stage: (1) literature synthesis, (2) framework synthesis, (3) interdisciplinary ideation and (4)

Table 4.2 Currently available biophilic design frameworks

Framework	Description
Kellert (2008)	the earliest design framework from Stephen Kellert (2008), which focused on the qualitative design principles of BD
Kellert and Calabrese (2015)	A shortened version of Kellert's design framework, based on the spatial experiences within a building, introduced as a guide for practical use of BD
Browning et al. (2014)	The *14 Patterns of Biophilic Design* provides a framework with 14 BD criteria, that can guide a BD design. The framework is detailed with references supporting each criteria
Abdelaal (2019)	A framework particularly developed for a biophilic campus by Abdelaal (2019)
Xue et al. (2019)	A framework by Xue et al. (2019) as an attempt to bridge the current ESD approach and BD principles
Wijesooriya et al. (2020)	A BD framework that focused on water, previously developed by the present authors
ILFI (2018)	The BD guide by the International Living Furniture Institute, developed to support the Living Building Challenge, remarkably the only guide found that provided instructions on developing a BD framework

expert knowledge. These are useful techniques that you may want to explore to develop your own framework.

Literature synthesis refers to the review of current literature to develop themes for a particular stage. Similarly, *framework synthesis* uses existing design frameworks to develop themes. When the development of the themes is a communal effort of a professional interdisciplinary team, it is refer to as *interdisciplinary ideation*, while, if the development is based on the internal expertise of the development team, it is referred to as *expert knowledge*. Table 4.3 summarises the use of each technique at different stages across the seven BD frameworks analysed.

We further summarised Table 4.2 to understand which techniques are more commonly used at each stage for each of the framework (Table 4.4).

According to Table 4.2, *literature synthesis* is the basis of most of the frameworks, except from the guide by ILFI (2018), which uses *interdisciplinary ideation*. Table 4.4 reveals that *literature synthesis* and *framework synthesis* are more predominant during the development process. *Expert knowledge*, although not a technique per se, can contribute when the framework is novel by building on the existing expert knowledge base. Table 4.5 summarises which of these techniques we used to construct the BD framework presented in this book.

4.3 Step-By-Step Use of the Process-Bridging Technique

This section presents a step-by-step guide to PBT. We start by deriving categories that can be applied to both an ESD and BD approach (Stage I). We use the nature-centric sustainability manifesto developed in Chap. 3, which defines *the built* and *nature* as comprising five elements: *earth*, *air*, *energy*, *water* and *habitat*. The following are the definitions given in Chap. 3 under 'Biophilic Thought' (Table 4.6).

These five elements are used as the main categories for both *place* and *performance* criteria lists. For each category, *place criteria* and *performance criteria* are required to bridge them and to derive a *biophilic criteria*. An NPI is developed to associate *place criteria* with *performance criteria*.

4.3.1 Developing the Place Criteria

In developing the *place criteria* (Stage II(a)), we suggest you use the *framework synthesis* and to take inspirations form the existing BD frameworks already in use. These frameworks are primarily qualitative, and, in many instances, some criteria found in them will fall into multiple categories. For example, consider three frameworks: Kellert (2008), Kellert and Calabrese (2015) and Browning et al. (2014). For clarity, we use only one category, *earth*. If you refer to these frameworks and you select the criteria used for *earth*, you will generate a list that contains the criteria presented in Table 4.7.

Table 4.3 Use of techniques for developing themes at different stages in biophilic design frameworks

	Stage				
Framework	Deriving categories	Generating criteria	Identifying design strategies	Proposing building components	Outlining implementation steps
Kellert (2008)	Expert knowledge	Literature synthesis	Expert knowledge	Expert knowledge	Not applicable
Kellert and Calabrese (2015)	Literature synthesis	Expert knowledge	Expert knowledge	Expert knowledge	Not applicable
Browning et al. (2014)	Literature synthesis	Literature synthesis	Literature synthesis/disciplinary expertise	Literature synthesis/disciplinary expertise	Literature synthesis
Abdelaal (2019)	Literature synthesis	Framework synthesis	Literature synthesis	Literature synthesis	Not applicable
Xue et al. (2019)	Framework synthesis	Framework synthesis/literature synthesis	Literature synthesis	Literature synthesis	Not applicable
Wijesooriya et al. (2020)	Literature synthesis	Framework synthesis/literature synthesis	Literature synthesis	Literature synthesis	Not applicable
ILFI (2018)	Not applicable	Framework synthesis	Interdisciplinary ideation	Interdisciplinary ideation	Interdisciplinary ideation

Note ILFI = International Living Furniture Institute

Table 4.4 Summary of techniques used during framework development stages

Stage	Literature synthesis	Framework synthesis	Interdisciplinary ideation	Expert knowledge
Deriving categories	✓	✓		✓
Generating criteria	✓	✓		✓
Identifying design strategies	✓		✓	✓
Proposing building components	✓		✓	✓
Outlining implementation steps	✓		✓	

Table 4.5 Techniques used for the development of biophilic design framework at different stages

Stage	Adopted technique
Deriving *categories*	Literature synthesis
Developing *place criteria* and *performance criteria*	Framework synthesis
Deriving a *natural process inventory*	Literature synthesis
Bridging to derive a *biophilic criteria*	Expert knowledge
Identifying design strategies	Literature synthesis, expert knowledge, interdisciplinary ideation
Proposing building components	Literature synthesis, expert knowledge, interdisciplinary ideation
Synthesising framework as a self-assessment tool	Expert knowledge

Table 4.6 Categories and definition of biophilic thought

Category	Definition
Earth	*Earth* is the materiality of the building that brings it into existence with colours and textures
Air	*Air* is the space that is trapped within the building to allow for ventilation and air quality performance and which contributes to the sense of space and light
Energy	*Energy* is the power of the building that brings warmth, comfort and light into the building; the visual attributes of daylight; and the perceived heat in the building
Water	*Water* is the fluidity within the building, serving aesthetic and utilitarian purposes
Habitat	*Habitat* is the living forms in and around the building that interact with humans, including flora and fauna that connects the inside with the outside

Table 4.7 Place criteria for earth

Earth place criteria sections	Earth place criteria themes
Natural material selection	Material connection with nature Natural material use Biomimicry Information richness Age, change and patina of time Growth and efflorescence
Place-making with earth resources	Visual connection with natural materials Non-visual connection with natural materials Materials for non-rhythmic sensory stimuli Connection with natural systems Prospect/refuge Mystery Risk/peril
Composition of material variability	Sensory variability Complexity and order in material variability Biomorphic forms and patterns Fractals in natural materials

This list is referred to as *place criteria* because, it is generated using BD frameworks focused on sensory attributes that contributes towards a sensory place experience within a building. The list is divided into 3 sections: natural material selection, place-making with earth resources and composition of material variability. Each section has themes for *earth* related *place criteria*.

4.3.2 *Developing the* **Performance Criteria**

Similar to *place criteria list*, it is recommended to use the framework synthesis technique for deriving the *performance criteria*. In this case, you can refer to common GBRTs that you might already be familiar with. In our example, we used four rating schemes detailed in Table 4.8.

Remembering that we are considering the category *earth*, the GBRTs are analysed to identify those criteria that can be related to our focus. In LEED, 'materials and resources' provide most of the criteria for *earth*, but some are extracted from the 'indoor air quality' and 'regional priority' categories. In BREEAM, 'materials' provides the majority of criteria, with a few from 'waste' category. Therefore, it is crucial to carefully go through the whole framework in selecting criteria items for each category.

Table 4.9 shows the list of *earth* criteria generated synthesising above four GBRTs. In this case, the list is called *performance criteria* because all criteria are generally quantifiable and commonly found in evidence-based design approaches.

Table 4.8 Details of selected green building rating tools

GBRT	Version used	Buildings certified	Year
LEED BD + C V4	LEED v4 Reference Guide for Building Design and Construction	More than 94,000	2013
BREEAM International NC 2016	BREEAM International New Construction 2016 Technical Manual	566,727	2016
WBS V2.1	WELL Building Standard v2 Pilot	1,166	2018
LBC V3.1	Living Building Challenge 3.1	386	2016

Note GBRT = green building rating tools; LEED = Leadership in Energy and Environmental Design; BREEAM = Building Research Establishment Environmental Assessment Method; NC = New Construction; WBS = WELL Building Standard; LBC = Living Building Challenge

Table 4.9 Performance criteria list for earth

Earth performance criteria sections	Earth performance criteria themes
Material selection	Low-emitting materials Regional priority Exterior materials and structures Responsible sourcing of construction products Designing for durability and resilience Material efficiency Rapidly renewable materials
Waste management	Net-positive waste Construction and demolition waste management Operational waste management Waste free safe and healthy surroundings
Impact management	Building life-cycle impact reduction Hazardous material abatement Enhanced material precaution and transparency Site remediation Avoiding pesticide use Hazardous material reduction Volatile compound reduction Long-term emission control Building life-cycle assessment

The *performance criteria* is directly associated with the materiality of the building and will not require design strategies to understand its implications. Again, with the long list, the criteria are categorised under three headings: material selection, impact management and waste management.

Table 4.10 *Natural process inventory* for *earth*-related processes

Associated place category	Natural process	Associated performance category
Earth	Earth walls for enhanced thermal performance	*Energy* (enhanced thermal performance)
Earth	Sand filters for water purification	*Water*
Earth	Clay as a thermal insulation	*Energy* (enhanced thermal performance); *Earth* (low-emitting materials; building life-cycle impact reduction)
Earth	Timber as a material for carbon offset	*Air* (carbon offset)
Earth	Timber as a rapidly renewable material	*Earth*
Earth	Earth as a low-embodied energy material	*Earth*
Habitat	Flora for air purification	*Air/Earth* (short-term emission control; long-term emission control)
Habitat	Flora for air quality enhancement	*Air/Earth*
Earth	Waste composting	*Earth/Habitat*

4.3.3 Deriving the Natural Process Inventory

Once the *place* and *performance* criteria lists have been derived, an NPI can be used to bridge the two. You can derive the NPI by selecting natural processes of preference from the literature. Unique *biophilic criteria* can be generated depending on the items included into the NPI. This step requires expertise in principles of building science, passive design and approaches for bioclimatic design. Your teacher will provide you with the references and resources necessary for this.[1] Table 4.10 shows an example of NPI derived using research on natural processes.

The list in Table 4.10 contains items associated with *earth* either in *place* and/or *performance*. For example, 'sand filters for water purification' has visible elements of sand that would mean it falls under *earth* in the place criteria, whereas its performance of enhancing water quality means it is in the *water* category. The associations between the two types of criteria under *place* and *performance* using NPI items depends on the user's interpretation, with an opportunity to individualise the final *biophilic criteria* list. This is further discussed in the next section.

[1] For educators: Please not that this step is highly customizable based on the overarching curriculum of your School. It is recommended that the studio will integrated the necessary knowledge to undertake this step with one of the modality described in Sect. 2.3.3.

4.3.4 Bridging to Derive Criteria List Items

With two criteria lists and the NPI compiled, bridging these list items generates the *biophilic criteria* list. Bridging is a unique step introduced in the PBT that also supports individualisation of your *biophilic criteria* list, depending on what items are included in the NPI and how the *biophilic criteria* items are written. Your expertise and personal preferences will shape which natural processes are selected and how they are associated with *place* and *performance* criteria. While writing the *biophilic criteria* descriptions, the proposed design strategies and elements allow for another level of individualisation that can reflect your architectural style and gusto.

Bridging can be done in three ways: (1) *place pathway*, (2) *performance pathway* and (3) *process pathway*. 'Process' is a shorter term used in this context to refer to NPI items. As the terms indicate, each path is identified based on where the bridging starts and its direction for association with other criteria items. Each pathway is shown below with examples using the generated lists.

4.3.4.1 Place Pathway

Place pathway bridging starts from *place criteria*. It is then associated with *process*, which is in turn is associated with *performance* (Fig. 4.3).

In this pathway, *place criteria* can be associated with multiple processes, as they contain abstract concepts that focus on the sensory experience in the built environment. Since the NPI items are specifically written for natural processes that contribute to building performance, the association with *performance* will give at least one link. This one link can lead to multiple *performance* items (Fig. 4.4) since one natural

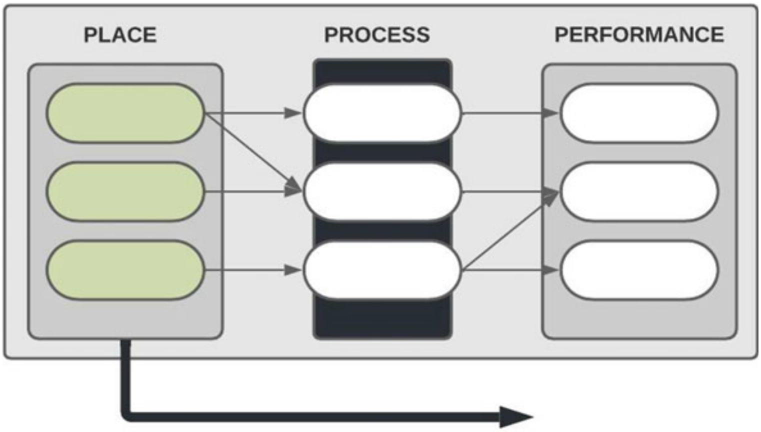

Fig. 4.3 Place pathway

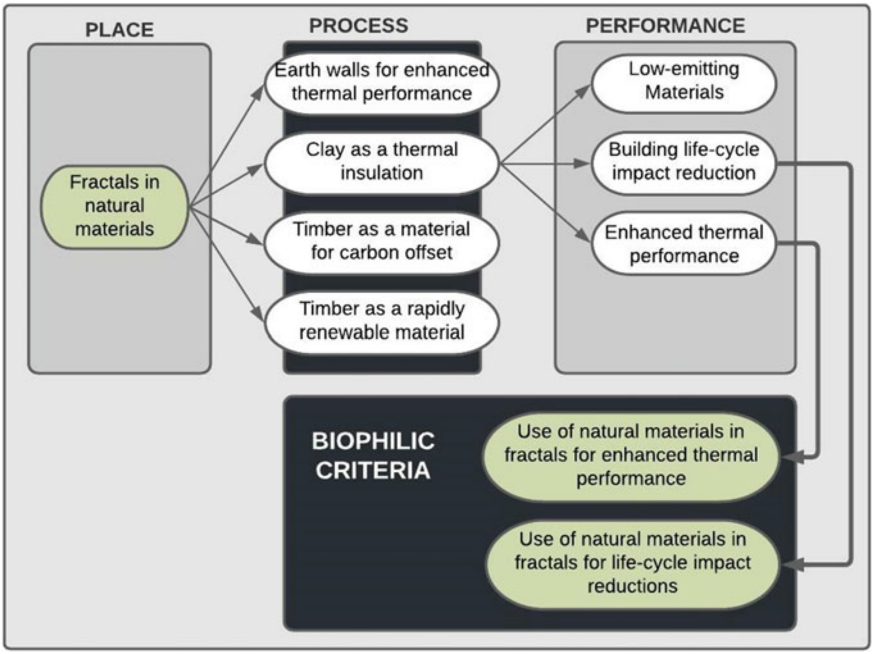

Fig. 4.4 *Place pathway* bridging for 'fractals in natural materials'

process can be used to achieve many building performances. Figure 4.4 demonstrates one example of a typical *place pathway* bridging.

As illustrated in Fig. 4.4 'fractals in natural materials', from the *place criteria list*, is associated with 'earth walls for enhanced thermal performance', 'clay as a thermal insulation', 'timber as a material for carbon offset' and 'timber as a rapidly renewable material' within the NPI. To associate this further with *performance criteria*, 'clay as a thermal insulation', as an example, can be associated with 'low-emitting materials' and 'building life-cycle impact reduction' from the *performance criteria list* for *earth*. *Earth* category mainly focuses on materials and the knowledge around the shift towards circular use of resources emphasised in concepts such as cradle-to-cradle, circular economy, circular construction processes are crucial. In this example use of clay support the cradle-to-cradle approach where clay is biodegradable material that can be disposed back to nature with no environmental consequences.

However, the direct implication of 'enhanced thermal performance' can be assumed to be in such a list derived for *energy*. This is quite a common phenomenon when the *place pathway* is used.

The *biophilic criteria* item for 'enhanced thermal performance' can, as an example, be written as 'use of natural materials in fractals for enhanced thermal performance'. By using the generic term 'natural materials' rather than the more specific term 'clay' in the criteria, there is more opportunity during design stages to respond with multiple design strategies.

The *place pathway* is recommended when place-making aspects are in focus and the design is required to improve upon its building performance without compromising on the BD considerations.

4.3.4.2 Performance Pathway

The *performance pathway* starts the association from an item within the *performance criteria list*. With some *performance* items including management aspects, it is difficult to associate with any natural processes. Due to this, there can be some items in the *performance* list without a link to a natural process. This can result in a *performance* criterion not contributing to the overall BD approach in the design. The potential associations are illustrated in Fig. 4.5.

This pathway can result in one of three potential associations: a *performance* can be linked to both *process* and *place*, *process* only or have no links at all. An example is given in Fig. 4.6 to demonstrate this.

The *performance* item ‘long-term emission control’ is associated with ‘flora for air purification’ and ‘flora for air quality enhancement’. When attempting to associate these to *place criteria*, numerous items can be linked due to their abstract level. It takes disciplinary expertise to determine what aspects should be covered by a particular NPI item and what should be included in the *biophilic criteria* list. In this example, ‘information richness’, ‘age, change and patina of time’ and ‘growth and efflorescence’ are selected from the *place criteria list* to associate with ‘flora for air purification’.

The *biophilic criteria* items are written as ‘use of flora contributing to information richness (or ‘age, change and patina of time’ or ‘growth and efflorescence’) for long-term emission control’.

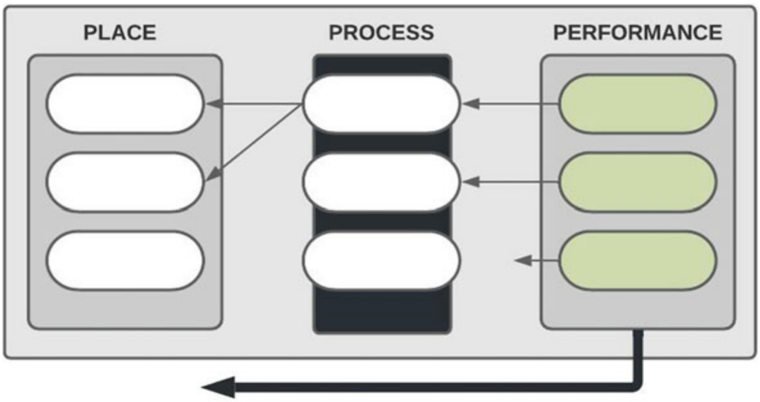

Fig. 4.5 Performance pathway

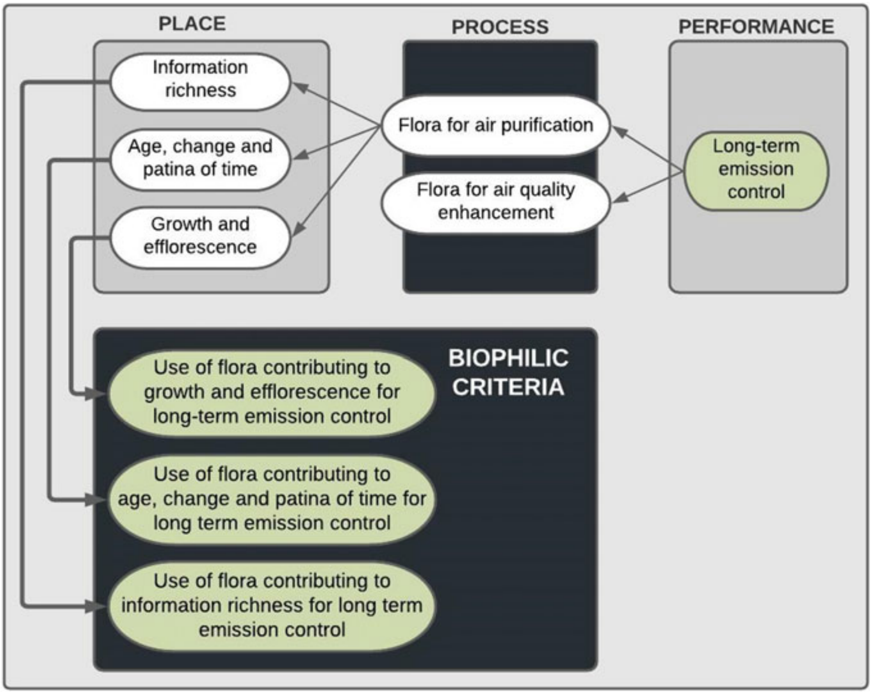

Fig. 4.6 *Performance pathway* bridging for 'long-term emission control'

This pathway is useful when the design is focused on building performance and there is a need to improve its BD response.

4.3.4.3 Process Pathway

The *process pathway* starts at the NPI by selecting a natural process and then associating it with both *performance* and *place*, as shown in Fig. 4.7.

This pathway usually results in one of two types of associations: links to both *place* and *performance*, or with a link only to *performance*. 'Solar electricity' from the NPI is one example of the latter, as there is no visible natural element to associate with the *place criteria* list. A pathway is shown in Fig. 4.8 using the generated lists for *earth*.

In this example the *process* item 'timber as a rapidly renewable material' is selected, and the item description itself indicates a *performance* item within *earth*: 'rapidly renewable materials'. Associating the *process* item with *place criteria* is not as direct, since the use of timber in *place* can link with multiple items; however, we have selected 'information richness', 'growth and efflorescence' and 'fractals in natural material'. All of these qualities can be achieved by using timber as a material.

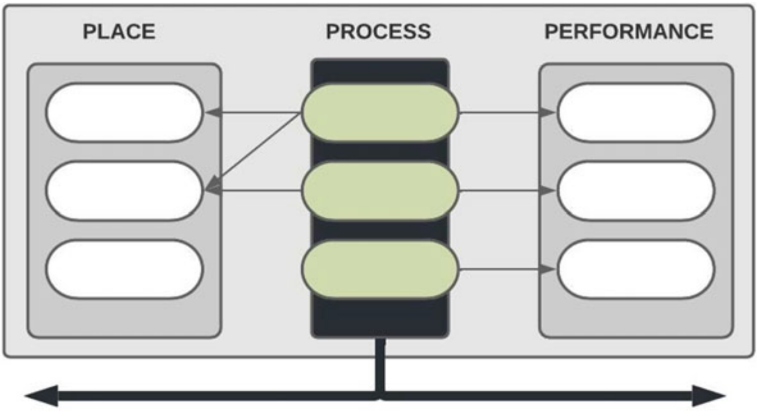

Fig. 4.7 Process pathway

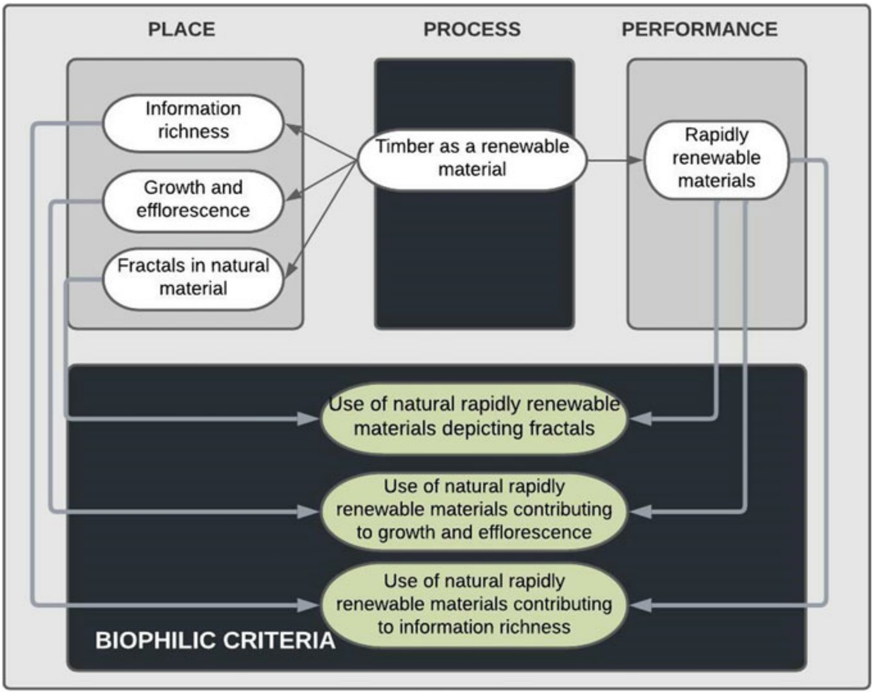

Fig. 4.8 Process pathway bridging for 'Timber as a renewable material'

Hence, *biophilic criteria* can be written as ‘use of natural rapidly renewable materials contributing to information richness’, ‘use of natural rapidly renewable materials contributing to growth and efflorescence’ and ‘use of natural rapidly renewable materials depicting fractals’. Again, this shows that writing *biophilic criteria* can vary according to user knowledge, with immense opportunity for original interpretations.

4.3.5 Design Strategies and Building Components

This is an additional step that is used to derive a more elaborated BD framework. A good example of associating with *design strategies* (referred to as ‘design considerations’ in the BD framework) and proposing *design elements* is given in the *14 Patterns of Biophilic Design* (Browning et al., 2014). Figure 4.9 shows this step for ‘use of flora contributing to information richness for long-term emission control’.

It is worth differentiating between *design strategy* and *building component* at this point. As shown in this example, a *design strategy* is an overall idea for achieving a certain criterion, whereas a *building component* is an actual feature included in the

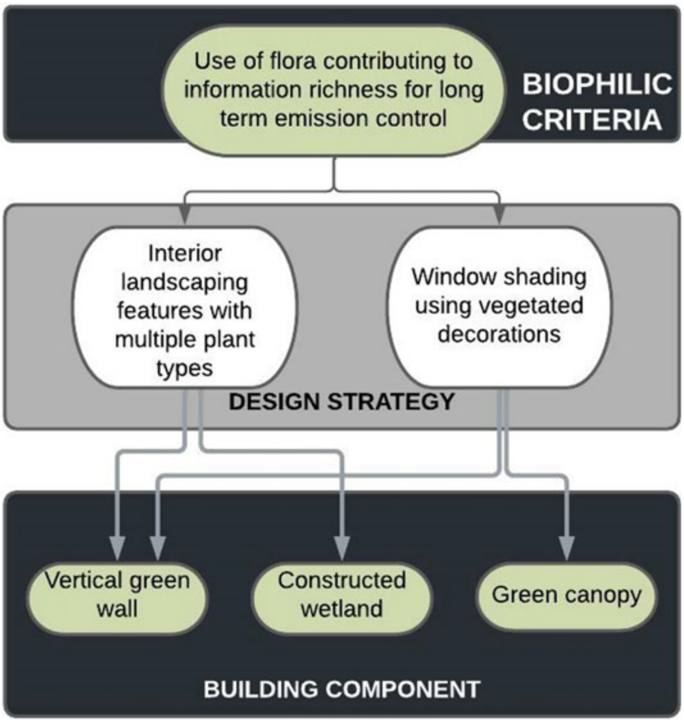

Fig. 4.9 Design strategies and building components for ‘use of flora contributing to information richness for long-term emission control’

building. In this example, ‘interior landscaping features with multiple plant types’ is a broader-level *design strategy*, while ‘vertical green wall’ and ‘constructed wetland’ are two *building components* used to achieve this. Sometimes, one *building component* can be used to satisfy multiple *design strategies*. Similarly, one *design strategy* can guide several *building components*, as shown in Fig. 4.9.

Expert knowledge, literature synthesis and interdisciplinary ideation can be used for this step. To use literature synthesis, you can review the current literature, to find *design strategies* and *building components* for each criterion. Alternatively, you may draw upon your expertise to do this task. If you are working in a group, you can each assume the different roles of stakeholders involved in the design and then generate ideas for *design strategies* and *building components* from different disciplinary viewpoints. By doing this, you are using interdisciplinary ideation. This is an opportunity to explore role-play to support your interdisciplinary learning.

4.4 Synthesising a Biophilic Design Framework

We use the term ‘BD framework’ to identify a guiding framework that includes a *biophilic criteria* list, *design strategies* and *building components* that can be easily used for your ESD project. This is similar to an industry GBRT. This section outlines how the generated themes for the *biophilic criteria* list, *design strategies* and *building components* can be developed into a BD framework. You can also develop a BD framework with only *biophilic criteria*, since the two other themes are follow up stages of the PBT (Fig. 4.2).

Your generated themes can be integrated into the success matrix as a separate category; this category will then become your BD framework. Alternatively, you can use the BD framework itself as the success matrix. We highly recommend that you use the latter option, since, building performance is already considered in writing *biophilic criteria* and is compatible with ESD criteria. You can further synthesise the BD framework into a self-assessment tool regardless of your integration option. Both options are discussed below.

4.4.1 Use of BD Themes Within the Success Matrix

With this option, your generated themes are integrated into the success matrix as a separate *category* of a *criteria*. This is very much similar to current ESD practice, where, in GBRTs, you would find either a separate category for BD or credits that can be achieved through other existing criteria. For example, the Living Building Challenge has BD as one of its 20 imperatives (Fig. 4.10). In LEED, there is a separate credit for BD that can be achieved through other categories.

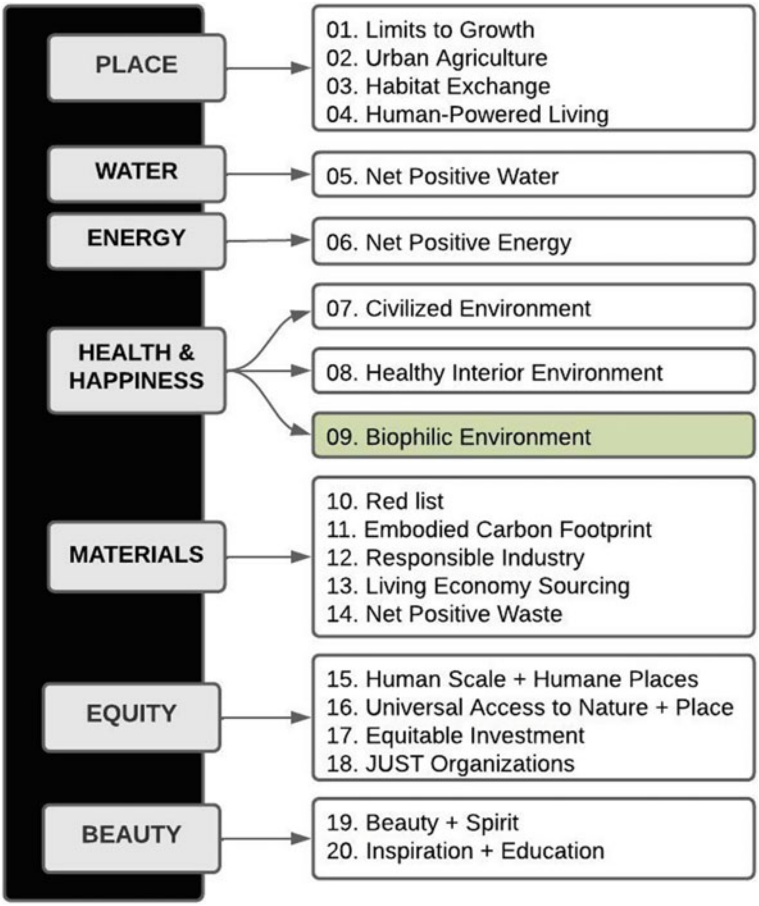

Fig. 4.10 Living building challenge's 20 imperatives. *Source* Adapted from International Living Future Institute (2018)

If you are to include your generated BD criteria list into your success matrix, you can also use either one of these methods. Figure 4.11 shows a sample success matrix that uses BD as a separate category.

In this example, the success matrix has five categories: site management, energy, air quality, water efficiency, materials and resources and biophilic quality. The BD framework only consists of *biophilic criteria* without *design strategies* and *building components*.

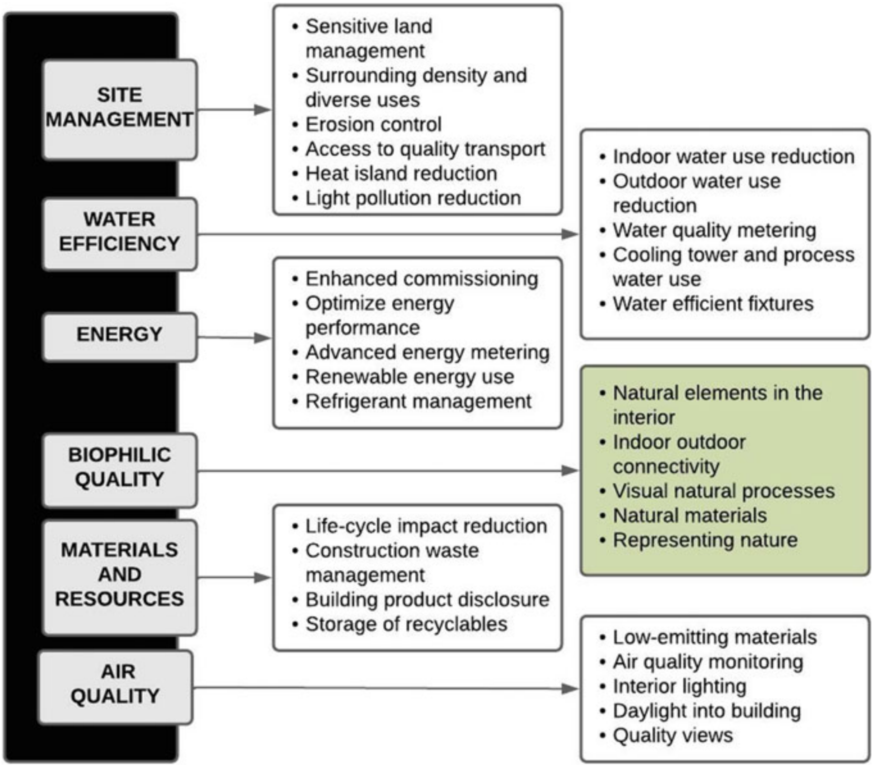

Fig. 4.11 Biophilic design framework as separate category

4.4.2 *Use a Biophilic Design Framework as the Success Matrix*

With this option, you can use the generated themes developed as a BD framework as your success matrix. This is similar to using a current BD framework, such as the *14 Patterns of Biophilic Design*, to guide your design (see Appendix B). The example given in Table 4.11 illustrates how a BD framework is used as a success matrix with the *earth* category. The total BD framework with five categories of *earth*, *air*, *water*, *energy* and *habitat* is given in Appendix C.

As shown in Table 4.11, categories used for PBT are repeated with *biophilic criteria*, with elaboration up to *design strategies*. During the *place* and *performance criteria* development, all the ESD criteria are mapped against the same categories. Therefore, it is sensible to use the same categorisation used in generating *biophilic criteria* for the success matrix.

Table 4.11 Biophilic design framework used as a success matrix

Category	Criteria	Design strategy/building components
Earth	Exposed natural materials	Materials use in natural forms for floors, walls, doors and windows etc. Exposed brick work Natural stone paving
	Low embedded energy natural materials	Use of natural materials with low embedded energy such as timber, clay etc. for floors, cladding and finishes
	Rapidly renewable materials	Rapidly renewable timber use in its natural form Bamboo for cladding and partitions
	Recycled natural materials	Use of materials recycled with low technology such as clay
	Sustainable finishing of materials restoring natural quality	Using finishing techniques to retain natural colours and textures for diversity of experience Use of non-toxic finishing materials

4.4.3 Developing the Biophilic Design Framework into a Self-Assessment Tool

This step is highly recommended: it will allow you to learn to judge the quality of your work and which is a necessary skill for using BD within an ESD approach. By synthesising your BD framework into a self-assessment tool, your success matrix will automatically become part of this tool. Whether you have BD criteria within the success matrix, or it is used as the success matrix itself, the method to be used to synthesise a self-assessment tool is similar.

The use of a design framework as a self-assessment tool is seen consistently in industry GBRTs. If you carefully investigate LEED, every category has certain criteria with assigned credit values. GBRTs generally provide design strategies and indicators to achieve these credits. Using a similar structure, you can convert your success matrix into a tool that can be used to assess the achievement of your sustainable design. You will need to assign credits to each criterion within the categories, which may result in differing weightings for each category. Figure 4.12 shows three key GBRTs and their weightings for each category.

Assigning credits and providing weightings for each category depends on your perception of sustainability. At this point, you can refer to your sustainability manifesto to decide which categories should have higher weightings.

The way you have integrated the *biophilic criteria* list will also lead to one of two different outcomes. If you used the BD criteria as a separate category, you could attain a building with higher biophilic quality only if you provide a higher weighting for the BD category. If you are using a BD framework as the success matrix, your design outcome will have a higher biophilic quality. In the second option, how you

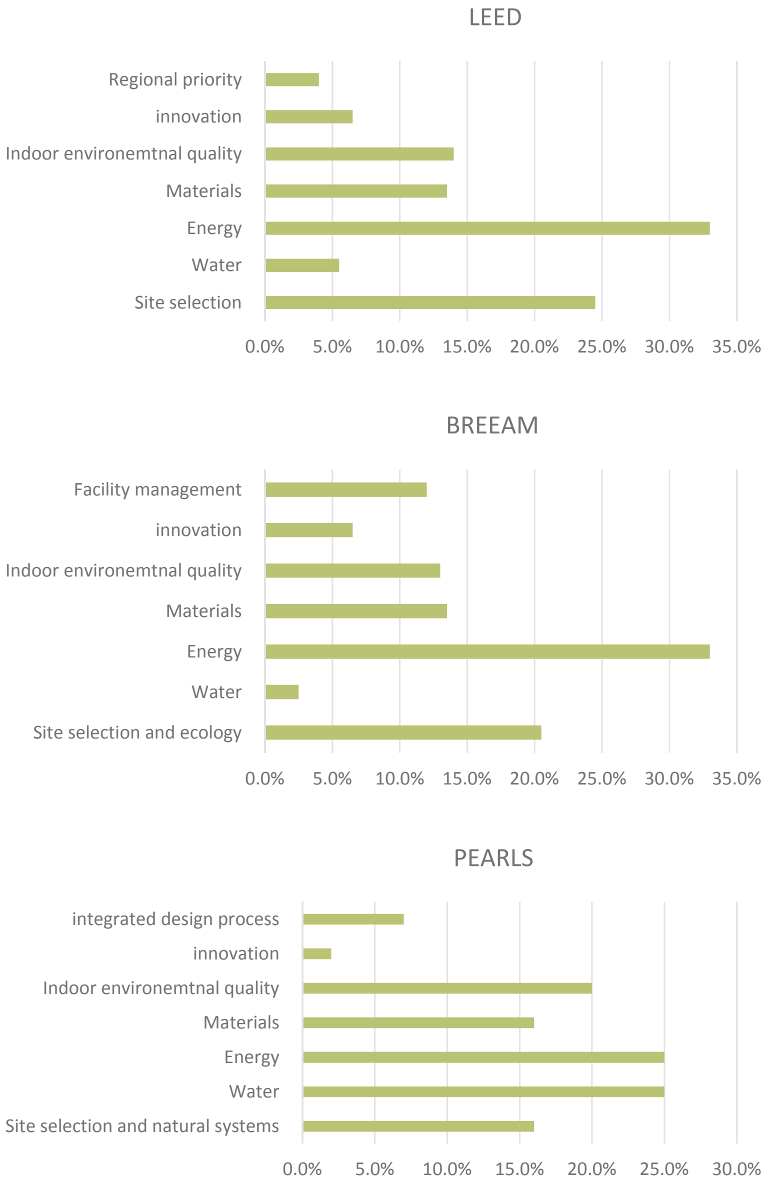

Fig. 4.12 Weightings across categories among green building rating tools. *Note* LEED = Leadership in Energy and Environmental Design; BREAAM = Building Research Establishment Environmental Assessment Method

assign weightings for each category may determine the focus of your BD response. Say, for example, you give more weight to water-related categories—your design may become focused on achieving BD principles using water as an element. Table 4.12 shows a BD framework that is developed to be used as a self-assessment tool with differing weightings across the categories.

Table 4.12 Biophilic design framework developed as a self-assessment tool

Category	Criteria	Credits	Total for category	% for category (%)
Earth	Exposed natural materials	6	24	11
	Low embedded energy natural materials	5		
	Rapidly renewable materials	4		
	Recycled natural materials	4		
	Sustainable finishing of materials restoring natural quality	5		
Air	Natural processes for air quality management	6	20	9
	Natural ventilation	4		
	Sensory air flow variation	4		
	Natural elements for carbon offset	3		
	Low-emitting natural material	3		
Water	Nature for water quality management	6	24	11
	Water for thermal comfort	6		
	Enhanced water area	3		
	Water saving in landscaping	4		
	Water elements for restoration	5		
Energy	Passive solar heating	6	26	12
	Circadian lighting design	4		
	Sensory thermal variation	4		
	Renewable energy use	6		
	Natural elements for heat reduction	6		

(continued)

Table 4.12 (continued)

Category	Criteria	Credits	Total for category	% for category (%)
Habitat	Restore natural habitat	6	27	13
	Restorative natural habitats	5		
	Bio-diversity	6		
	Experience direct nature	5		
	Inter-species connectivity	5		

4.5 Validating the Biophilic Design Framework

An important step in the process is the validation of the developed BD framework in terms of its compatibility with ESD criteria. For this step, you can use the method proposed by Xue et al. (2019). This method is simple, and it provides clarity by visualising the results. The key objective of the validation is to assess the success of the developed *biophilic criteria* in achieving the building performance anticipated by the selected GBRT. Each criterion in the GBRT has a credit-awarding points assigned to it. By using a *design strategy* within the building design, the credit point will be awarded to the criteria. Hence, the method is simply to find how many credits can be achieved in a certain criterion by using the *design strategies* in response to the developed *biophilic criteria.*

As an example, select LEED as the GBRT and provide all the *performance criteria* items from LEED and which are categorised into *earth* (Table 4.13). The credits assigned to the LEED items are shown in the second column, 'LEED credits'. Once the *biophilic criteria* are derived, an evaluation is performed to ascertain how much credits can be gained by using this *biophilic criteria*, and the credit value is given under the third column, 'biophilic criteria potential credits'.

After the credits are assigned, a radial diagram is generated to compare and visualise the achievement (Fig. 4.13).

The radial diagram in Fig. 4.13 illustrates how generated *biophilic criteria* can be used to achieve the credits in LEED credit-awarding systems. Further conclusions can be drawn by totalling the credits from LEED and finding what percentage can

Table 4.13 Comparison of LEED credits and potential achievement through *biophilic criteria*

Performance items from LEED	LEED credits	Biophilic criteria potential credits
Building life-cycle impact reduction	2	2
Construction and demolition waste management	2	1
Low-emitting materials	1	2
Regional priority	1	1
Building product declarations	2	0

Note LEED = Leadership in Energy and Environmental Design

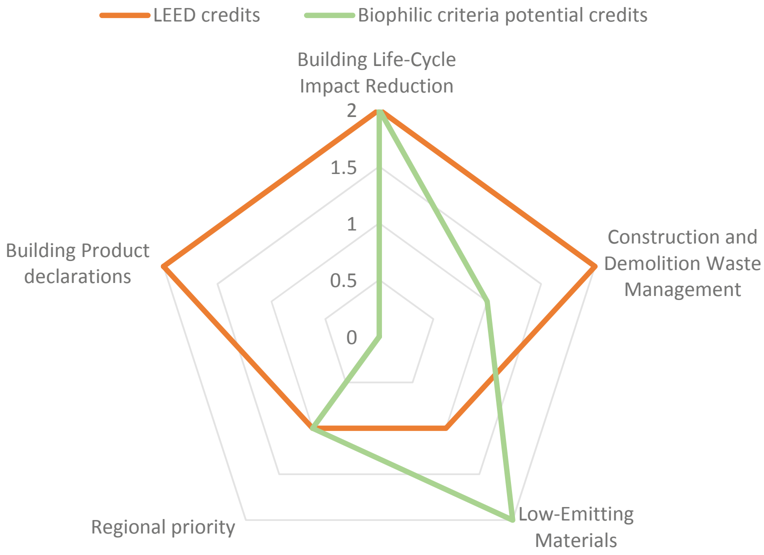

Fig. 4.13 LEED credits achievement through Biophilic criteria. *Note* LEED = Leadership in Energy and Environmental Design

be achieved using the *biophilic criteria*—in this example, the result is 75%. The same validation and analysis can be repeated for each GBRT using this process. When multiple GBRTs are used, the analysis can also indicate which GBRT is more supportive towards developing a BD framework for enhanced human–nature connectedness.

4.6 Concluding Remarks

This chapter provided a methodology for developing a BD framework. The strategic step in this is generating the *biophilic criteria* using PBT. We showed how to develop a *place criteria list*, a *performance criteria list* and the NPI required for this technique. You will need a sustainability manifesto to generate these lists so that you have the same categories in the *place*, *performance* and *process* lists.

You need to integrate the criteria into your success matrix, a design framework used in sustainable design studio. We showed how to synthesise the *biophilic criteria* as a BD framework, with additional instructions for using it as a self-assessment tool. You can also use the validation method if you are working with a standard GBRT. You may have to refer to Student Guide 1 (how to develop sustainability manifesto) to start with the PBT, and Student Guide 3 (how to model your BD thinking process) to understand how the BD framework is used in your design thinking process.

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Chapter 5
Student Guide 3—How to Model Your Biophilic Design Thinking Process

Abstract Sustainable studios are pivotal courses in today's architecture education. Their unique characteristic is the use of a design framework to guide the design process, grounded in design thinking. This chapter discusses the fundamental ideas behind the design thinking process while elaborating five models used by students to integrate biophilic design frameworks into an environmentally sustainable design studio. These models are the (1) biophilic category model, (2) biophilic overlay model, (3) biophilic criteria model, (4) biophilic process model and (5) biophilic conceptual model. Further instructions are given for articulating and modelling the design thinking process.

5.1 Introduction

When you are enrolled in a design studio, you are asked to provide a design solution to a problem that varies depending on the specific brief. To do so, you usually follow a certain process. The terms 'design process' and 'design method' have been interchangeably used to identify this process, though in recent times the term 'design thinking' is more frequently used. They all refer to a systematic way of developing a design, with activities along different phases. Design thinking processes are usually depicted using diagrams.

Additionally, in ESD studios you are usually required to demonstrate that your project responds to specific criteria, benchmarked against a specific framework. So to say, now that you have developed your own BD framework, you should be able to integrate it into your design thinking process. The aim of this guide is to assist you in understanding how you can undertake this important step by illustrating five main models to use the 'success matrix' as an integrated part of your design thinking.

This guide includes a board discussion about design thinking models and their development in the context of sustainable design to facilitate your understanding on what is a design thinking model. You may recognize your own approach to design and realise that you may have used a similar process knowingly or unknowingly in your previous projects.

N. Wijesooriya et al., *A Biophilic Design Guide to Environmentally Sustainable Design Studios*, SpringerBriefs in Education,
https://doi.org/10.1007/978-981-19-4428-4_5

This guide also includes instructions on how to record the design thinking process using a reflective diary, design sketches, models and critical reflections. We encourage you to consciously use a design thinking process and to record it properly, this will support you in controlling your design activities and return to an earlier step if you need to refine the design.

5.2 Design Thinking Process and Models

The term 'design thinking' was initially used in business studies to promote innovation and referring more generally to 'the cognitive activities that designers employ in operating the design process to generate ideas, solve problems, and make decisions' (Ghonim, 2016, p. 553). However, it quickly became popular in architecture. There are three main typologies that may be of interest for you: (1) design thinking models commonly used in design disciplines, (2) architectural design thinking process models and (3) sustainable design thinking models.

In the context of design thinking, you should note that there is a distinction between the process and the model. All the activities that take place during design is a process, and when you synthesise them into a replicable diagrammatic presentation, you will have a model. If you adopt a specific process, once you developed the related model you will be able to use this model again in the future.

5.2.1 Design Thinking Models

The notion of design thinking was introduced by Lawson (1980), with further developments by Cross (1982) and Schön (1983). However, with the wide popularity of design thinking across disciplines, numerous design thinking models have been later introduced.

A first approach was based on the fundamental idea of divergent and convergent thinking as an integrated part of the design thinking. Alexander (1964) and many other design researchers have emphasised this dual mode in the design process (Fig. 5.1).

As illustrated in Fig. 5.1, divergent thinking breaks the design problem into parts, usually denominated by the term 'analysis', while convergent thinking reassembles the parts into a new solution and is usually termed 'synthesis'. These two parts are employed to respond to the rational problem- and solution-finding exercise that characterize the design process.

This problem–solution pursuit can be presented as two relations: as a linear process (Brigs & Havlick, 1976; Pena & Parshall, 2012) or as an iterative process (Rittel & Webber, 1973; Schön, 1983). Figure 5.2 shows both processes.

Analysis–synthesis and problem–solution are the basis of all successive formulations of the design thinking process, with the further additions of communication (Archer, 1965; Cross, 2001; Thornley, 1963), evaluation (Koberg & Bagnall, 1972;

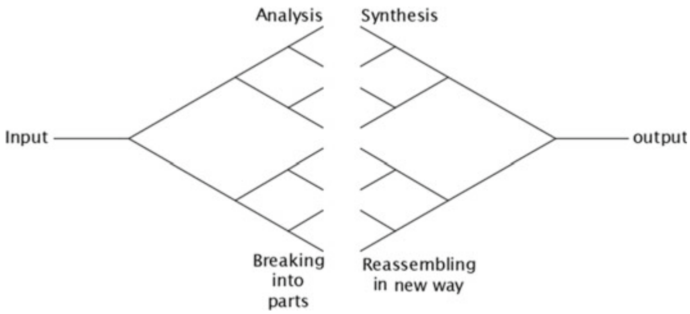
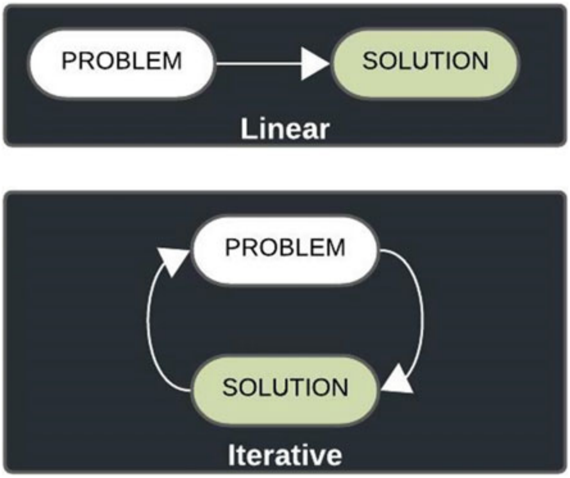


Fig. 5.1 Divergent/convergent model of design thinking based on Alexander (1964)

Fig. 5.2 Linear versus iterative problem–solution processes



Nigel Cross, 2000) and implementation (Koberg & Bagnall, 1972; IDEO, 2004), depending on the context of use.

The first-generation models considered the design process as a rational, linear process for optimising decisions (Plowright, 2014), which was then expanded from analysis to synthesis and into the seven-phase model by Koberg and Bagnall (1972), as shown in Fig. 5.3.

An extended version of the divergent–convergent approach was presented by Banathy (1996), as shown in Fig. 5.4.

However, these linear problem-solving models have a common weakness: their lack of consideration of users (Plowright, 2014). An alternative model, proposed by Schön (1983), focuses on the practice of design by the designer. This model is called reflection-in-action and it is based on iterative cycles (Fig. 5.5).

Based on the idea of iterative cycles, Archer (1965) introduced a model that is versatile enough to be applied within varied disciplines. This is the first model to include communication while reflecting iterative loops (Fig. 5.6).

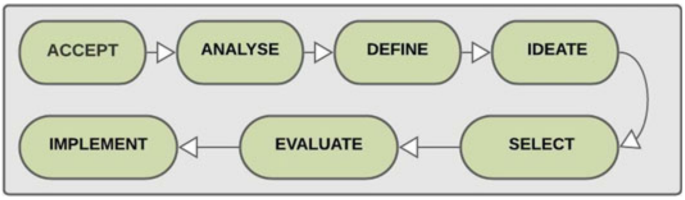


Fig. 5.3 Design thinking model by Koberg and Bagnall (1972)

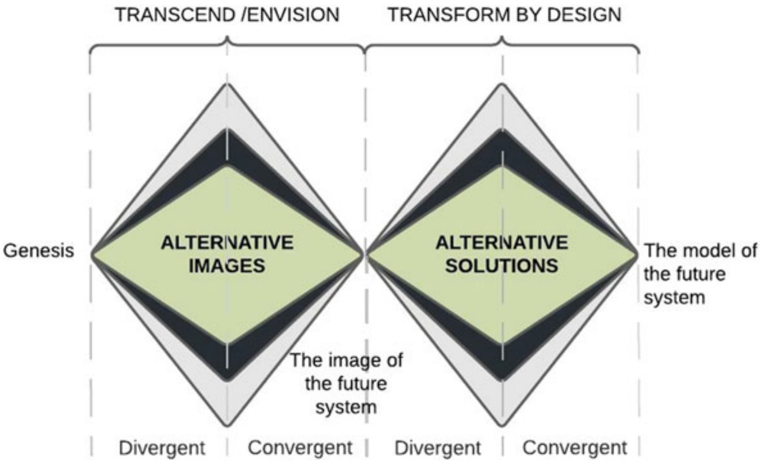
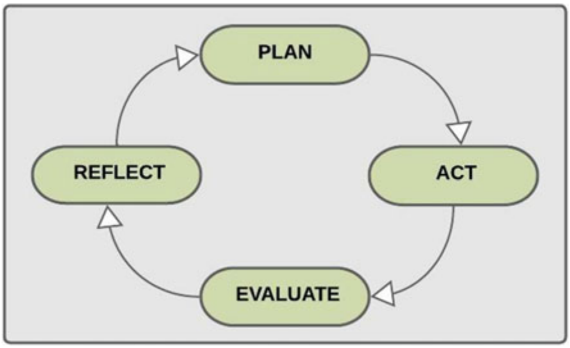


Fig. 5.4 Double diamond design thinking model by Banathy (1996)

Fig. 5.5 Reflection-in-action design thinking model, based on Schön (1983)



5.2.2 Architectural Design Thinking Process Models

Architecture, and the architectural process, usually requires complex models that incorporate additional steps in an attempt to reflect the balance of rationality and creativity required for architectural solutions (Todoroff et al., 2021).

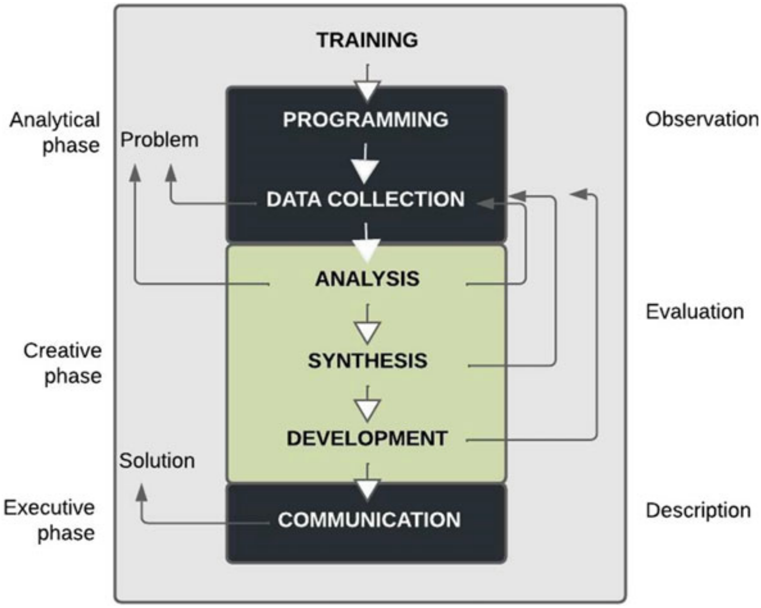


Fig. 5.6 Three-phased detailed design thinking model, by Archer (1965). *Source* Adapted from Dubberly (2004)

One of the earliest models for architectural design education, developed by Thornley (1963), and adopted by the Royal Institute of British Architects (Fig. 5.7), is the basis of the *RIBA Plan of Work*, which accounts for traditional steps and actions found in industry practice.

When we look specifically at a studio setting, the model described by Akpinar et al. (2015) demonstrates the complexity of activities taking place within the studio (Fig. 5.8), and it expands upon the previous iterative design thinking models while addressing the specificities of the architectural process.

This model reflects an iterative design process with numerous activities identified within a design studio. As you may already understand, a very important part in developing a design thinking approach is the activities and their relationships to each

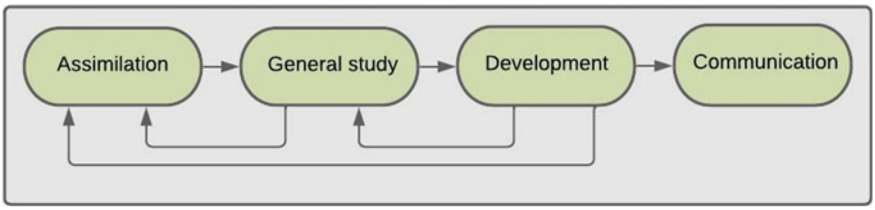


Fig. 5.7 Architectural design thinking processes. *Source* Adapted from Royal Institute of British Architects (1965)

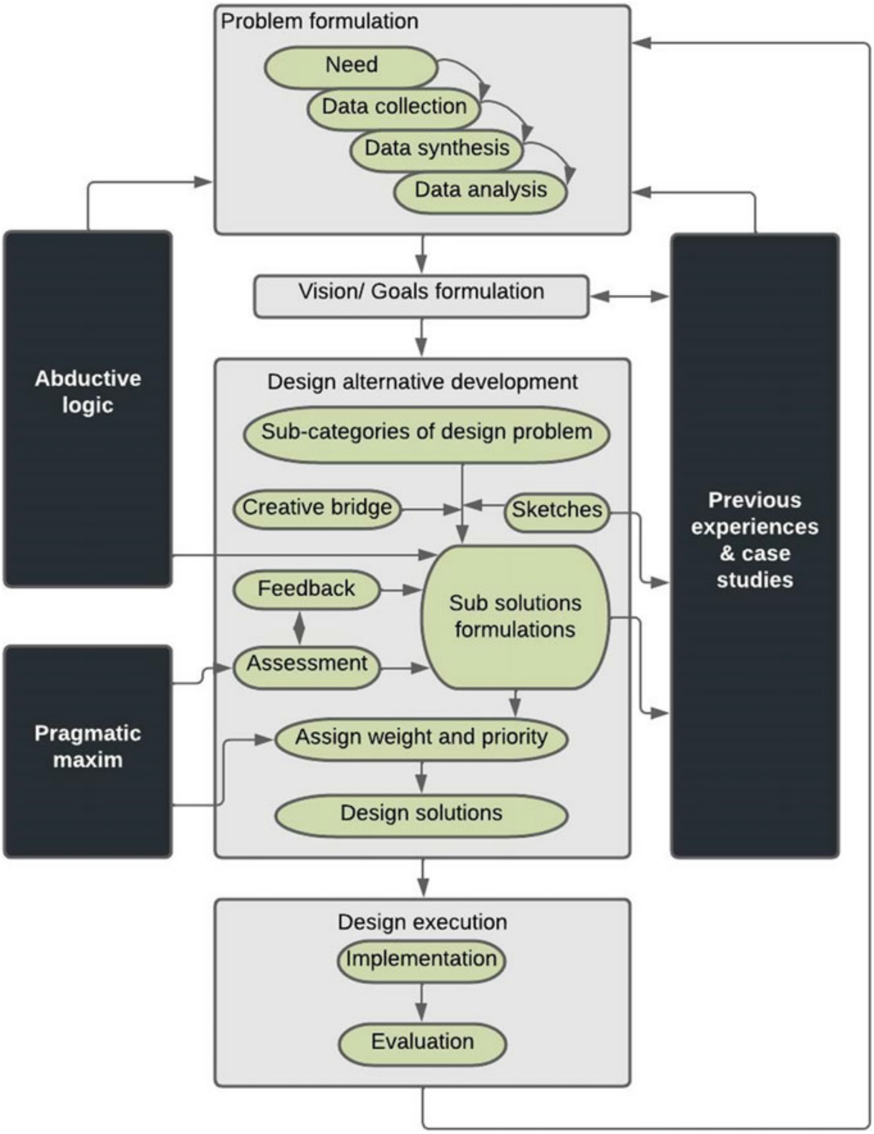


Fig. 5.8 Design thinking model for architectural design studio. *Source* Adapted from Akpinar et al. (2015)

other. Studies by Goldschmidt (1994) and Ahmed et al. (2003) provide a good set of activities you may come across in design studio. Main activities include:

- Studying the brief
- Planning the design process

- Collecting information
- Looking at examples
- Consulting with others
- Thinking solutions and sketching
- Analysing and comparing alternatives
- Evaluating interim and final proposals
- Preparing the final presentation

The list of activities in given above is not exhaustive, but it can guide your design thinking process.

5.2.3 Sustainable Design Thinking Models

Now, when looking at sustainable design processes, it is clear that something is missing from the picture in the above-mentioned models. Indeed, they all refer to the development of a product, which can be also an architectural object, overlooking the impact on sustainability during production and use of the product.

Hoolohan and Browne (2020) have proposed a design thinking model structured as a toolkit that can be used for intervention planning (Fig. 5.9).

You may notice that the steps in this model are quite different from those presented in the previous sections. Specifically, the step 'influence mapping' has been included

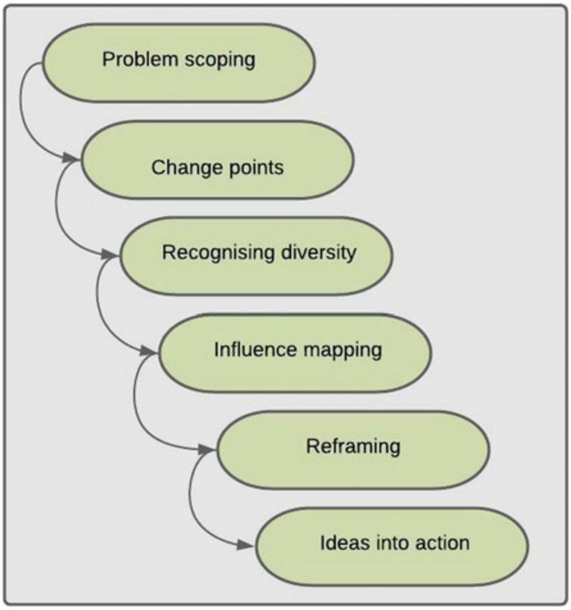


Fig. 5.9 Sustainable design thinking model for intervention planning. *Source* Adapted from Hoolohan and Browne (2020)

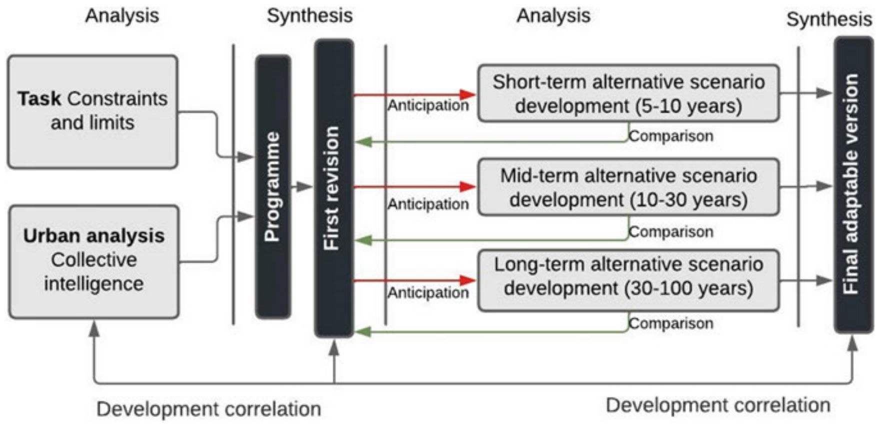


Fig. 5.10 Scenario-based feedback loop design thinking model, by Lüley (2020)

to reflect the planning activity for influencing user behaviour, that is important in the use of the product.

Lüley (2020) believes that we need to look at the architectural design process from a new perspective to integrate sustainability and has proposed a detailed model premised on scenario-based design loops, as shown in Fig. 5.10.

This model includes unique activities, but you can recognize a generic analysis–synthesis typology. The different scenarios for sustainable design are categorised into short-term, mid-term and long-term to anticipate future changes. This is unique step that will also account for user behaviour and building operation. However, this model includes activities in realistic design situation and long-term planning, limiting the use for studio settings pertaining to building design.

A design thinking framework developed by Berg et al. (2014) is better suited for studios. It provides the associations among design considerations (Fig. 5.11) used by students in developing a lamp using reused materials.

Figure 5.11 represents design thinking in a complex systems diagram. This use “systems thinking” a diagrammatic way to showcase show how different elements are connected to each other. The use of systems thinking has its merits for resolving sustainability issues, which have a complicated, multifaceted nature. This diagram is closer to a mind map that reflects the thinking behind design and could be used in modelling design thinking.

5.3 Types of Biophilic Design Thinking Models

The models presented in previous sections constitute a good starting point to understand design thinking, however, they need further modification to be adapted for specific ESD studio requirements. ESD studios demand additional activities such as

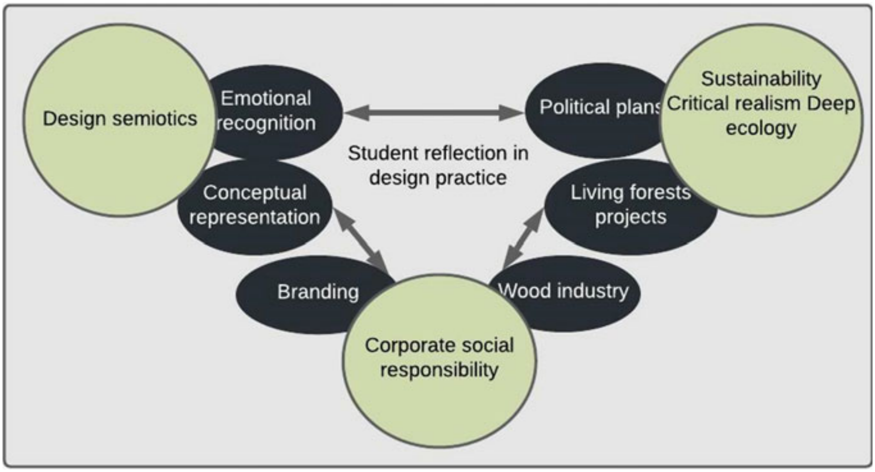


Fig. 5.11 Design thinking mind map for sustainable design. *Source* Adapted from Berg et al. (2014)

developing a sustainability manifesto, developing a design framework and providing evidence for sustainability achievement, to be undertaken by students.

Depending on how you integrated and synthetised the biophilic criteria within your success matrix, the design process and the design thinking process that you may undertook will vary. What we present in following sections are five design thinking models that differ by when the biophilic criteria is integrated into the design process. We developed these models using empirical data from students adapting BD within sustainable architecture design studio.

Table 5.1 shows the phases common to all models.

5.3.1 Biophilic Category Model

This design thinking model is more common where biophilic criteria are synthesised into a separate category. Across the design thinking process, the BD criteria and other ESD are designed separately. The BD response is initiated in early design stages (Fig. 5.12) and could be integrated well into the design.

The developed biophilic category within the success matrix can have criteria either to achieve building performance or to contribute to the sensory place-making of the design. Depending on the number of biophilic criteria used for building performance, compatibility with the ESD approach may differ. An important aspect in this model is that the evaluation is distinct for the BD response. The weighting assigned in the success matrix can influence the biophilic quality achieved in the overall design.

Table 5.1 Descriptions of phases in biophilic design thinking models

Phase	Description
Information gathering	Environmentally sustainable design would require a high volume of data, including a systematic search to find similar environmental solutions, sustainable materials, case studies, design guidelines and any other relevant information
Sustainability manifesto development	Developing a sustainability manifesto that communicates the sustainability perception adopted for the design
Success matrix development	Developing a success matrix that includes biophilic criteria
Evidence supplying	Use of simulation software or computations to demonstrate the achievement of sustainability criteria identified in the success matrix. This may also require research into environmental solutions, material properties and performance
Site and context analysis	Both site and context are analysed using climatic data, demographic data and other social and environmental aspects that can shape the building program
Conceptualisation	Building is conceptualised, representing both architectural and environment responses
Design strategies	Design strategies are developed to suit the criteria in the success matrix
Building components	Building components are designed to suit the design strategies
Design synthesis	Synthesising all relevant and customised design strategies along with building components into a design proposal
Evaluation	Evaluation of the design using the success matrix if developed as a self-assessment tool. In the absence of a self-assessment tool, the design is evaluated by justifying the design decisions and supplying evidence
Critical reflection	Critically reflecting on design process phases and returning if there is a need for amendments

5.3.2 Biophilic Overlay Model

In the biophilic layover model, a typical ESD design is completed and then an overlay of BD strategies is included to improve its biophilic response. The generated BD criteria are scattered across the success matrix or possibly not explicitly mentioned during every phase. The design thinking process only brings in concerns around enhancing biophilic quality in latter stages of the design (Fig. 5.13).

This design thinking model can be adapted even without generating biophilic criteria during success matrix development. Since this model contemplates the BD

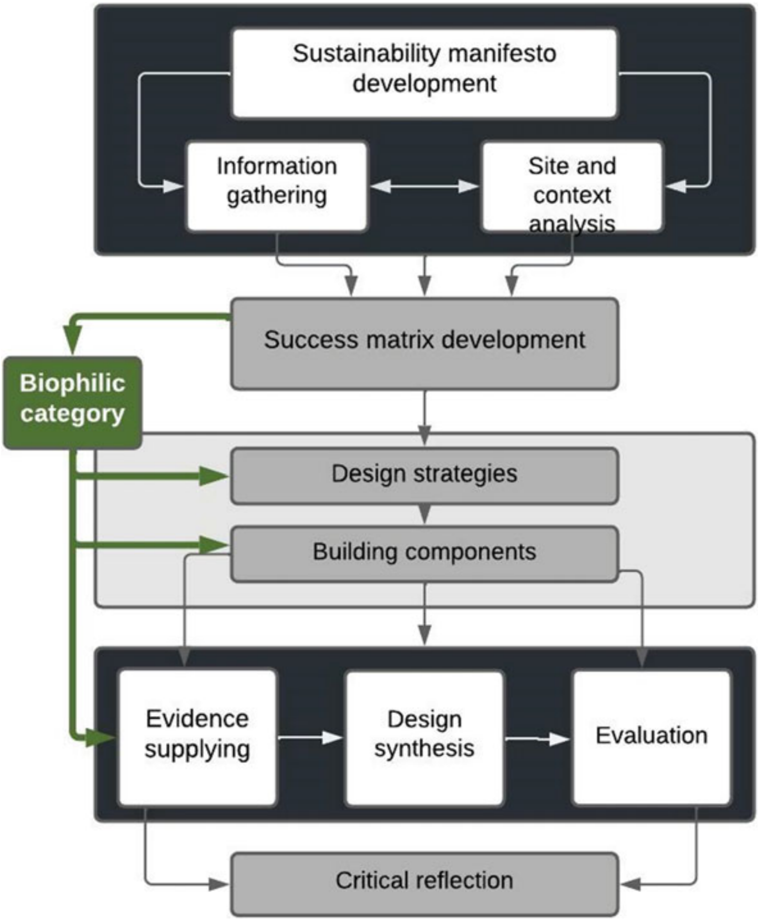


Fig. 5.12 Biophilic category design thinking model

response during the design strategy or building component phases, the potential to use natural biophilic elements for building performance is limited. Further, the use of BD strategies could conflict with the ESD approach, reducing compatibility. This can still potentially improve biophilic quality with a strong layover of BD responses. However, if the success matrix is developed as a self-assessment tool, this may not contain assessment criteria for BD, necessitating a specific justification for the BD strategies used in the design.

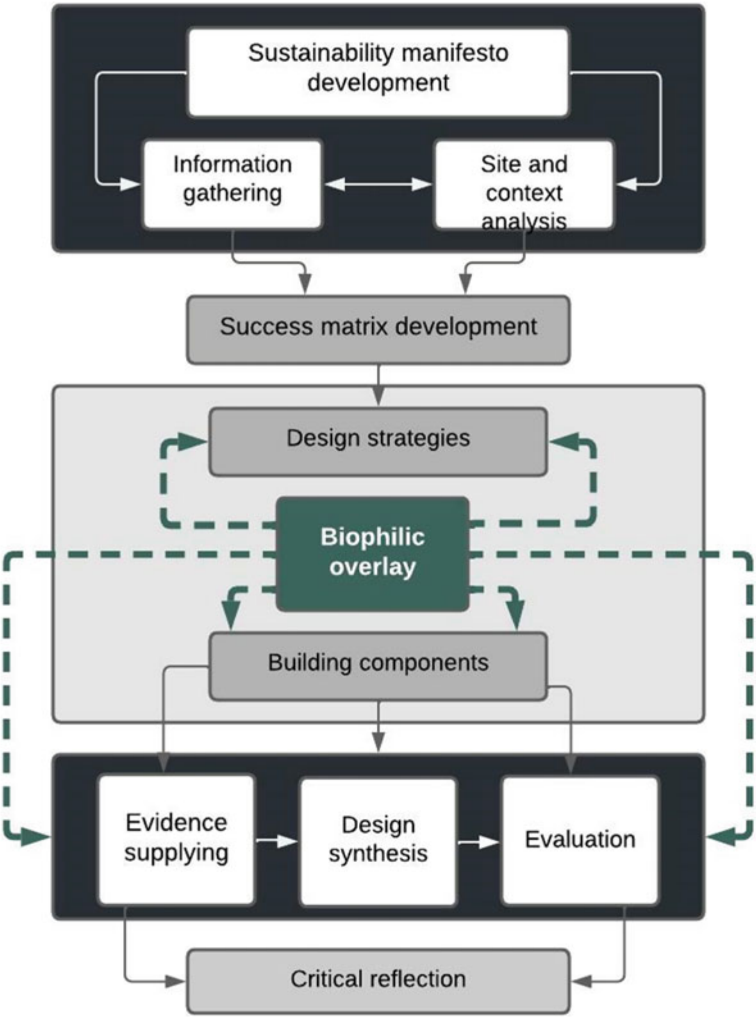


Fig. 5.13 Biophilic overlay design thinking model

5.3.3 Biophilic Criteria Model

This design thinking model has concise biophilic criteria highly compatible with the ESD approach. However, the placing of biophilic criteria is within a typical ESD-focused success matrix. Each category in the success matrix will include biophilic criteria that can be used to achieve building performance. The BD response is initiated at the early design stages and considered throughout the design thinking process (Fig. 5.14).

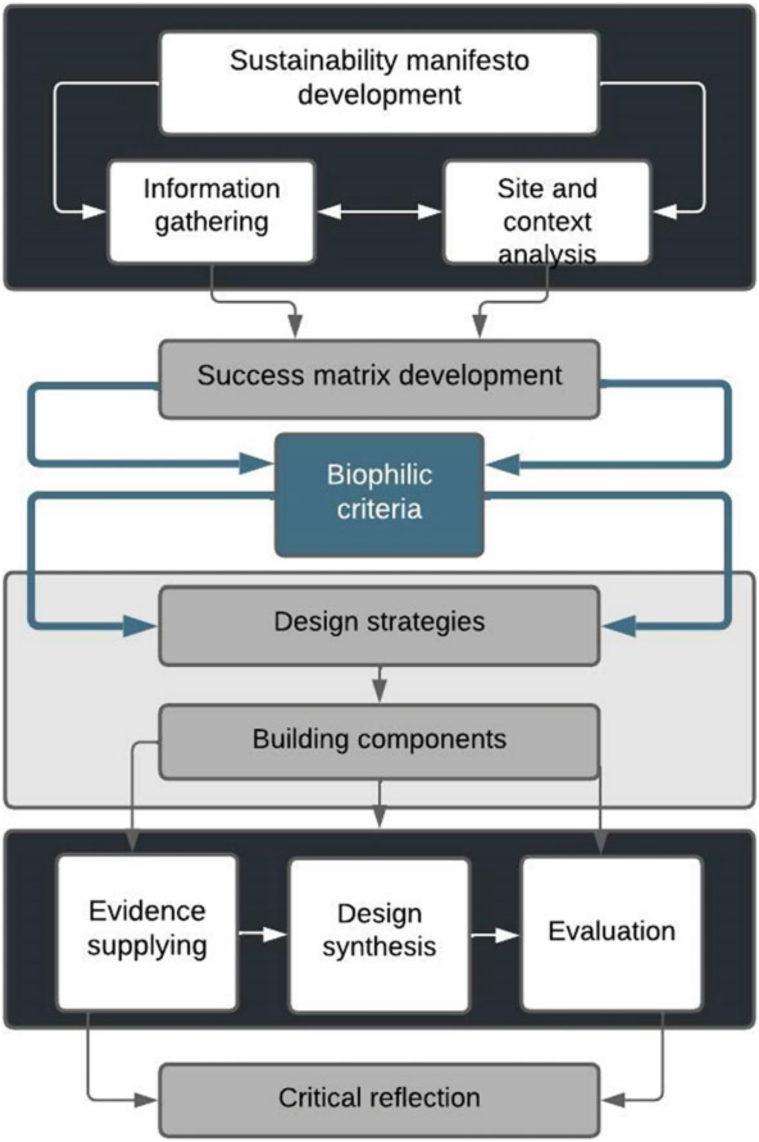


Fig. 5.14 Biophilic criteria design thinking model

If you synthesised your biophilic criteria into a BD framework and use it as the success matrix, this design thinking model is the most appropriate to be used. If the biophilic criteria is being explicitly generated to achieve building performance, using the process-bridging technique, BD response will have high compatibility with the ESD approach. The assessment of the BD response is not distinct, since the criteria are within ESD categories, yet design strategies will be supported with solid evidence. Overall, the design can achieve a high BD quality with BD design considerations brought in at early design stages.

5.3.4 *Biophilic Process Model*

This is an interesting design thinking model, wherein BD responses are brought into the design to achieve building performance through natural processes. Biophilic criteria are not explicitly observed in the success matrix, similarly to a typical ESD framework. However, when identifying design strategies for sustainability criteria, natural processes are given priority, thus enhancing the BD response. Adoption of BD is found only during the design strategy phase (Fig. 5.15).

This model requires extensive research on how natural processes are used for building performance, rather than a specific set of biophilic criteria. Using this model, you can achieve high BD compatibility with the ESD approach. However, you will not have a distinct assessment of biophilic quality through your success matrix. Indeed, this design thinking model does not highlight the sensory place-making response by using visible elements. Therefore, even if you used natural processes, your biophilic quality may not be high.

5.3.5 *Biophilic Conceptual Model*

This design thinking model presents a process that adopts a biophilic concept for the overall design. This model is based on a BD framework that is used as the success matrix. This concept is more of a metaphorical representation of the building that connects all the ideas and decisions. Plowright's (2014) concept-based architecture is the most dominant way to generate architecture. The concept may be present in abstraction from the inception of the design, which will also guide success matrix development. The influence of the overarching concept is visible across the process (Fig. 5.16).

In most instances, for biophilic conceptual model, you would generate biophilic criteria, synthesised into a BD framework, and use the framework as your success matrix. If you generate biophilic criteria using the PBT we introduced in the previous guide, you can achieve high compatibility with the ESD approach. However, with a biophilic concept, you can also have a BD response with high BD quality focused on sensory place-making aspects of the design. Evaluation is highly focused on biophilic quality, and you may have to make extra effort to supply evidence for building performance achievement.

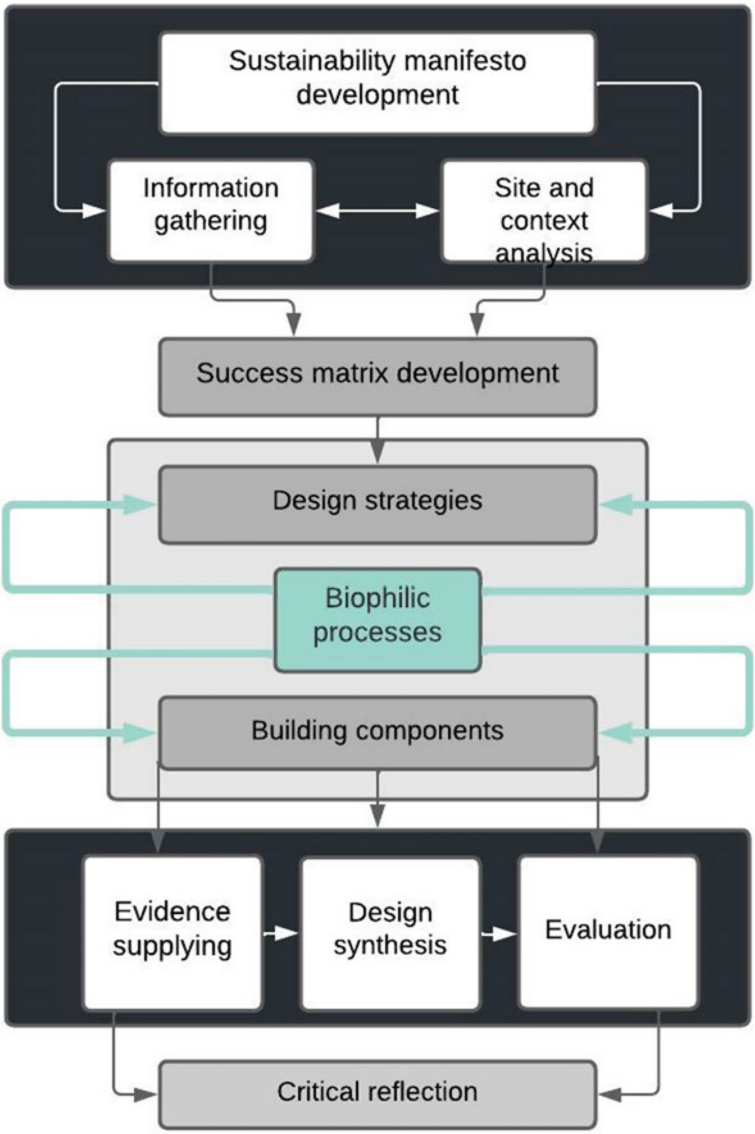


Fig. 5.15 Biophilic process design thinking model

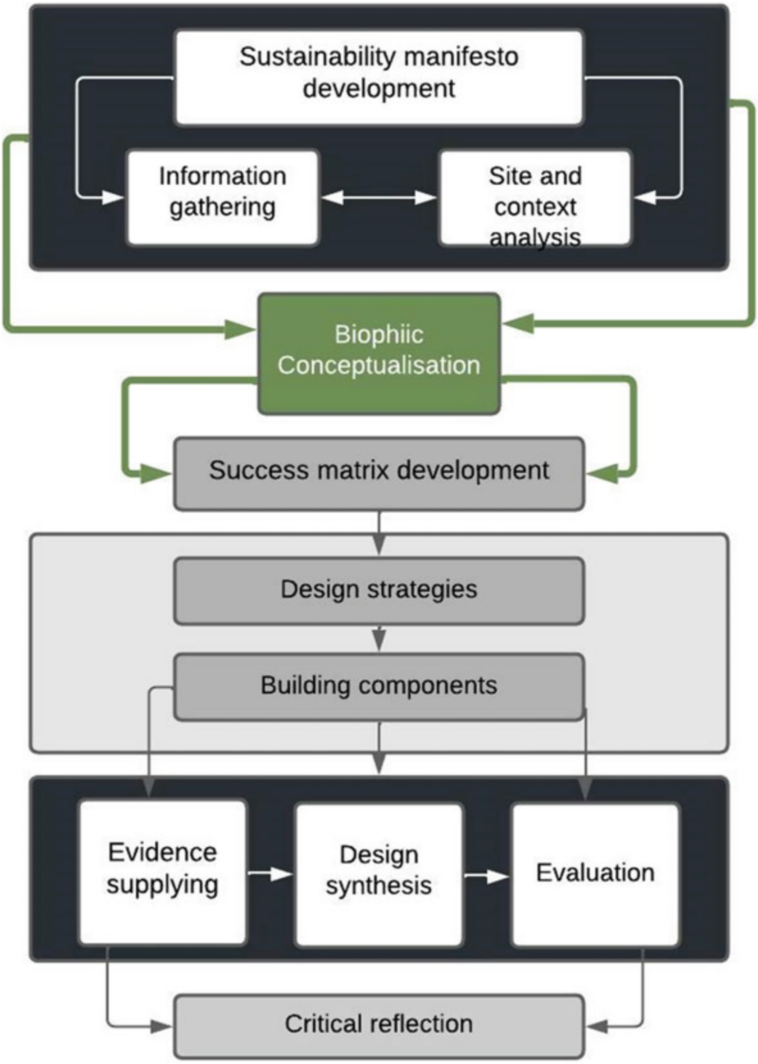


Fig. 5.16 Biophilic conceptual design thinking model

5.4 Recording and Modelling Your Design Thinking Process

To create your own personalized and tailored design thinking process, you need to report the design activities undertaken. Recording your design thinking as you move across different phases, detailing the sequence of activities and rationale for decisions, is crucial for you to analyse, implement, and reproduce your design thinking process.

You would be familiar with final design presentation or development portfolio, where you are usually asked to report your design development. However, this document often represents one specific design solution and not always systematically connect one studio to another. Therefore, they may not suffice to comprehensively record the process of design thinking.

There are reporting methods that help designers successfully detect, document and reflect upon their design thinking process. These methods are:

– Reflective design diary
– Design development sketches and working models
– Critical reflections

You can use one of these techniques or a combination of the three, depending on what suits better your own learning journey.

5.4.1 Reflective Design Diary

The use of design journals and diaries is quite common in design education. They can be used to record your daily design activities, either as written notes or as sketches. The diary should not just report the development of your design, but also your own reflections upon the process: e.g. Why did you take a specific decision? What are the drivers, barriers, enablers and their impact on the design? This will assist you in two ways. First, you revisit your earlier design decisions when you make a new entry, allowing you to improve your design process by reflecting on the rationale and the impact of the decision. Second, your reflections will assist you in identifying where you are in regard to the design process, which, ultimately, will allow you to iterate in between phases more efficiently.

Traditionally, designers have been using physical notebooks and sketchpads as diaries, but now digital media also becomes commonly used for diaries and record keeping. You may create your own way of doing this, or use digital portfolio or diary in your learning management system, if it has such record keeping functions.

Some tips to remember in making entries:

- Always date your entry
- This is like individual brainstorming—just record your thoughts; this is not about correct or wrong thinking
- Use diagrams—they help you to organise your thoughts—then reflect
- You can record insights you gain from research
- You can use mind-mapping and concept maps to organise information from research
- Use the diary to also record feedback you get from your tutors, and include your reflections.

5.4.2 Design Development Sketches and Working Models

This is the conventional practice in the design studio, whereby you construct artefacts in the learning process. We use sketches and working models to show design development. In an ESD studio, you may find yourself exploring a high number of design options and development processes as response to specific environmental needs and impacts mitigation. If you use simulation modelling, the various iterations will also be part of your design development.

This technique requires, however, further elaboration to define the design thinking model. Starting from your sketches and models you will need to analyse and synthetise them at a later stage.

Some tips to remember in recording with sketches and models:

- Dating your models makes it easier to sequence the design development
- After going through the design development phase, you may have to analyse the process and sketch the development process
- You can have a separate development process for simulation models
- Try to use same scale for all the models
- If models are in different scales, use photographs.

5.4.3 Critical Reflections

The ability to critically reflect on the design process is an essential skill for a design student. This differs from the reflective diary in that it means systematically reflecting on important aspects rather than upon your routine design activities. In a sense, this technique uses a complementary approach to the reflective diary: if we use the reflective method describe by Bain et al. (1999), there are four main steps, that are reporting, relating, reasoning and reconstructing. ‘Reporting’ means describing the activity that you intend to reflect upon. In ‘relating’, you connect the activity to your design process phase. In ‘reasoning’, you will think through why you conducted an activity a particular way. Finally, in ‘reconstructing’, you consider the future use of the activity and whether and how you will repeat it. It is easier to reflect by using guiding questions to prompt your thinking and write the reflection by answering those questions.

The following example gives you some guiding questions that you can use to reflect on the BD in your design thinking process.

Main question: Where do I fit BD into my design thinking process?

- **Reporting:** At what point did I use BD principles in my design thinking process? Was it during conceptualisation? Or did I bring them in during design development? Or did I just add them in my model to make things better? Is my whole design generated around human–nature connectedness and the use of BD principles?

- **Relating:** Did I use a design thinking process at all? Was BD part of my whole design thinking process? Did I consciously use it? Did I think about the implications of BD and incorporate it as an integral component into my design thinking process?
- **Reasoning:** Did I have enough information on BD to include it in my design thinking process? Did I think it had a value? Was it in my philosophy to have a design thinking process focused on nature? Did I have the skills or tools to incorporate BD into my thinking process? What was difficult in adopting BD within my design thinking process?
- **Reconstructing:** Will I be consistently using BD in my design thinking process? How can I overcome the difficulties in adopting BD for my design thinking process? What learning support I need to understand the implications of BD within the design thinking process?

While using this method, you may not have to answer all the questions as part of one reflection, but they can give you options to suit your line of thinking. Critical reflections are generally presented in written form.

5.4.4 Modelling the Process

Once that you recorded and reflected on your design thinking process used, you can derive your design thinking model. For the analysis of your recorded data, you can use mind maps, systems diagrams or concept maps to organise design activities and design thinking. Starting from scratch and developing a design thinking model is a time-consuming task, and we recommend you select an existing design thinking model and map your activities onto it. In Sect. 5.2, we provided design thinking models that are either used across design disciplines, or specifically developed for architectural design or found in sustainable design. The BD thinking models discussed in Sect. 5.3 are tailored for ESD studios, and you can directly adapt them.

You can use the following steps to model your design thinking, assuming that you have selected an applicable model from the five given models.

- Step 1: Select an appropriate design thinking model
- Step 2: Define each phase and activity with your understanding
- Step 3: Identify activities and thinking, using your recorded data for each phase
- Step 4: If there are activities that do not fall within any phase, map them onto the design thinking model as new phases or activities
- Step 5: Check whether links to each phase and iterative activities are correctly recorded
- Step 6: Include additional links and feedback loops that you used
- Step 7: Revisit your critical reflections and check whether phases, activities, links and iterative loops are all presented in the model
- Step 8: Redraw the design thinking model while optimising diagrammatic presentation for visual clarity and simplicity.

5.5 Concluding Remarks

This chapter provided guidance on how to engage in the design thinking process in your sustainable design when a BD framework is used. We outlined five models: sometimes, you may have a unique process and model, other times it will be a combination of more. Examining the functioning of the five BD thinking models provides a framework for understanding the design process within an ESD studio, the key activities and when they take place. We also found that use of the biophilic conceptual design thinking model will result in designs with high biophilic quality; the exemplar shown in the next chapter uses this biophilic concept model. We also provided instructions for recording and modelling your design thinking.

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Chapter 6
Exemplar—Development and Use of a Biophilic Design Framework

Abstract This chapter demonstrates the development of a biophilic design (BD) framework and success matrix, as well as how these are adapted in a design thinking process. This example presents a BD framework that uses different weightings for different criteria items, and it also shows how the framework is used as a self-assessment tool. Its compatibility with standard sustainable design framework is benchmarked against four common green building rating tools. Finally, the BD framework is used to develop BD responses detailed in a building design proposition. The aim of this chapter is to provide a practical example of how biophilic sustainable design is achieved through the use of a BD framework and biophilic conceptual design thinking (DT) process.

6.1 Response to Design Brief

The design object is a resort hotel in the tourist zone of Bentota, Sri Lanka. This area is well-recognized as a pioneering tourism hub characterized by the presence of several internationally known unique architectures. Bentota hosts eminent buildings of the internationally recognized architect Geoffrey Bawa, whose life-long commitment to promoting sustainability in the built environment shaped the whole approach to design of this region.

The tourism industry was hit hardly by the pandemic in 2020–2021, and many financial incentives were handed out to help investors survive. Projects required a sustainable approach for financial survival while also envisaging and meeting the expectations of future tourists.

The design brief required to design a resort hotel that could:

- Identify a new paradigm for sustainable design.
- Reduce its footprint to maximum 30% of the plot area.
- Represent an outstanding example of the modern regionalism style.
- Adhere to the local building code and standard.

N. Wijesooriya et al., *A Biophilic Design Guide to Environmentally Sustainable Design Studios*, SpringerBriefs in Education,
https://doi.org/10.1007/978-981-19-4428-4_6

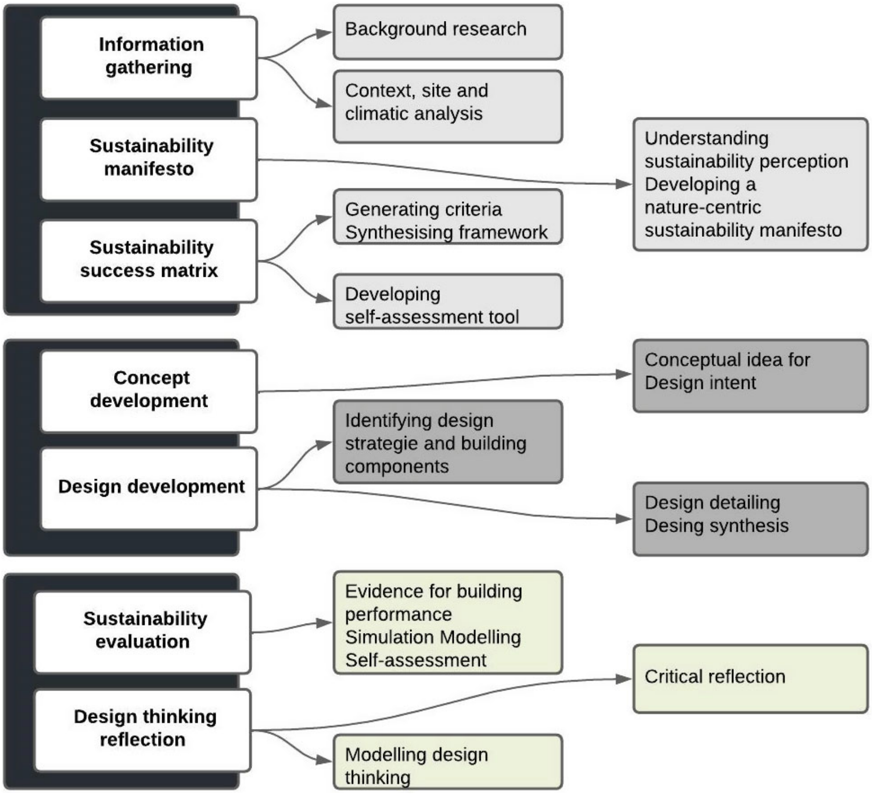

Fig. 6.1 Identified activities for designing

The project attempts to embrace and reflect the qualitative expression of the relationship between the Country and the sea, through the development of an innovative salt spa. This concept is highly focused on a natural element and its relationships with human well-being, and it was the key factor that influenced all the design decisions. Considering that the natural element is at the centre of the design, the most appropriate design thinking model is the biophilic conceptual model. Following Fig. 6.1 shows the design steps identified for the design process at the beginning.

6.2 Sustainability Manifesto Development

The first step is the development of the sustainability manifesto underpinning the overarching approach to the design. In this case, the biophilic thought is the fundamental concept that underpins the manifesto. Hence, we interpret buildings as an extension of the natural setting, comprising earth, air, water, energy and

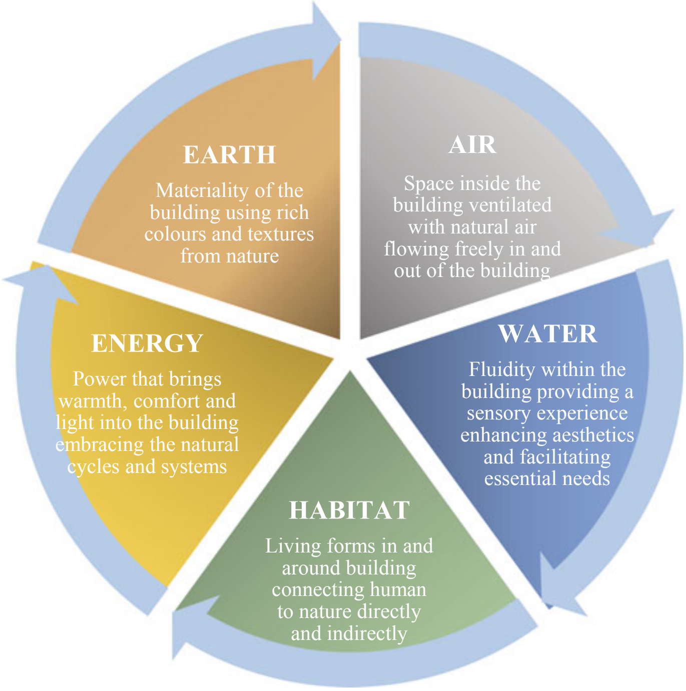

Fig. 6.2 Sustainability manifesto for "saltery" project

habitat. Figure 6.2 illustrates the definitions and the graphical presentation of the sustainability manifesto.

6.3 Context, Site and Climatic Analysis

6.3.1 Context Analysis

Bentota is located at the centre of a busy suburban social life with the lush green and waterfront tourism resort within very close proximity, which gives significant character to the place. The close centres of attraction are handful of world-class hotels, the popularity of water sports, Ayurveda healing therapies, the popularity of coconut toddy production and turtle conservation hatcheries. The colonial influence was apparent with its location being in the route to the south from the capital Colombo city. The area has a rich ethnic mix with cultural diversity and many traditional vocations.

Bawa Garden—the house and garden of renowned architect Geoffrey Bawa and his brother, landscape architect Bevis Bawa—is also located in the vicinity of Bentota, adding immense contemporary architectural value to the context.

Bentota is also easily accessible through the southern costal rail line, Galle road and the Southern Expressway. However, Bentota has only a small railway station and most trains stop at Aluthgama, 2.5 km north of Bentota, which is then reached through Galle road. Further, access to the Southern Expressway through Welipenna interchange from Bentota is only 10 km away, and helicopters flying shuttle services on a charter basis are also available.

Figure 6.3 illustrates the context analysis.

6.3.2 Site Analysis

The site is within the Sri Lanka Tourism Development Authority Bentota tourism resort, and it measures approximately 64 acres.

The site is well connected to transport infrastructure, with one designated access path to the land. The site is located in a strategic location, with close proximity to local attractions.

The main characteristic of the site is the lush vegetation that dominate its area, typically tropical coastal trees, such as mangroves and coconut trees. Moist, sandy soil is found across the land. A first analysis suggested to reduce further the total building footprint to 20% of the terrain, allowing to retain the original natural landscape of the site. The monsoon nature of this Country, however, asked for the introduction of additional landscaping to guarantee the adequate drainage during the rain period.

The site is placed between two bodies of water, providing a variety of natural views. Different design iterations intentionally explored how the building could capture this variety and maximise its potential.

Figure 6.4 illustrates the Site Analysis.

6.3.3 Climatic Analysis

Bentota, 13 m above sea level, has a tropical climate with significant rainfall throughout the year, even in the driest month. In a year, the rainfall is around 3,141 mm (123.7 inch).

The average annual temperature is 28.8 °C (80.3 °F), with maximum temperatures of 36 °C and minimum of 25.4 °C. Being a tropical climate, Bentota does not show four different seasons and the temperature results pretty stable across the year with high humidity levels.

Fig. 6.3 Context analysis. Adapted from PAIGE Consultants

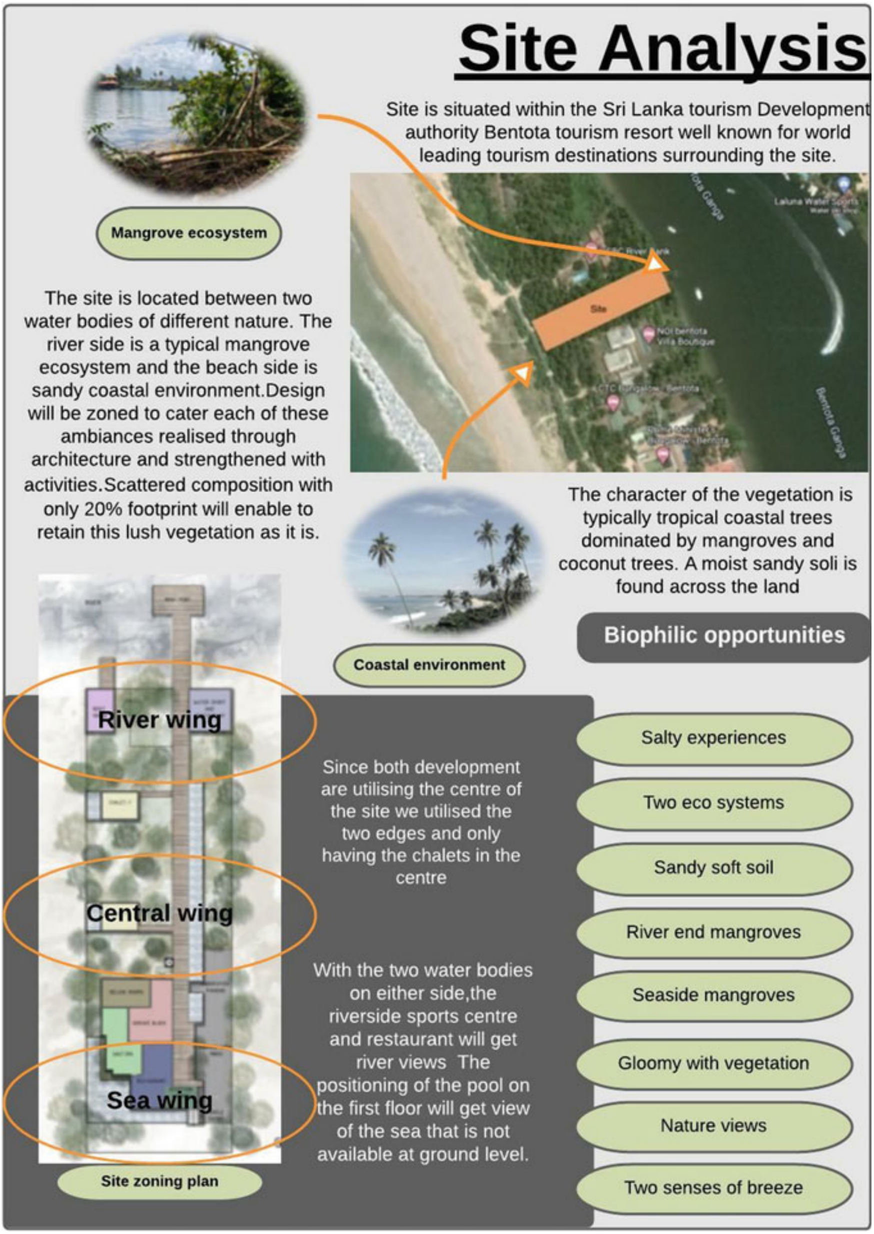

Fig. 6.4 Site analysis. Adapted from PAIGE Consultants

The sun path diagram for the site shows a high solar angle with almost half a day of sunlight. Understanding the sun is essential to establish effective bioclimatic strategies. The zinging followed the sun angle, with the chalets located to the side, where there is less sun exposure, while the suites in the south-west corner shade the remainder of the building, including the pool lounge.

Figure 6.5 illustrates the Climatic Analysis.

6.4 Design Intent: "All About Salt"

The site is located between two bodies of water, both with varying degrees of salinity. The breeze that lightly flows through the vegetation is salty as well. This natural setting inspired the conceptualisation of a building within which to appreciate this inherent sensory experience. The plot coverage is kept to a minimum by having a linear form, which also allows for the natural environment to penetrate into the building. The proposed 'saltery' focuses on being close to nature—with its consistent interaction with outside—and its closeness to nature supports a biophilic and sustainable design approach. Figure 6.6 shows the conceptual imagery and its development.

6.5 Success Matrix

Following the previous guides, we:

I. Developed a *place* criteria and a *performance* criteria
II. Developed a NPI for each category
III. Adapted the PBT to synthetise a BD framework
IV. Employed the framework directly as a success matrix

Tables 6.1, 6.2, 6.3, 6.4, and 6.5 show extracts from the *place*, *performance* and *process* list for each natural element that we identified as fundamental in our manifesto. The complete lists are given in Appendix D. For bridging *place* and *performance*, we used the *process* pathway. Figures 6.7, 6.8, 6.9, 6.10, and 6.11 demonstrate the *place criteria*, *performance criteria* and associated natural processes for one criteria generation in each category. The associations found between *place*, *performance* and *process* assisted us to write biophilic criteria for each of the elemental *category.*

Once the biophilic criteria were generated we did not develop this framework with design strategies and building components. Therefore, synthesised these BD criteria into a design framework that was used as the success matrix. Figure 6.12 illustrates the success matrix developed as a biophilic design framework for self-assessment.

We termed success matrix developed for this project as Biophilic House Guide allowing it to be used for other projects. The biophilia criteria we generated were not

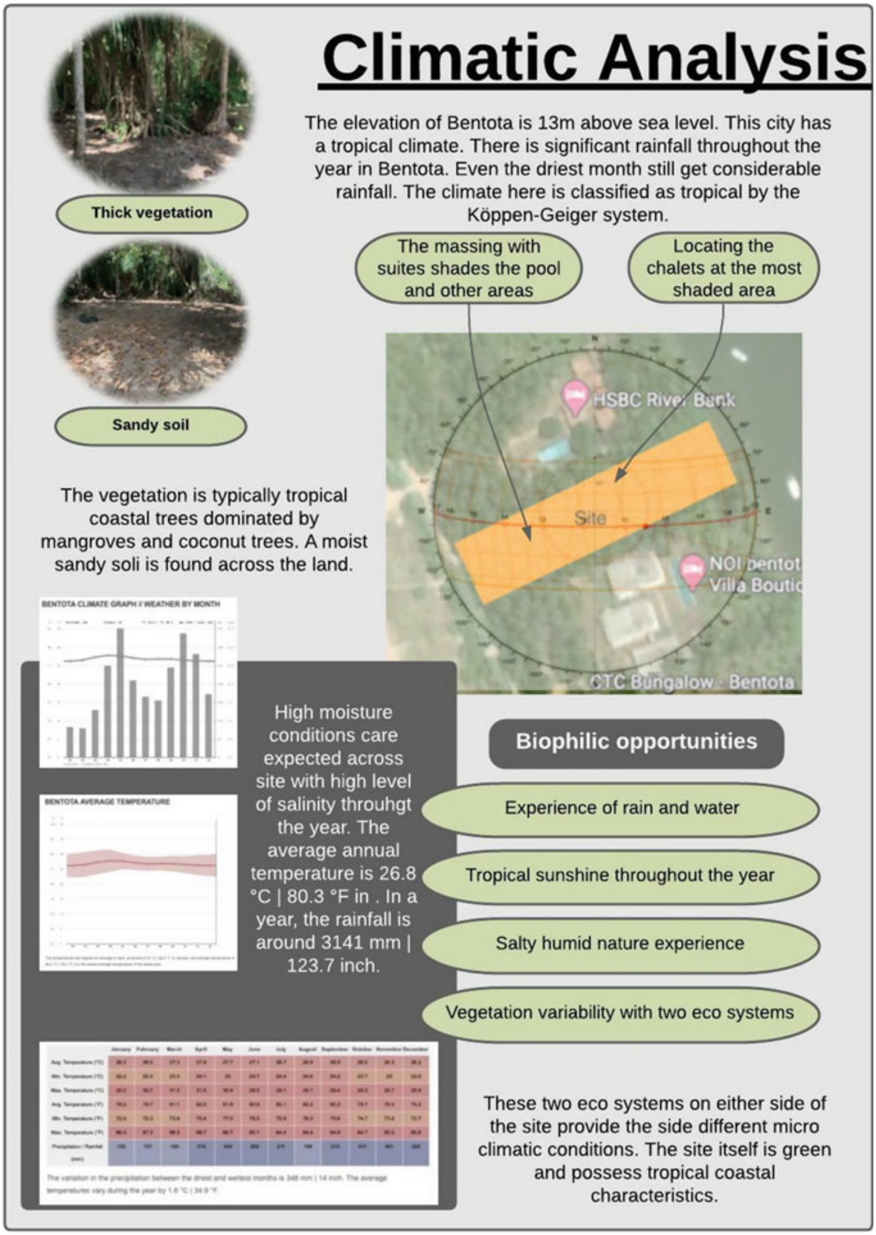

Fig. 6.5 Climatic analysis. Adapted from PAIGE Consultants

Fig. 6.6 Conceptual imagery

Table 6.1 Place, performance and process lists for earth

Place criteria	Natural processes	Performance criteria
• Natural material selection • Biomimicry • Information richness through material variability • Place making with earth resources • Prospect/refuge • Composition of material variability • Sensory variability • Complexity and order in material variability • Fractals using natural materials	• Earth walls for enhanced thermal performance • Sand filters for water purification • Clay as a thermal insulation • Timber as a material for carbon offset • Timber as a rapidly renewable material • Earth as a low embodied energy material	• Responsible sourcing of construction products • Designing for durability and resilience • Rapidly renewable materials • Low-emitting materials • Building life-cycle impact reduction • Net positive waste • Hazardous material abatement • Site remediation • Reduced pesticide use • Volatile compound reduction • Long-term emission control

elaborated with design strategies or building components resulting in more general criteria. Due to these broader descriptions, the criteria are applicable in a range of design situations. Therefore, the BD framework is reusable for other projects. However, in this BD framework more weight is given to *earth* and *water* categories since the concept has more emphasis to embrace salt and its earthly properties through the building.

Table 6.2 Place, performance and process lists for air

Place criteria	Natural processes	Performance criteria
• Presence of natural air • Inside outside space connections • Non-visual connection with space • Connection with natural air systems • Prospect/refuge • Composition of spatial variability • Sensory experience • Complexity and order in spatial variability	• Air for power generations • Natural air for ventilation • Flora as carbon storage • Flora for air purification • Flora for air quality enhancement • Timber as a material for carbon offset	• Air quality management • Healthy interior environment • Enhanced indoor air quality strategies • Low-emitting materials • Minimization • Air filtration • Active VOC control • Humidity control • Ventilation • Ventilation effectiveness • Enhanced ventilation • Operable windows

Table 6.3 Place, performance and process lists for water

Place criteria	Natural processes	Performance criteria
• Water elements • Information richness • Fractals depicting water • Biomimicry with water • Place making with water • Non-visual connection with water • Connection with water systems and elements • Mystery • Composition of water variability • Sensory variability • Complexity and order in water elements • Sensory comfort	• Solar water heating • Solar water purification • Moisture in air for water generation • Water for power generation • Water for thermal performance • Rain water collection for water use • Flora as a water purifier	• Water quality • Water contaminants • Legionella control • Enhanced water quality • Water quality consistency • Water use • Net positive water • Drinking water promotion • Moisture management • Handwashing • Onsite non-potable water reuse • Water leak detection • Water efficient equipment • Flood and surface water management

6.6 Design Synthesis

The success matrix prompted the development of different design strategies identified as potential enablers of the performance required. An initial phase of case studies analysis and in-depth research allowed us to design, identify and propose several options in terms of building components, passive strategies, materials and functional systems for the building that could aid in the achievement of our targets.

Table 6.4 Place, performance and process lists for energy

Place criteria	Natural processes	Performance criteria
• Exposed sunlight • Dynamic and diffuse light • Light pools • Warm light • Light as shape and form • Inside outside connecting • Visual connection in light and energy • Connection with natural energy systems • Prospect/refuge • Composition • Fractals of light and energy • Complexity and order in light and energy	• Solar space heating • Solar water heating • Solar water purification • Solar energy • Solar lighting • Moisture in air for water generation • Water for power generation • Water for thermal performance • Plant shading for heat gain reduction • Clay as a thermal insulation	• Heat island reduction • Enhanced thermal performance • Individual thermal control • Thermal comfort monitoring • Light exposure and education • Circadian lighting design • Glare control • Enhanced daylight access • Visual balance • Electric light quality • Lighting occupant control and visual comfort • Low carbon design • Energy efficient equipment • Optimize energy performance

Table 6.5 Place, performance and process lists for habitat

Place criteria	Natural process inventory	Performance criteria
• Facade greening • Habitats and eco systems • Age, change and patina of time • Botanical and animal motifs • Tree and columnar support • Shells and tubular forms • Complexity and order in natural elements • Affection and attachment • Attraction and beauty • Sensory variability • Visual and non-visual connection with nature	• Flora as a water purifier • Flora for heat gain reduction • Flora for shading • Flora as carbon storage • Flora for air purification • Flora for air quality enhancement	• Habitat promotion • Restore habitat • Habitat exchange • Quality views • Urban agriculture • Food production • Biophilic environment • Enhanced access to nature • Health and wellbeing • Restorative opportunities • Restorative spaces • Sleep support

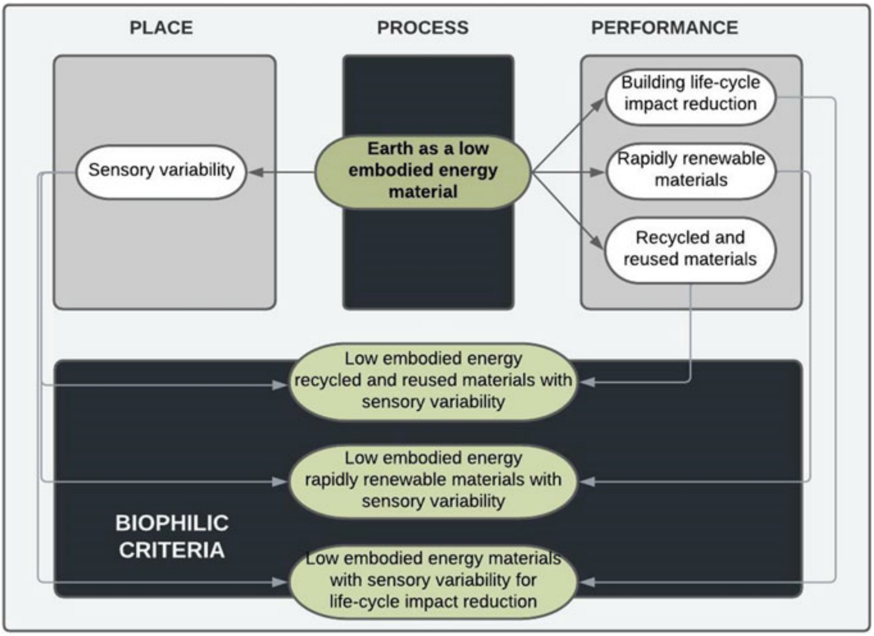

Fig. 6.7 Sample biophilic criteria for earth category

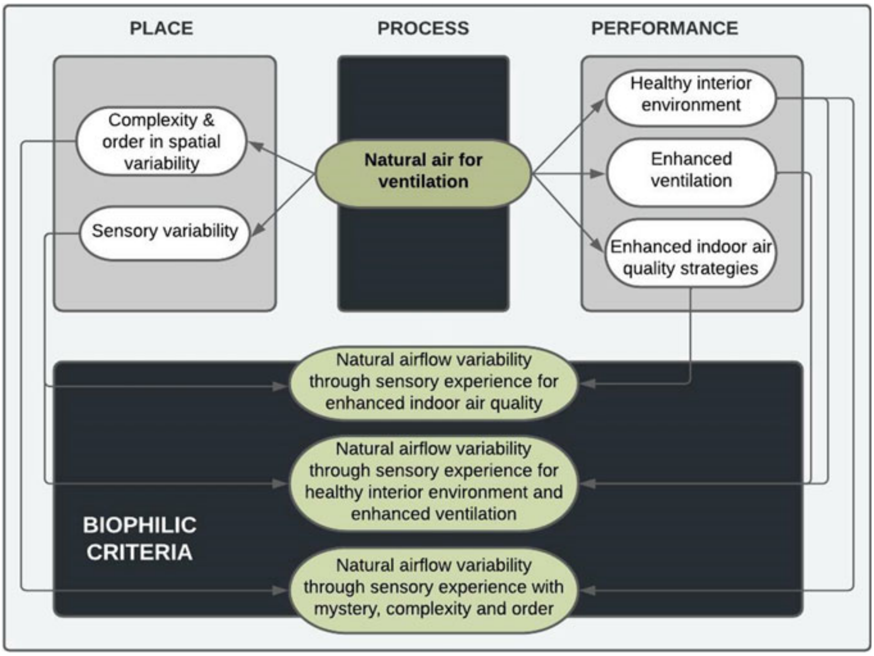

Fig. 6.8 Sample biophilic criteria for air category

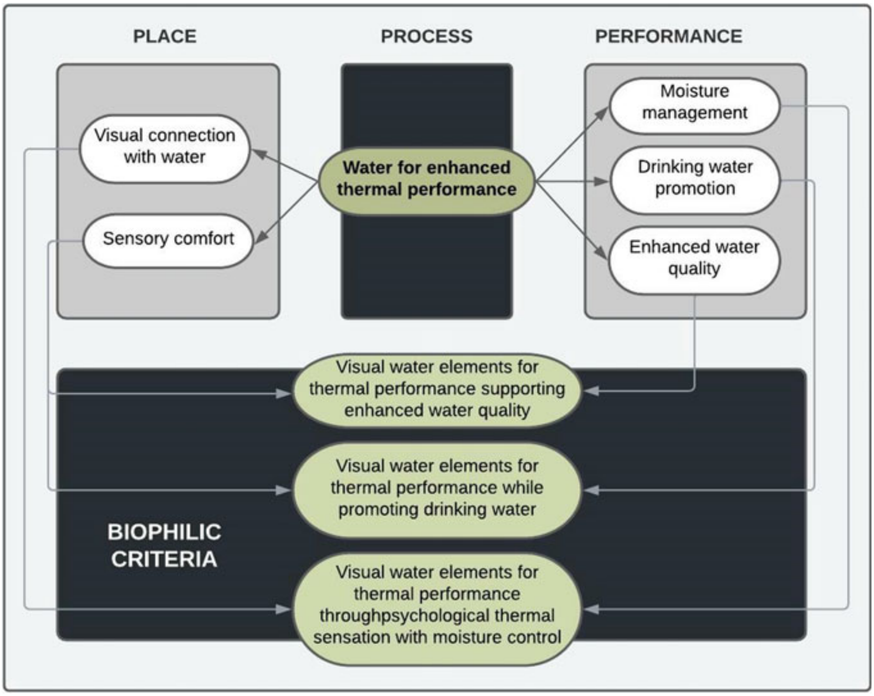

Fig. 6.9 Sample biophilic criteria for water category

The matching of design strategies and building components was a cyclic process that provided us with numerous design options.

Design synthesis focused on developing an architectural design to suit the context, climate and site while trying to optimise the use of most appropriate design options. The following figures show the basic design scheme in conceptual level plans, section and elevations, 3D images, which communicate the architectural quality of the building, and ESD section to summarise all the features (Figs. 6.13, 6.14, 6.15, 6.16, 6.17, and 6.18).

6.7 Evaluation

The last step comprised the evaluation of the design using ESD and BD criteria to assess the overall quality of the design against the success matrix. For this step, we have used the self-assessment tool and provided a final rating for the scheme. Figure 6.19 illustrates the assessment on the tool.

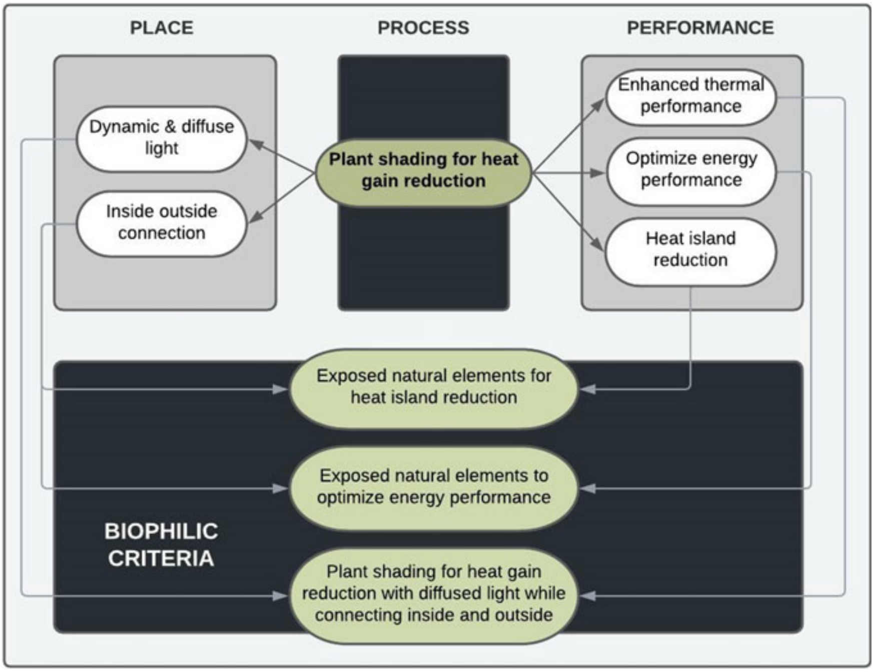

Fig. 6.10 Sample biophilic criteria for energy category

As the figure depicts the overall score is in platinum standard with 86% overall point value. The water has performed high in the tool accounting for 91% of achievement. The earth being the dominant category in the design got 90% of available credits. Energy has less performance in comparison by achieving 73% of allocated credit points.

6.8 Critical Refection and Design Thinking Model

As final step, a critical reflection enabled us to record our process and capture the lessons learned in this project. This will help us to approach other projects with more awareness and the knowledge gained to come to fruition in the future. This reflection is based on the Student Guide 3 given in Chap. 5. Following Table 6.6 summarises our responses.

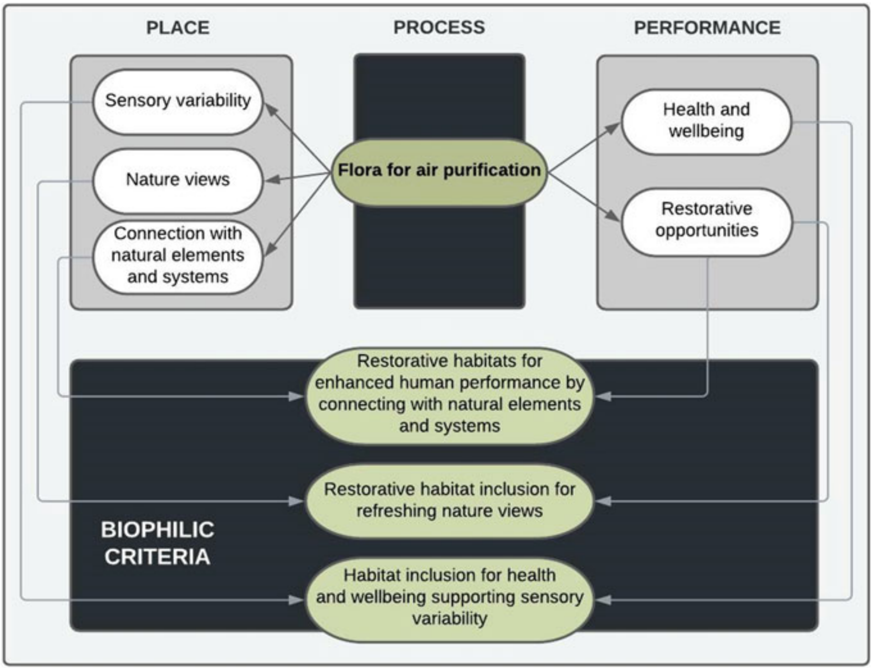

Fig. 6.11 Sample biophilic criteria for habitat category

6.9 Concluding Remarks

This exemplar showcased the use of the guides in an actual design project. Even though it is presented as a linear process, we were constantly moving back and forth across each phase. In this exemplar, we started with the sustainability manifesto early in the design. This also assisted us to gather relevant information and integrate our ideas around sustainability into research phase. You may notice that the conceptualisation has a significant influence on the design decisions. We used the concept from layout planning to detail of specific elements.

We used *process bridging technique* outlined for the success matrix development in Chap. 4 using the *place* pathway. This resulted in a matrix that has a focus on achieving sensory place making characteristics and comparatively weak in building performance. The least score achieved by force category is due to the selection of *place* pathway. We were able to critically reflect on the process and model our DT process slightly differing that the biophilic conceptual DT model. You may also generate your own DT model depending on the design brief, sustainability manifesto, success matrix and conceptualisation.

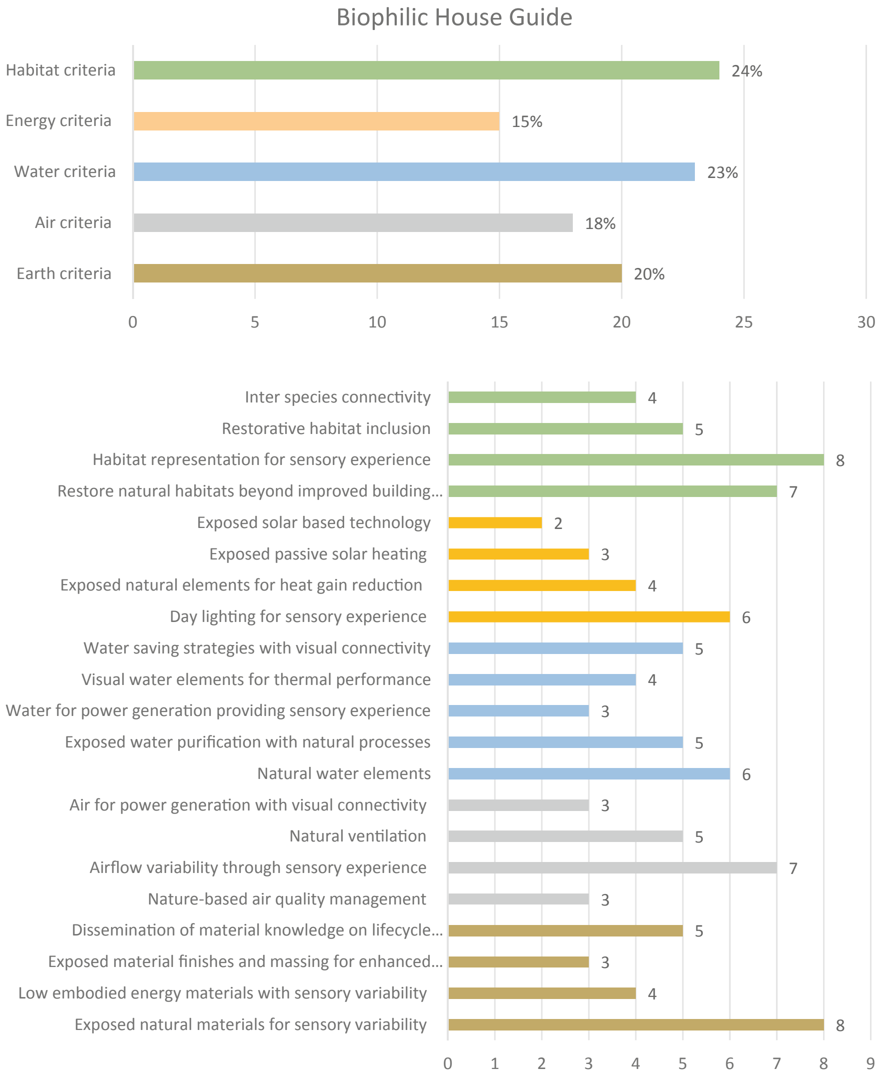

Fig. 6.12 Success matrix: Biophilic House Guide

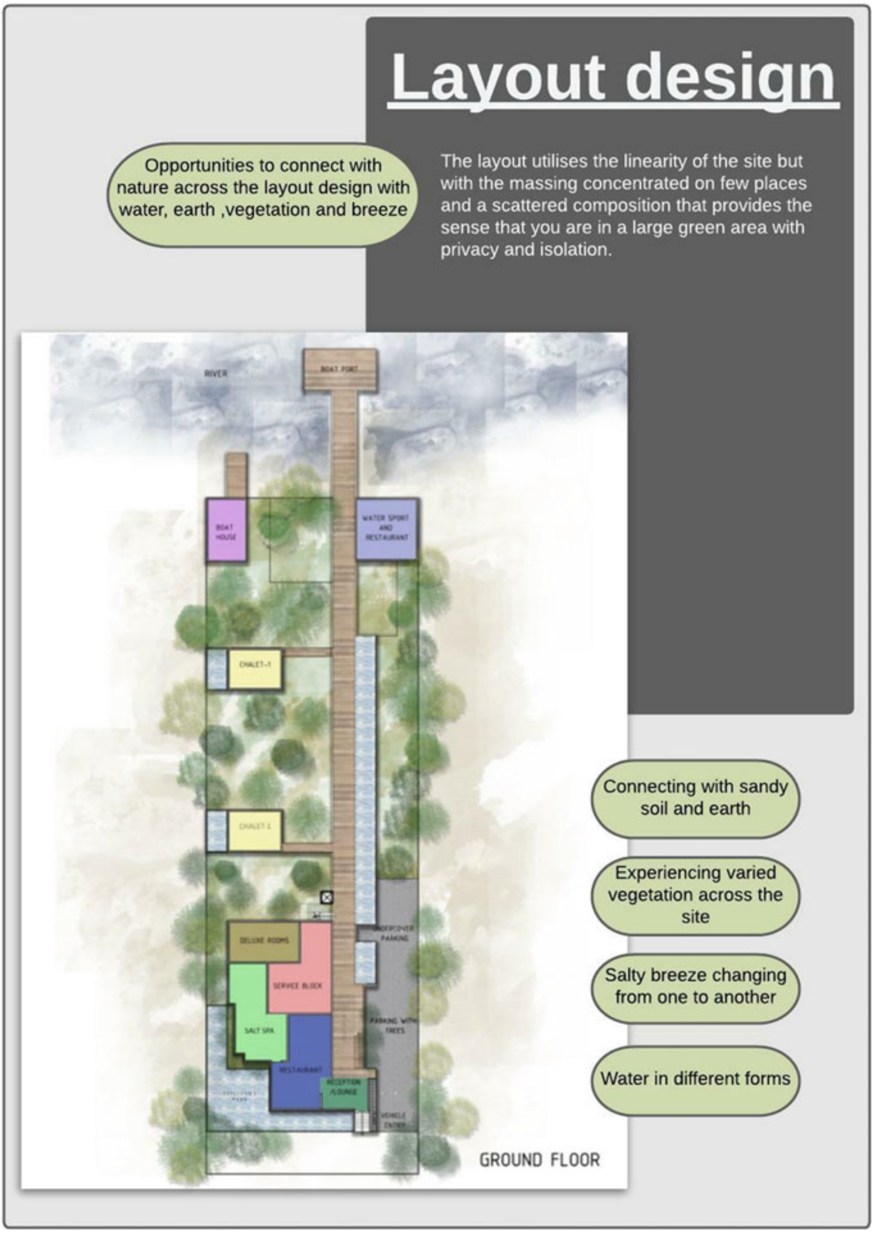

Fig. 6.13 Layout design. Adapted from PAIGE Consultants

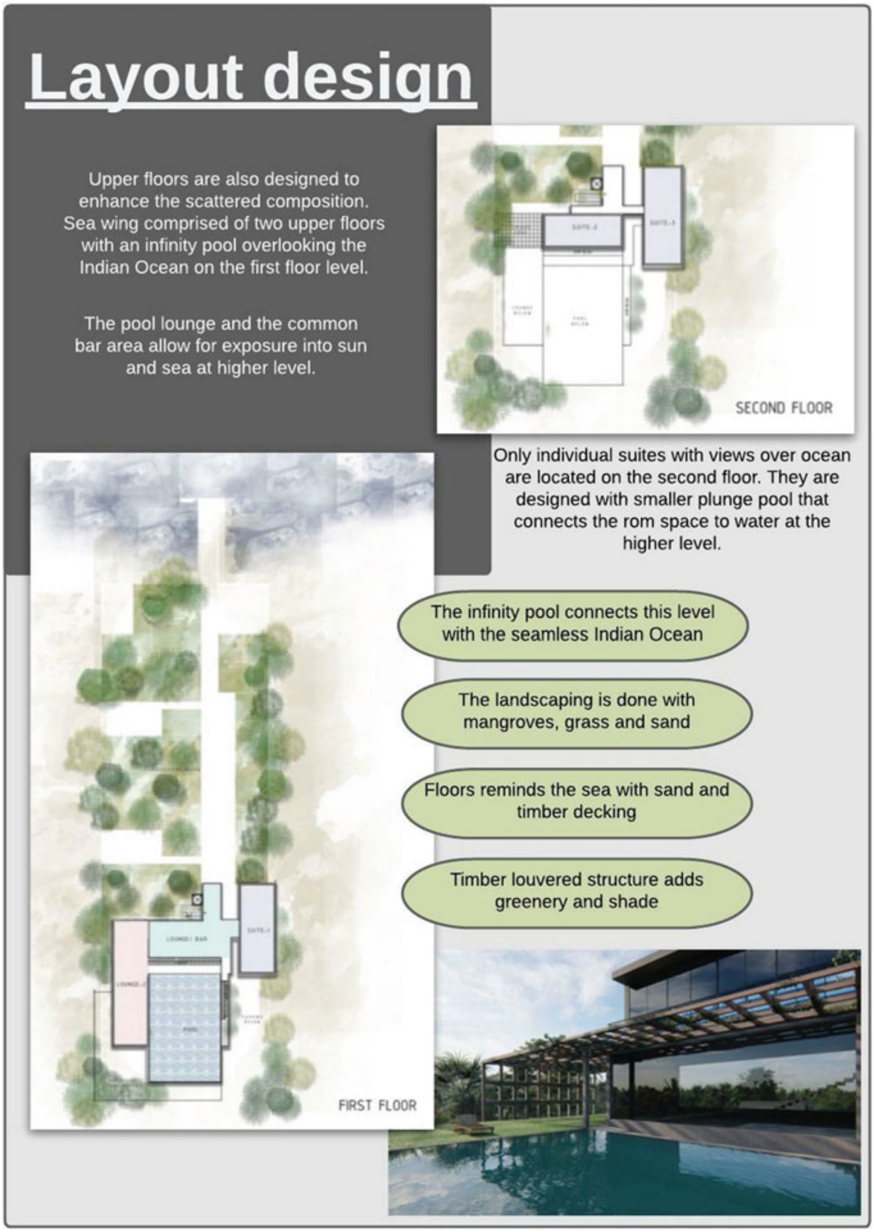

Fig. 6.14 Layout design—upper floors. Adapted from PAIGE Consultants

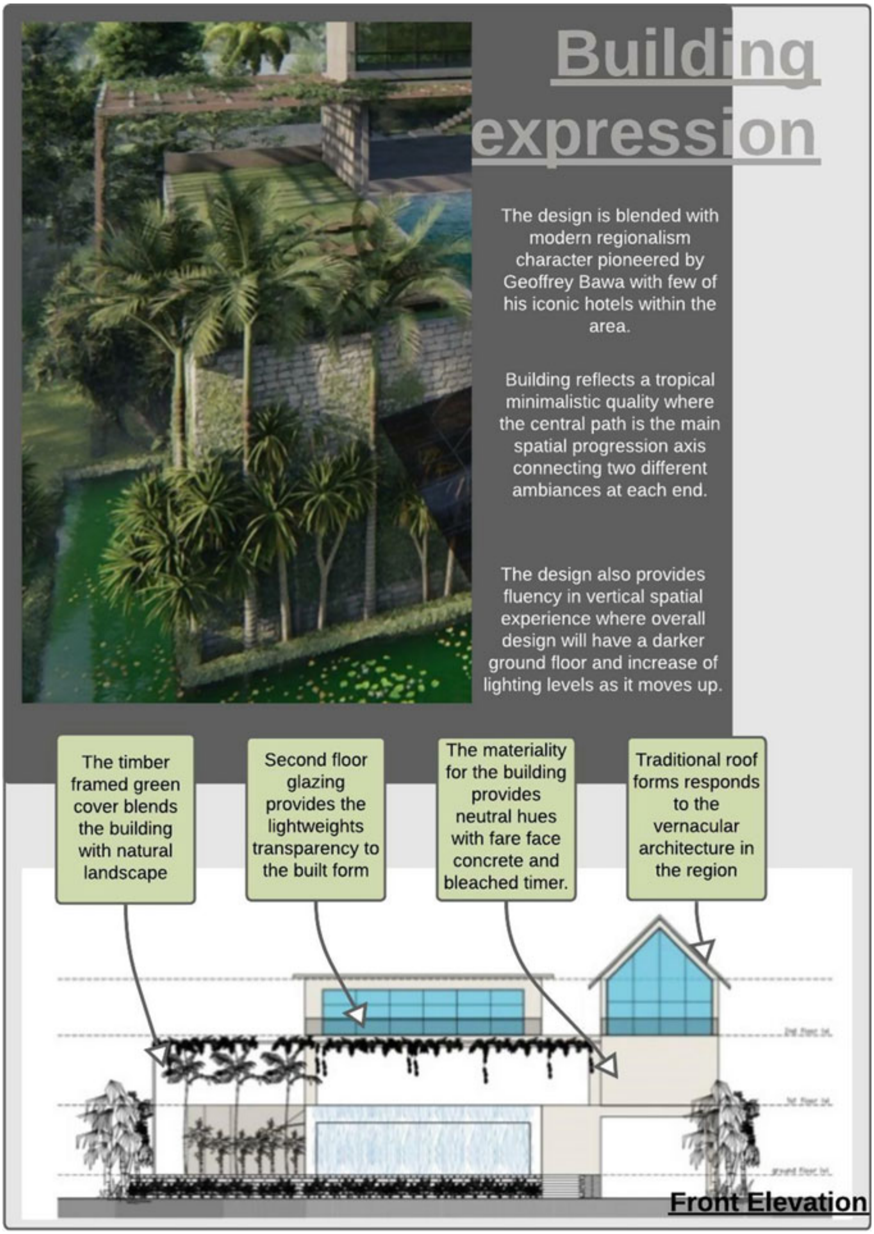

Fig. 6.15 Building expression. Adapted from PAIGE Consultants

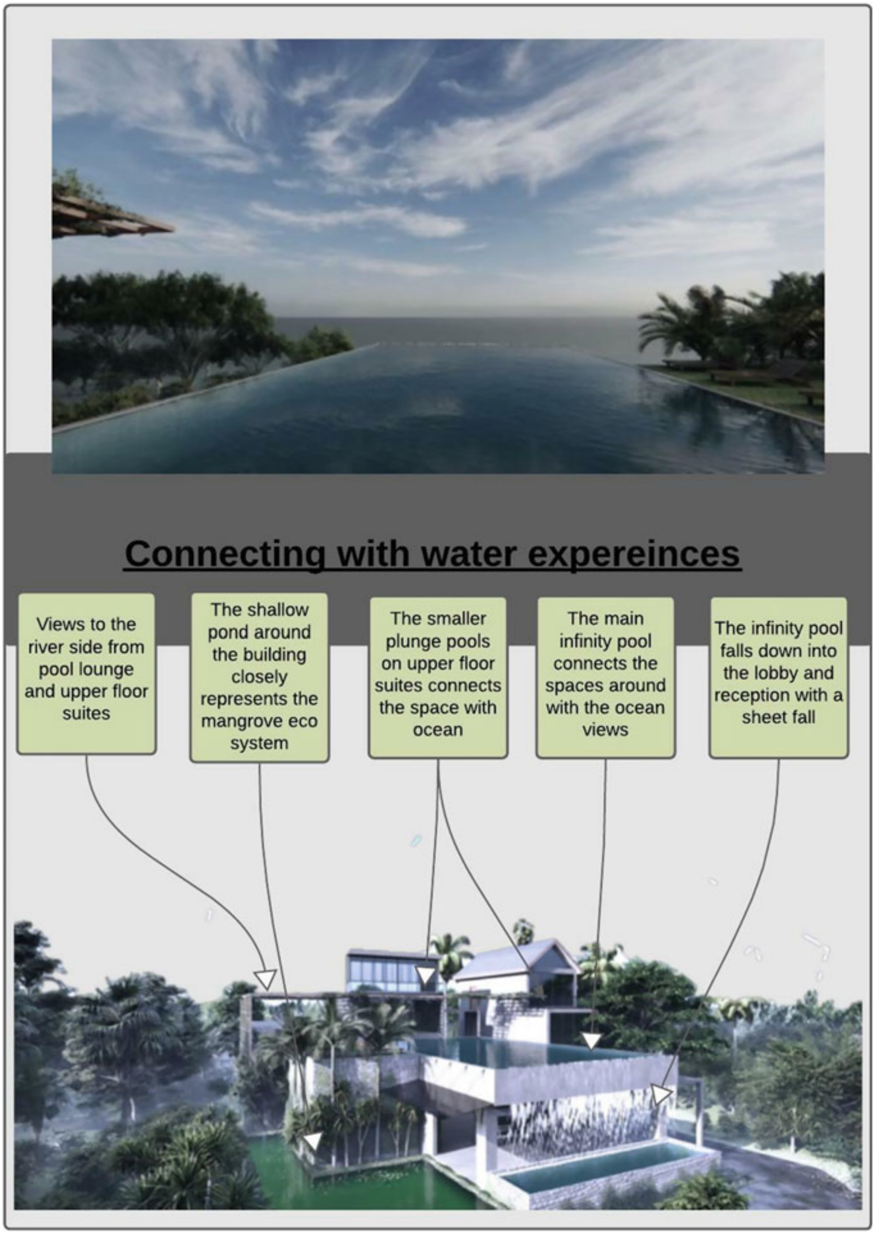

Fig. 6.16 Connecting with water experiences. Adapted from PAIGE Consultants

Fig. 6.17 Accommodation design. Adapted from PAIGE Consultants

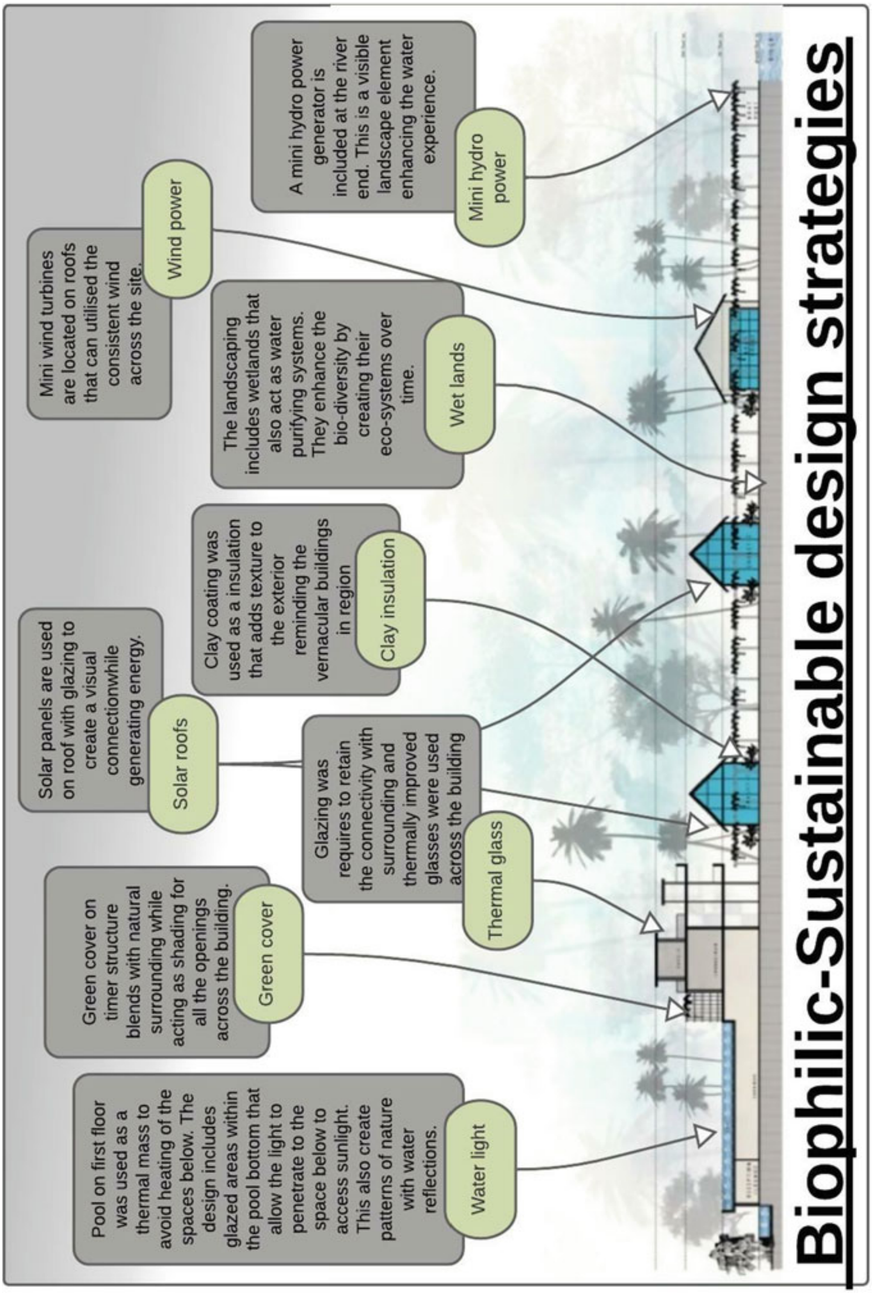

Fig. 6.18 Sustainable design strategies. Adapted from PAIGE Consultants

Table 6.6 Critical reflection on the biophilic design process

Reflecting aspect	Reflections
Reporting: At what point did I use BD principles in my design thinking process? Was it during conceptualisation? Is my whole design generated around human–nature connectedness and the use of BD principles?	I started my design process with the intention to create a biophilic environment. initial thoughts were brought in even prior to the conceptualisation. My whole design approach and project evolved around to create a place that enhance human-nature connectedness
Relating: Was BD part of my whole design thinking process? Did I consciously use it? Did I understand the implications of BD to incorporate it as an integral component of my design thinking process? Did I use a design thinking process at all?	I generally use a design thinking process. I feel that I usually generate my architecture around nature and appreciating its beauty. Therefore, BD is an integral component in the way I design. Maybe I was not conscious that I have this tendency, but now I understand my need to bring nature into built environment
Reasoning: Did I have enough information on BD to include in my design thinking process? Did I think it had a value? Was it in my philosophy to have a design thinking process focused on nature rather than on built environment? Did I have the skills or tools to incorporate BD into my thinking process?	My design philosophy is highly focused on nature by responding to the natural surrounding and recreating nature in and around the building. Use of natural processes helped me as a strategy to bring nature while designing for sustainable building performance
Reconstructing: Will I be consistently using BD in my design thinking process? How can I overcome the difficulties in adopting BD for my design thinking process? What learning support is required to understand the implications of BD within the design thinking process?	I am sure I will use the same design thinking process in future. I need to explore more on identifying how natural processes could assist in achieving sustainability in the building. The challenge for me was to balance nature and built in the project to ensure modern lifestyle needs are also met

Reflecting back on the DT process we were able to model it as shown in Fig. 6.19 (Fig. 6.20)

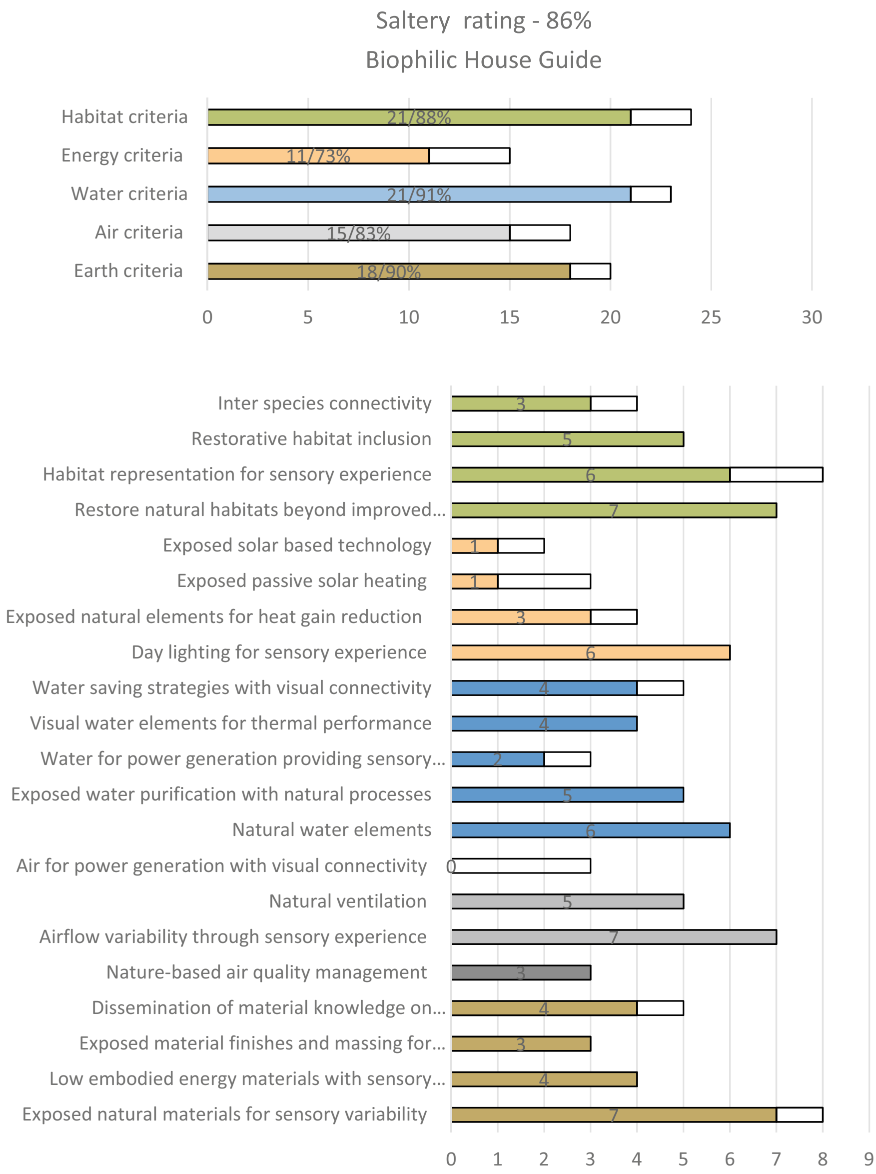

Fig. 6.19 Design evaluation using the Biophilic House Guide rating tool

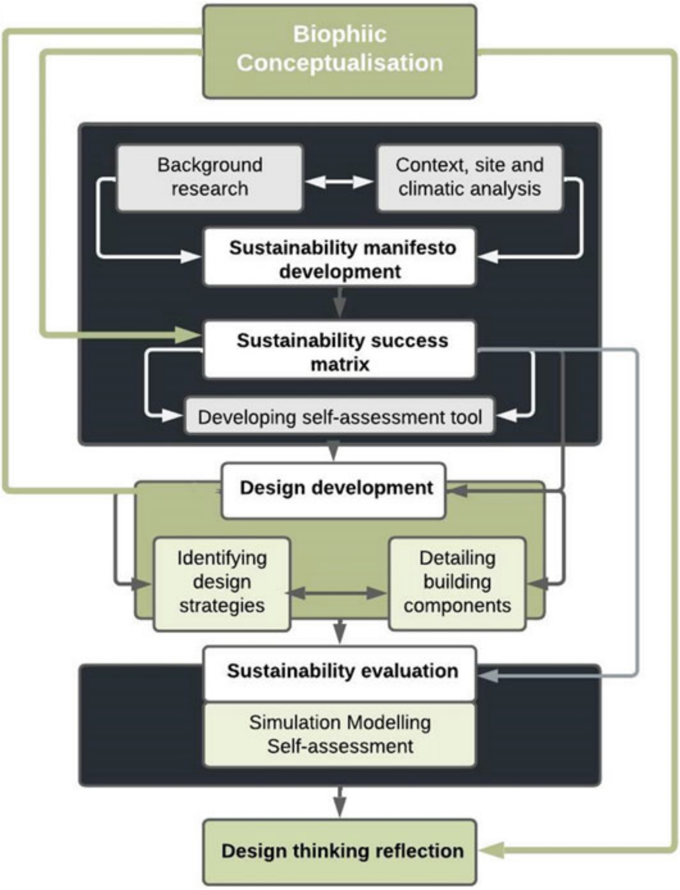

Fig. 6.20 Biophilic conceptual design thinking model used in the "saltery" project

Chapter 7
Implications for Educational Practice and Research

Abstract Facilitating students to practice environmentally sustainable design is crucial for preparing architectural professionals who meet the contemporary environmental challenges. Integrating biophilic design (BD), an approach that harnesses the benefits of nature on human health and wellbeing, into sustainability practice can result in a holistic design solution. An educational innovation for BD developed upon reflective action conjecture mapping (RACOM) approach comprised of embodied educational design elements under tools and materials, task structures and discursive practices. This chapter outline how task structures and discursive practices can be used to facilitate students to adapt BD in a sustainable studio. Areas for further investigation are given by highlighting five future research areas.

7.1 Introduction

In Chap. 2, a detailed account of the development of an educational innovation is presented, followed by three design guides for students (Chaps. 3, 4, and 5). Chapter 6 presented an exemplar showcasing the use of the student guides. Finally, this chapter presents embodied educational design elements that can be used by educator to design a sustainable design studio based upon the principles explained in the previous chapters. These elements are: (1) arrangement of studio tasks, (2) weekly task structures, (3) peer assessment, and (4) weekly discussion forum. These elements have been designed and proposed based upon a critical reflection and iteration of a two-year project where the methodology to develop BD framework has been integrated into an ESD studio. How to assess the learning outcomes are briefly discussed with indicators and measurements. The chapter further discusses assessment and highlights practical implications that are useful for educators wanting to adapt the presented educational design. These task structures and discursive practices are presented as a general guide that can be adapted for scaffolding learning in the design studio. By reflecting on the development and implementation of this educational innovation, theoretical and empirical knowledge and application gaps are identified to direct future research and strengthening the use of BD in environmentally sustainable design studios.

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https://doi.org/10.1007/978-981-19-4428-4_7

7.2 Embodied Educational Design Elements

The RACOM for BD frameworks given in Fig. 2.1 included several embodied design elements. Following Fig. 7.1 illustrates the pedagogical ideas given under embodiments within Fig. 2.1 categorised into tools and materials, task structures and discursive practices.

The guides (Chaps. 3, 4, and 5) for students and the exemplar (Chap. 6) are presented in previous chapters, while the simulation software is integrated as support for the students to evaluate the building performance and assess their design choices' implications. The task structures include arrangement of the design studio tasks, weekly task structures, peer assessments and weekly feedback.

The studio can be structured to facilitate the adoption of a design thinking model, support students in developing and integrating the design framework into the design

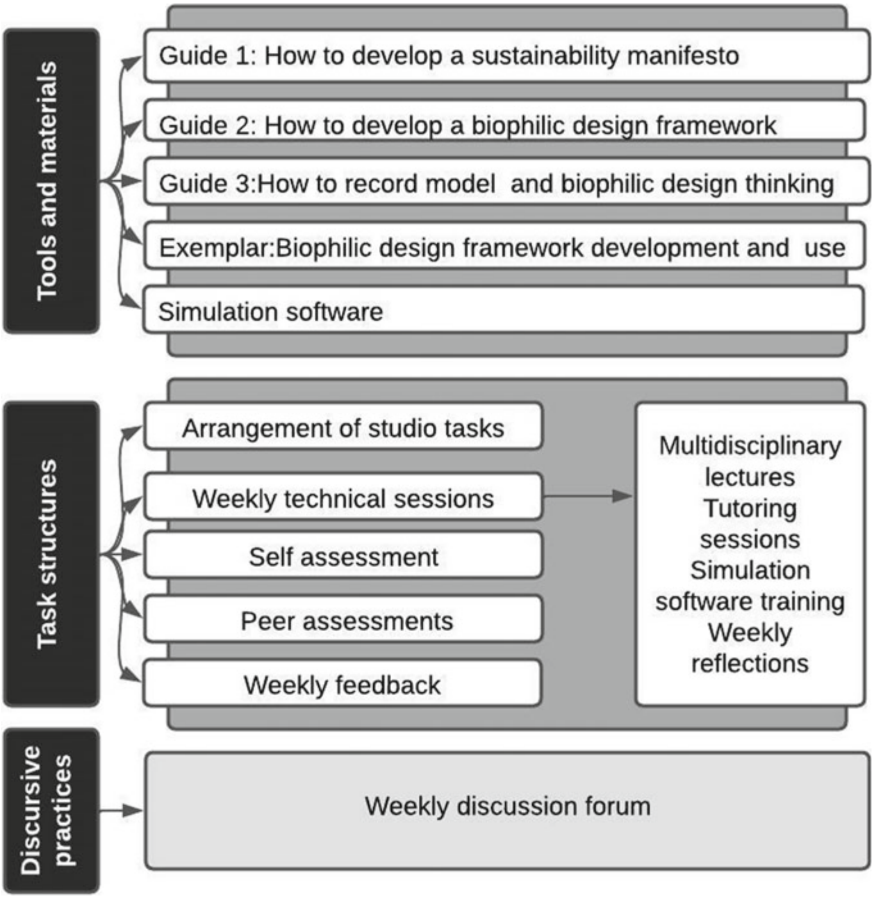

Fig. 7.1 Detailed embodied design elements

process and facilitate the development of their evaluative judgement. To this end, the weekly tasks should include weekly multidisciplinary lectures, regular and consultant tutoring sessions, simulation software tutorials and reflective diary entries.

The lectures discuss ESD from different disciplinary perspectives (e.g., passive solar design, biophilic design) and support interdisciplinary learning through peer interactions. Lectures are then complemented by tutorials and consulting sessions to help students gain expertise knowledge in specific domains, such as life cycle analysis and water sensitive design. The studio incorporates peer assessment as a learning methodology to strengthen the students' ability to judge others' work as well as their own. A weekly discussion forum supports the discursive practice to encourage dialogue around ESD.

These elements are discussed in following sections.

7.2.1 Arrangement of Design Studio Tasks

The structure of the studio reflects a fully integrated model where technical knowledge is embedded into the studio (Altomonte et al., 2014) through task structures. The studio structure suggested in this chapter is based on a 13-week semester, and it includes three different assessments. All the studio activities included are focused on guiding students to develop a BD framework. Table 7.2 shows the activities across the 13-week studio program.

The studio is organized in five phases, each targeting a specific development of students learning. Each week is given focus on an ESD aspect with weekly tutorial sessions supporting students to complete.

The first phase guides students in the development of their sustainability manifesto. During this stage, the tutoring sessions focus on introducing different ESD approaches and explaining their underlying conceptualisations of sustainability. Students are also required to conduct autonomous research to build a holistic view of the design issues at hand such as responding to climate, ecological impact etc. Students are encouraged to develop an initial ideation for a success matrix along with the manifesto, however some students may have fully developed success matrixes at this stage. For this reason, it is important to remind that the first assessment artefact is the manifesto, regardless from the development stage of the matrix. This first assignment is suggested to be 10% of the total final mark.

The second phase begins after the manifesto with students developing their success matrix. This matrix is required to have enough details, criteria, evaluation measures and description to be used as a self-assessment tool. The weight of this assessment artefact is 20% on the total mark.

Phase 1 and phase 2 are individual tasks, however, the design exercise that starts in phase 2 is proposed as a group task. Groups are required to discuss the matrix of each member and synthetize their discussion and reflections in a coherent group matrix that could capture the group standpoint on the sustainability debate. This task has revealed to be essential in building the students' confidence and understanding of sustainability as a holistic concept. The third phase concentrates on the development of the conceptual design and it concludes with a peer assessment, where groups discuss and critique each other conceptual design in regard to the matrix, prompting discussion and reflection upon priorities and strategies to achieve sustainability.

The successive phase is the development and finalization of the design to be presented to an external jury. The presentation ca be associated to 55% of the final mark. The feedback received in this phase and their implementation into the design guide students to the final phase of the studio: the reflective portfolio development.

Throughout the course, students are encouraged to keep a weekly reflection diary, which constituted the basis for the final assignment. This final phase is again individual, and each student is required to prepare a portfolio based on their design development process and weekly reflections. The scope is to correlate design and reflective practice to increase the students awareness about the iterative nature of the process and the importance of an informed design development. The arrangement of the studio tasks will enable students to follow the suggested design process while simultaneously creating opportunities for individualisation.

7.2.2 Weekly Task Structures

These phases are similar to those in a typical design thinking process and are complemented by weekly tasks that support students learning and development.

Weekly multidisciplinary lectures will cover different ESD aspects such as daylighting, energy efficiency, bioclimatic design and life-cycle analysis. Given the highly specialized nature of the contents, they might require professional or academic experts on the topic. Clearly, considering that the focus of the studio is bridging BD and ESD, one specific lecture on biophilic design should explain the development of BD frameworks, biophilic thought and the use of design thinking in par with the guides.

The weekly topic is also used to frame the weekly discussion, which is recommended to be facilitated and guided from the educator by posting specific questions on the online discussion forum to spur the conversation. The discussion can be prompted after the lecture, to consolidate learning, or few days before the lecture, to force students starting to think about the topic and create a fertile basis for a deeper understanding of the topic.

This studio is designed as a fully integrated model, hence lectures are not only focused on the design brief given to the students but, rather, provide a general overview of the topic, focusing on students' ability to use the knowledge and skills in varied design projects. The regular tutors will support the students on completing their assessments whilst introducing the three guides to adopt BD. Specialized consultants on the various topics, such as life-cycle analysis, BD and energy simulation, can integrate the design development while replicating a real-life scenario where architects work in collaboration with project consultants.

The simulation software sessions aim at providing students with a practical tool for generating the evidence needed to guide their ESD decisions. These sessions include practical lab training as well as studio-based tutoring opportunities to demonstrate and apply the knowledge to the specific project.

All these activities are integrated by a weekly reflective practice. Students are required to record their reflections weekly to increase their awareness about their own design thinking process. Guide 3 includes instructions on writing reflections and using reflective practice as an integral part of the design process. It is found that students will, most of the time, be not familiar with this practice, requiring more guidance and support. Tutors should encourage students in undertaking this activity by engaging in the reflection and providing regular constructive feedback on the diary entries. To increase the level of participation in this activity, a small 5% of the final mark can be accounted for (see Table 7.1).

7.2.3 Peer Assessment

Both feedback and peer assessment have been found to be crucial educational design elements that nurture evaluative judgement (Tai et al., 2018). The peer assessment could be conducted through the course learning management system, where students provide detailed commentary on the peers' designs. Students' peer feedback could be scaffolded using a form or template (Table 7.2).

7.2.4 Weekly Discussion Forum

To develop students' skills to engage in professional dialogue and reflective practice, students could be asked to discuss ESD aspects and practices in an online forum. On par with the weekly lecture, a few questions can be posted to prompt student responses and trigger a thought process. Table 7.3 outlines some typical questions that can be included into weekly themes.

Weekly discussions prior to the lectures can assist students to engage with the topics by relating their prior knowledge and personal experience to the principle of sustainable design. The discussions can also help students in initiating a reflective process and allow students to resolve their fundamental questions, such as what sustainability is and how it relates to the built environment.

The success of the discussion can be measured by the interaction between students, hence it is important to facilitate this process. When the studio is conducted for master's level students with a mix of backgrounds and experience, this will nurture interdisciplinary learning.

Table 7.1 Sustainable architecture studio activities

		Lecture theme	Weekly tasks during tutoring sessions		Assessment	
			Tasks	Responsibility	Assessment artefact	Weightage (%)
Week 1	Phase I Sustainability manifesto development	Introduction to sustainable design	Introduce guide 1	Studio tutor	Sustainability manifesto	10
Week 2		Energy efficient design	Introduce guide 2	Studio tutor		
Week 3		Bio climatic design	Peer assessment and feedback on sustainability manifesto	Studio tutor/students		
			Simulation software tutorials	Consulting tutor		
Week 4	Phase II Success matrix development	Passive solar design	Demonstration of the process bridging technique using exemplar	Studio tutor	Success matrix	20
			Simulation software tutorials	Consulting tutor		
Week 5		Water sensitive design	Exercise to develop biophilia criteria using process bridging	Studio tutor		
			Simulation software t tutorials	Consulting tutor		

(continued)

Table 7.1 (continued)

		Lecture theme	Weekly tasks during tutoring sessions		Assessment	
			Tasks	Responsibility	Assessment artefact	Weightage (%)
Week 6		Biophilic design	Demonstration of BD framework development using exemplar	Studio tutor		
			Simulation software tutorials	Consulting tutor		
Week 7	Phase III Conceptual design	Design thinking	Introduce guide 3	Studio tutor	Design proposal	55
			Simulation software tutorials	Consulting tutor		
Week 8		Daylighting design	Demonstration of design strategy development using exemplar	Studio tutor		
			Simulation software tutorials	Consulting tutor		
Week 9		Lifecycle analysis	Interim assessment, peer assessment and feedback	Studio tutor/student		
			Simulation software tutorials	Consulting tutor		
Week 10	Phase IV Design development	Low carbon design	Demonstration of building component development using exemplar	Studio tutor		
Week 11			Presentations for external jury	Studio tutor		

(continued)

Table 7.1 (continued)

		Lecture theme	Weekly tasks during tutoring sessions		Assessment	
			Tasks	Responsibility	Assessment artefact	Weightage (%)
Week 12	Phase V Reflective design portfolio preparation	Reflective writing	Writing of biophilic reflections	Studio tutor	Reflective portfolio	
Week 13		Sustainable design thinking models	Peer assessment and feedback on identified individual design thinking processes	Studio tutor/student		
					Reflective diary entries	5
					Biophilic design thinking modelling	10

Table 7.2 Structured peer assessment template

Assessment criteria	Total mark	Given mark	Comments
Sustainability manifesto			
Understanding of sustainability concepts	15		
Interpretation of sustainable design	15		
Appropriateness of identified sustainable design approach	10		
Explaining the positioning the sustainable perception within nature-centric, built-centric, human-centric focus	30		
Expressing the sustainability manifesto (verbal or graphical)	15		
Research and referencing	15		
Success matrix			
Categorization to suit biophilic design approach	10		
Biophilic criteria generation	15		
Compatibility of biophilic criteria with ESD approach	20		
Synthesis of the criteria	25		
Clarity of instructions given to identify design strategies while developing as a self-assessment tool	10		
Justification of assigning credits for each criteria while developing the self-assessment tool	10		
Clarity of representing self-assessment tool	10		
Biophilic design thinking model			
Clarity of design thinking process	10		
Understanding the use of biophilic design framework within the design thinking process	25		
Justification of position within design thinking process where biophilic design response is applied	25		
Graphical expression of the biophilic design thinking model	15		
Clarity and depth of critical reflections on the biophilic design thinking process	25		

*Authors during their implementation found that peer assessment comments are detailed but require structured comments on achieving learning outcome whilst preparing their assessment artefacts

7.3 Assessment of Learning Outcomes

The RACOM discussed in Chap. 2 (See Fig. 2.1) includes five learning outcomes that could demonstrate the students' ability to use BD. Table 7.4 reports some indicators that can be incorporated into the assignment rubric to evaluate the achievement of the specific learning outcomes and the student's ability in using BD. However, to assess the overall quality of the BD response, it is possible to use the biophilic quality

Table 7.3 Weekly questions to spur the discussion

Theme	Questions
Introduction to sustainable design	What does sustainable design mean to you? Can you provide an example of an outstanding sustainable design and explain what make it so?
Energy efficient design	Energy conservation, efficiency or curtailment? What would be the dominant energy supply source in the future?
Bio climatic design	What lessons can we learn from natural systems to design our buildings? Can you find an example of vernacular architecture based on bioclimatic principles and an example of contemporary architecture that uses the same?
Passive solar design	Have you ever experienced the benefits of passive solar gains? How?
Water sensitive design	Can you think about a case study that has a particular approach to water (conserve, regenerate, harvest)?
Biophilic design	Have you ever experienced biophilia: where you had a desire to connect with nature? Why and what benefits do you personally find in connecting with nature? What are the natural processes that can be used for enhancing the building performance? Which can contribute towards the visual experience as well?
Design thinking	Do you have a unique design thinking process? Is it appropriate for biophilic and sustainable design?
Daylighting design	Why do we need daylight in buildings and how can be used to enhance performances or the architectural expression?
Lifecycle analysis	How do you take decisions for use of sustainable materials in the building? Do you look for durability or rapid regeneration?
Low carbon design	Does biophilic and sustainable design promote low carbon living?

matrix (BQM), a systematic way to assess the use of BD in an architectural design during early design stage (Wijesooriya et al., 2022). BQM consists of 10 criteria, each rated on a 7-point scale for 10 qualifiers. An example is shown in Table 7.5.

The average rating is to be taken as the overall mark, e.g. 54 in the example (Table 7.5). This mark can give an indication of the success of the educational innovation.

7.4 Directions for Future Development and Research

BD is a trending research area within sustainable design, however a significant research gap is found in the BD education (Wijesooriya & Brambilla, 2021). During the development and implementation of a RACOM for BD frameworks, a few

Table 7.4 Summary of indicators for evaluating BD learning outcomes for each student

Learning outcomes	Assessment artefacts	Indicators	Method of measuring/evaluating
Ability to transform the sustainability perception to encompass biophilic design and environmentally sustainable design	Sustainability manifesto	Extent of using nature-centric perception within the sustainability manifesto	Rating on a 7-point scale for using nature-centric perception
Ability to generate biophilic design criteria compatible with the environmentally sustainable design approach	Success matrix	Percentage of biophilic criteria compatible with the environmentally sustainable design approach included into the success matrix	Counting the number of BD criteria compatible with the ESD approach included into the success matrix and calculating its percentage against the total criteria
Ability to use the generated biophilic design criteria as a self-assessment tool	Success matrix	Clarity of the tool to identify design strategies in response to biophilic criteria	Rating on a 7-point scale for clarity of the tool in terms of instructions given to identify design strategies, credits for each criterion and graphical expression
Ability to use the biophilic design framework in the design thinking process	Reflective design portfolio	Positioning of biophilic design response within the design thinking process	Modelling the design thinking model to identify the DT model
Ability to articulate the biophilic design thinking process using critical reflections	Reflective design portfolio	Reflections referring to biophilic design within the design thinking process	Thematic analysis of BD reflections

specific areas identified as potential enablers of the application of BD within an ESD approach are found to require further research: BD thinking models, evaluation of learning processes and outcomes, evaluating architectural expression, the use of interdisciplinary learning and place-based learning. These aspects are briefly discussed below.

7.4.1 Validating Biophilic Design Thinking Models

Looking into the different design thinking models, it is clear that there is a significant gap in studies on sustainable DT models adaptable for design studios. The five models

Table 7.5 Sample marking of biophilic quality matrix

		Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6	Criteria 7	Criteria 8	Criteria 9	Criteria 10
		Earthly materials	Natural air flow	Water	Sun light	Natural thermal sensation	Plants	Ecological systems	Animals	Natural colours	Natural textures
	64%	23	21	30	25	23	33	26	27	21	27
Direct use	38	4	4	4	4	4	4	4	4	3	3
Sensory perception and variability	29	3	3	4	4	2	4	3	3	0	3
Place based relationships	29	2	3	3	3	2	4	4	4	2	2
Organized spatial complexity	27	3	3	3	2	3	3	3	2	2	3
Visual composition	29	3	2	3	3	3	3	3	4	2	3
Use of natural shapes and forms	20	1	0	2	2	2	3	2	3	2	3
Use of natural patterns and fractals	13	0	0	3	2	1	2	0	0	2	3

(continued)

Table 7.5 (continued)

		Criteria 1	Criteria 2	Criteria 3	Criteria 4	Criteria 5	Criteria 6	Criteria 7	Criteria 8	Criteria 9	Criteria 10
		Earthly materials	Natural air flow	Water	Sun light	Natural thermal sensation	Plants	Ecological systems	Animals	Natural colours	Natural textures
In direct use and simulations	8	1	0	0	0	0	3	0	0	2	2
Emotional attachment	27	2	3	4	2	3	3	3	3	2	2
Enhanced human nature connectedness	36	4	3	4	3	3	4	4	4	4	3

presented in this book require further validation by both theoretical and empirical applications. Previous studies relied on interviews with students and class observations to model specific DT models. For example, Berg et al. (2014) uses students' critical reflections, whilst Akpinar et al. (2015) used students' design artefacts.

7.4.2 Evaluation of Learning Processes and Outcomes

Table 7.3 presented the assessments and indicators for each learning outcome within the BD educational design. These indicators can be used by the educators to assess the impact of the educational innovation. More research is required to test, refine and strengthen the robustness of these assessment methods. Further, new tools can be developed for formative evaluation and students' self-assessment. Such tools could assist students to self-assess and reflect on their BD perspective. Some of such assessment tools have been already proposed, but not yet fully validated. For example, authors proposed the biophilic quality matrix to assess the biophilic response in student design, however it must be noted that it requires further testing and validation.

7.4.3 Interdisciplinary Learning

Interdisciplinary learning is crucial for ESD education. Multidisciplinary teamwork is common in professional ESD projects, but the same can be challenging in educational settings. A potential embodied educational design element to overcome this issue could be the role-play identified during mind mapping of pedagogical ideas (see Fig. 2.2). However, it needs to be carefully considered. For example, the Living Building Challenge BD guide (ILFI, 2018) suggests introducing the roles of an ecologist or a historian, but this means that students would require to prepare and learn about the different roles that are usually far from architecture. While this could be useful, it could be also time consuming. This area offers a great potential for further research, where a new RACOM could even be developed to support the interdisciplinary learning. The discussion forums can also support interdisciplinary learning, provided that they also bring in practitioners from industry or students from other disciplines. Studies by Badurdeen et al. (2013) and Becerik-Gerber et al. (2011) provide inspiration for similar studies.

7.4.4 Evaluating the Architectural Expression and Meaning

Particularly since BD is premised on elevating emotional contact with nature, evaluating the architectural expressions within sustainable design. However, the final success is usually assessed through post-occupancy evaluation process. A design proposal can be evaluated to certain extent by using virtual reality or augmented reality to ascertain the emotional impact, as shown by Berg et al. (2014). However, further research is necessary to link the visual-only experience to the atmosphere and biophilic quality of spaces.

7.4.5 Place-Based Learning

The recent increase of green campuses and living labs assigns place-based learning a prominent position in ESD education. The RACOM has an emphasis on nurturing evaluative judgement, where exemplars are a fundamental part. Since BD is identified as a sensory design approach, experiencing a building in its final form could immensely assist students in understanding its quality and standard. This can be an interesting addition to the RACOM, opening the door for further research aimed at understanding the students' response and the impacts on their design. Specifically, inspiring architectures can guide students in developing deeper understanding of sustainability. Examples are given by Janda and von Meier (2004), who use two green buildings in a university campus to provide evidence of sustainability, Massek (2017), who used a living lab in Barcelona to teach sustainability, and Barnes (2012), who focuses on library buildings used as education tools. Despite these examples, further evidence on the impacts of place-based teaching success are still lacking.

7.5 Concluding Remarks

This chapter discussed the implementation of the proposed BD education innovation in a studio setting. The identified critical areas are: selecting educational design embodiments, arrangement of the studio tasks, and assessment of learning outcomes. The chapter included a 13-week studio program with a guidance for assessment. The indictors given in Table 7.4 can be amended to suit the studio circumstances and type of data collected. Briefly outlined biophilic quality matrix could become a useful tool to assess biophilic quality during early design stages. This chapter provides a useful model than can be implemented and adapted to different studios, based on the duration and student's preparation. The RACOM for BD introduced in the Chap. 2 is a new approach for educational design demanding further exploration and therefore this chapter also outlined areas for future development and research.

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Chapter 8
Conclusions

Abstract There were multiple benefits biophilic design (BD) could bring into built environment. Particularly within environmentally sustainable design dominated by the use of sophisticated and advance technology BD was identified as an approach that could enhance human-nature connectedness (HNC). BD has a focus and human health and well-being with a sensory design approach. Even though the need BD in ESD practice and education were advocated the difference between how these two design approaches are practiced have limited the wide use of BD. This guidebook aimed to outline a systematic education design innovation development that facilitate both educators and students working within ESD studios to adapt BD to elevate HNC.

The guidebook outlined an approach for educational design in ESD studio that integrated reflective action research model and conjecture mapping. Using this reflective action conjecture mapping (RACOM) an educational innovation was developed to facilitate student to adapt BD in ESD studio. The RACOM develop starts with a high-level-conjecture that identified three key challenges: (1) Shifting the perception of sustainability to bridge environmentally sustainable design and biophilic design, (2) Embracing a systematic technique to generate criteria for a biophilic design framework compatible with an environmentally sustainable design approach, (3) Embedding biophilic design frameworks in the design thinking process.

Considering these challenges and the unique use of design frameworks within ESD studio the high-level conjecture was derived as 'Adapting BD within ESD approach requires developing BD frameworks compatible with ESD and integrating them into design thinking process'. The educational design development identified three design artefacts student are required to construct to overcome the challenges and successfully develop a BD framework. They are: (1) an artefact that reflects the student's sustainability perception, (2) an artefact that demonstrates the BD framework and (3) an artefact that illustrates the student's use of the BD framework in their design thinking process. Each of these artefacts was further elaborated by developing a conjecture map. During this exercise mediating learning processes were identified that required completing prior to achieving the learning outcomes (Fig. 2.4). The

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mediating learning processes were expanded connecting the theoretical and design conjectures providing educators with an ability to adapt them in similar situations.

The RACOM developed for BD included three guides and the exemplar as the materials within the embodiments corresponding to the three design artefacts sustainability manifesto, success matrix and reflective portfolio. Each Student Guide support to construct a design artefact that could overcome challenges where the exemplar demonstrated the use of the introduced design approach. While transitioning through these mediating learning processes it was expected to achieve the learning outcomes:

(1) Ability to transform the perception of sustainability that encompasses BD within ESD
(2) Ability to generate BD criteria compatible with the ESD approach
(3) Ability to synthesise the generated BD criteria into a framework that can be used as a self-assessment tool
(4) Ability to use the BD framework in the design thinking process
(5) Ability to articulate the design thinking process through critical reflection.

This educational innovation focused on three assessment artefacts, providing materials to support students in successfully transitioning and achieving above given learning outcomes. However, educators likely will need to adapt these learning outcomes to their contexts, along with potential assessment artefacts and other components.

Chapter 3 outlined how to develop a sustainability manifesto for a sustainable building design. The Fig. 3.1 showcased a classification of various sustainable design approaches based on interrelations between the three dimensions of *built*, *nature* and *human*. Six interrelationships were identified as follows: *built-to-express*, *built-to-mitigate*, *human-built-comfort*, *human-nature-wellbeing*, *nature-for-wellbeing* and *nature-to-mitigate*. The decision tree given in Fig. 3.4 provided a way to identify these varied ESD approaches that could assist to develop an individualised design approach. The example sustainability manifesto *Biophilic thought* given in a written and diagrammatic presentation will inspire students to develop their own individualised perception on sustainability.

The systematic methodology outlined in Chap. 4, can guide to develop a BD framework to use BD in a ESD studio project. The six-staged methodology included the process bridging technique (PBT) to develop the *biophilic criteria* that is the crucial aspect in the methodology. The PBT allow opportunity for individualization with *place*, *performance* and *process* pathways for bridging. Instructions on identifying *design strategies* and proposing *building components* could elaborate the BD framework. Proposed synthesis methods provide guidance on integrating the BD framework within the success matrix and using it as a self-assessment tool.

Design thinking (DT) process within the architectural design studio setting is complex and Chap. 5 provided directions to understand this process from three aspects; generic DT, sustainable DT and architectural DT. However, considering the focus of the guide on using BD within ESD studio, the instructions given are useful to adapt a BD framework in a sustainable design studio. Five DT models presented based on student work can guide to develop an individualised DT process for a biophilic and sustainable building design. These DT models are: (1) biophilic category model, (2) biophilic criteria model, (3) biophilic layover model, (4) biophilic process model and (5) biophilic conceptual model.

Chapter 6 demonstrated the use of the guides to develop a sustainability manifesto, BD framework and adapting a DT process. The design process was initiated with the project theme based on a biophilic element. The design intent to appreciate salt and develop a project around this natural element connected all the other design activities. Designing was started with background studies and developed a sustainability manifesto. Thereafter a comprehensive success matrix was developed termed *Biophilic house guide*. Design strategies were identified and building components were developed to suit the building and functions. Once the design was fully developed simulations were used to evaluate the building performance. Developed rating tool was used to evaluate the sustainability achieved in a BD approach. Finally, a reflection on the design process and modelling of the biophilic conceptual DT model was showcased.

Chapter 7 provided guidance for educators with a detailed the embodiments, that included weekly arrangement of the studio, peer assessment and weekly discussion forums. A proposed guide was given to assess the design artefacts where educators can adapt them for their own circumstances. The directions for further research highlighted the areas for improvements with future work.

The educational design innovation presented in this book is primarily intended for master's level students, based on a 13-week semester. Identifying the assessment artefacts, learning outcomes and suitable ways for evaluating is a cyclic process that requires alignment to match the objectives of the educational innovation.

Appendix A
Themes Identified from Environmentally Sustainable Design (ESD) Studio Education Projects for Reflective Action Conjecture Map (RACOM) Components

Component	Themes
Key challenges	Achieving the balance between aesthetics and technology in the design Guiding students to develop a sustainable world view Guiding students to develop a design framework Complexity of sustainability concepts and design approaches Incorporating design frameworks into design thinking Finding appropriate information from a large volume of knowledge
Characteristics of ESD studio	Uses design frameworks Requires students to provide evidence that their designs achieve sustainability Includes significant research component Deals with complex design problems Draws on learning by doing Uses critical reflections Focuses on one or more sustainable design approach Transformation of student worldview in expected
Learning theories	Learning by doing Self-directed learning Experiential learning, Place-based learning Transformational learning Problem-based learning Project-based learning, Case-based learning Empathy-based learning Interdisciplinary learning
Theories of design practice	Design thinking Reflective practice Evaluative judgement Participatory design Evidence-based design

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Component	Themes
Embodiments	Guides to develop design frameworks Self-assessment tasks Simulation software, Computer serious games, Online resources Theory lectures, Workshops, Research tasks Field visits, Case studies, Living labs Stakeholder participation Roleplay tasks Peer assessment tasks, Feedback, Discussion forums
Student artefacts	Sustainable design frameworks Self-assessment reports Research reports Design portfolios Design proposals, Prototypes Reflections, Concept maps
Learning outcomes	Problem-solving skills Self-awareness Evaluative judgement Knowledge of sustainability principles Procedural knowledge Sustainable design thinking Critical reflection Sustainability perception transformation

Appendix B
Biophilic Design Framework Used as a Success Matrix Adapted from Browning et al. (2014)

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Category	Criteria	Design consideration/strategies	Building features/components
Nature in the space patterns	1. Visual connection with nature	• Prioritize real nature over simulated nature; and simulated nature over no nature • Prioritize biodiversity over acreage, area or quantity • Prioritize or enable exercise opportunities that are in proximity to green space • Design to support a visual connection that can be experienced for at least 5–20 min per day • Design spatial layouts and furnishings to uphold desired view lines and avoid impeding the visual access when in a seated position • visual connections to even small instances of nature can be restorative, and particularly relevant for temporary interventions, or spaces where space is limited • The benefits of viewing real nature may be attenuated by a digital medium, representation where real nature or views to are limited	• Mechanical flow of a body of water • Koi pond, aquarium • Green wall • Artwork depicting nature scenes • video depicting nature scenes • Highly designed landscapes
	2. non-visual connection with nature	• Prioritize nature sounds over urban sounds • Design for non-visual connections that can be easily accessed from one or multiple locations, and in such a way that allows daily engagement for 5–20 min at a time • Integrate non-visual connections with other aspects of the design program • A single intervention that can be experienced in multiple ways can enhance the impacts • Design for visual and non-visual connections to be experienced simultaneously to maximize potential positive health responses	• Digital simulations of nature sounds • mechanically released natural plant oils • Highly textured fabrics/textiles that mimic natural material textures • Audible and/or physically accessible water feature • music with fractal qualities • Horticulture/gardening, including edible plants • Domesticated animals/pets • Honeybee apiary
	3. Non-rhythmic sensory stimuli	• Many stimuli in nature are seasonal, so a strategy that is effective year-round, will ensure that non-rhythmic sensory experiences can occur at any given time of the year • In some cases, the intervention may be similar to that of visual or non-visual Connection with nature • An intervention that leverages simulation depicting natural stimuli • A non-rhythmic stimuli strategy can be interwoven with almost any landscape or horticulture plan	• Billowy fabric or screen materials that move or glisten with light or breezes • Reflections of water on a surface • Shadows or dappled light that change with movement or time • nature sounds broadcasted at unpredictable intervals • mechanically released plant oils

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Category	Criteria	Design consideration/strategies	Building features/components
	4. Thermal & airflow variability	• Incorporation of airflow and thermal conditions into materials, daylighting, mechanical ventilation and/or fenestration will help distribute variability over space and time • When thermal and airflow variability is implemented in a way that broadens people's perception of thermal comfort, it may also help reduce energy demands for air conditioning and heating • Designing in features that allow users to easily adapt and modify their perceived thermal conditions of their environment	• HVAC delivery strategy • Systems controls • Window glazing and window treatment • Window operability and cross ventilation
	5. Presence of water	• Prioritize a multi-sensory water experience to achieve the most beneficial outcome • Prioritize naturally fluctuating water movement over predictable movement or stagnancy • High volume, high turbulence water features could create discomfort, impact humidity levels or decrease acoustic quality, so proximity may influence appropriateness • Water features can be water and energy intensive and as such should be used sparingly, particularly in climates with little access to water. Shading the water, using high albedo surfaces, and minimizing the exposed water surface area will minimize water loss through evaporation, and possibly contribute to the biophilic experience	• Water wall • Constructed water fall • Aquarium • Fountain • Constructed stream • Reflections of water (real or simulated) on another surface • Imagery with water in the composition

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Category	Criteria	Design consideration/strategies	Building features/components
	6. Dynamic & diffuse light	• Dynamic lighting conditions can help transition between indoor and outdoor spaces • Drastically dynamic lighting conditions, such as with sustained movement, changing colours, direct sunlight penetration and high contrasts, may not be appropriate for spaces where directed attention activities are performed • Circadian lighting will be especially important in spaces the people occupy for extended periods of time	• multiple low glare electric light sources • Illuminance • Light distribution • Ambient diffuse lighting on walls and ceiling • Day light preserving window treatments • Task and personal lighting • Accent lighting • Personal user dimming controls • Circadian colour reference (white light during the day and lack of blue light at night • Colour tuning lighting that produces white light during the day, and minimizes blue light at night
	7. Connection with natural systems	• Integration of rainwater capture and treatment into the landscape design that respond to rain events • In some cases, providing visual access to existing natural systems will be the easiest and most cost effective approach. In other cases, the incorporation of responsive design tactics structures and land formations will be necessary to achieve the desired level of awareness • Design for interactive opportunities, especially for children, patients, and the elderly (e.g., integrative educational curriculum; horticulture programs, community gardens; seasonal cooking/diet)	• Simulated daylighting systems that transition with diurnal cycles • Wildlife habitats (e.g., birdhouse, honeybee apiary, hedges, flowering vegetation) • exposure of water infrastructure • Step wells for seasonal rainwater storage and social convergence • natural patina of materials (leather, stone, copper, bronze, wood)

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Category	Criteria	Design consideration/strategies	Building features/components
Natural analogues patterns	8. Biomorphic forms & patterns	• Apply on 2 or 3 planes or dimensions (e.g., floor plane and wall; furniture windows and soffits) for greater diversity and frequency of exposure • Avoid the overuse of forms and patterns that may lead to visual toxicity • More comprehensive interventions will be more cost effective when they are introduced early in the design process	**Decor** • Fabrics, carpet, wallpaper designs based on Fibonacci series or Golden mean • Window details: trim and mouldings, glass colour, texture, mullion design, window reveal detail • Installations and free-standing sculptures • Furniture details • Woodwork, masonry • Wall decal, paint style or texture **Form/function** • Arrangement of the structural system (e.g., columns shaped like trees) • Building form • Acoustic panelling (wall or ceiling) • Railings, banisters, fencing, gates • Furniture form • Window details: frit, light shelves, fins • Pathway and hallway form
	9. Material connection with nature	• Quantities of a (natural) material and colour should be specified based on intended function of the space (e.g., to restore versus stimulate). In the same vein, a degree of variability of materials and applications is recommended over high ratios of any one material or colour • Real materials are preferred over synthetic variations because human receptors can tell the difference between real and synthetic, so minimally processed materials from real nature are preferred whenever possible • Incorporating instances of the colour green may help enhance creative environments; however, scientific studies on the impact of the colour green have mostly been conducted in controlled lab environments, so dependence on colour to engender creativity should be considered experimental	**Decor** • Accent details made (natural wood grains; leather; stone, fossil textures; bamboo, rattan, dried grasses, cork) • Interior surfaces (veneer, countertops) • Woodwork, stonework • natural colour palette, particularly greens **Form/function** • Wall construction (wood, stone) • Structural systems (heavy timber beams) • Façade material • Furniture form • Footpaths, bridges

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Category	Criteria	Design consideration/strategies	Building features/components
	10. Complexity & order	• Prioritize artwork and material selection, architectural expressions, and landscape and master planning schemes that reveal fractal geometries and hierarchies • Fractal structures with iterations of three will be more impactful than a design limited to two iterations • Computer technology using the algorithms of mathematical and geometric functions can produce fractal designs for architectural, design and planning applications with ease. If a fractal design is being created, consider using geometries with a mid-range dimensional ratio (broadly speaking, $D = 1.3–1.75$) • Over-use of and/or extended exposure to high-fractal dimensions could instill discomfort or even fear, countering the intended response: to nourish and reduce stress. Avoidance or under-utilization of fractals in design could result in complete predictability and disinterest • A new building or landscape design should take into account its impact on the fractal quality of the existing urban skyline	**Decor** • Wallpaper and carpet design • material texture and contour • Window details: trim and mouldings, glass colour, texture, mullion design, window reveal detail • Plant selection variety and placement • Complex plant oil fragrances • Auditory stimuli **Form/function** • exposed structure/exoskeleton • exposed mechanical systems • Façade materials • Façade, spandrel and window hierarchy • Building skyline • Floor plan, landscape plan, urban grid • Pedestrian and traffic flows • Resource flows

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Category	Criteria	Design consideration/strategies	Building features/components
Nature of the space patterns	11. Prospect	• Orienting building, fenestration, corridors and workstations will help optimize visual access to indoor or outdoor vistas, activity hubs or destinations • Designing with or around an existing or planned savanna-like ecosystem, body of water, and evidence of human activity or habitation will help the information-richness of the prospect view • Providing focal lengths of ≥ 20 feet (6 m), preferably 100 feet (30 m); when a space has sufficient depth, spatial properties can be leveraged to enhance the experience by removing visual barriers. Limiting partition heights to 42″ will provide spatial barriers while allowing seated occupants to view across a space. understory vegetation or hedges should use a similar guide; preferred height limitations will depend on terrain and how the space is most experienced (e.g., while sitting, standing, on a bicycle) • Locating stairwells at building perimeter with glass façade and interior glass stairwell walls can form a dual prospect condition • When high ceilings are present, perimeter or interior spaces elevated 12–18″ will enhance the Prospect condition • Often the view quality and the balance between Prospect and Refuge will be more important than the size or frequency of the experience	**Spatial Attributes** • Focal lengths ≥ 20 feet (6 m) • Partition heights ≤ 42 inches (hedges; opaque workplace partitions) **Common features** • Transparent materials • Balconies, catwalks, staircase landings • Open floor plans • elevated planes • views including shade trees, bodies of water or evidence of human habitation

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Category	Criteria	Design consideration/strategies	Building features/components
	12. Refuge	• Indoor refuge spaces are usually characterized by lowered ceiling conditions. For spaces with standard ceiling heights, this may equate to approximately 18–24 inches below the main ceiling, and is often achieved through treatments like a soffit, a drop-ceiling or acoustical panelling, or suspended fabric • Outdoor or indoor spaces with particularly high ceilings (>14 feet), a more drastic differential may be necessary to achieve the desired outcome; freestanding or vegetative alcoves and mezzanine-like structures are often effective • When designing for larger populations or multiple activity types, providing more than one kind of refuge space can address varying needs, which can often be met through differing spatial dimensions, lighting conditions, and degree of concealment • Light levels in refuge spaces should differ from adjacent spaces and user lighting controls will broaden functionality as a refuge space	**Spatial Attributes** • modular refuge: Small protection (high-back chair, overhead trellis) • Partial refuge: Several sides covered (reading nooks, booth seating, bay window seats, canopy beds, gazebos, canopy trees, arcades, covered walkways or porches) • extensive refuge: near or complete concealment (reading/telephone/sleeping pods, meeting rooms • with 3 + walls, private offices, tree houses) **Common features** • Spaces with weather/climate protection, or speech and visual privacy • Spaces reserved for reflection, meditation, rest, relaxation, reading, or complex cognitive tasks • Operable, adjustable or translucent (or semi-opaque) shades, blinds, screens or partitions • Drop or lowered ceiling or soffit, overhang or canopy • Lowered or varied light colour, temperature or brightness

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Category	Criteria	Design consideration/strategies	Building features/components
	13. Mystery	• Curving edges that slowly reveal are more effective than sharp corners in drawing people through a space • Dramatic shade and shadows can enhance the mystery experience • Strategies that provide dark shadows or shallow depth of field could instil unappreciated surprise or fear • The speed at which users are transiting through a space will influence both the size of the aperture and the size of the subject; faster typically means bigger • Organically evolved mystery conditions (e.g., low maintenance gardens with winding paths) are expectedly going to change characteristics over time. These changes should be monitored as they may enhance the mystery condition, or otherwise degrade it as it evolved into a surprise condition (e.g., overgrowth of plantings leads to obscuring of depth of field)	**Spatial Attributes** • views are medium ($\geq$ 20 ft) to high ($\geq$ 100 ft) depth of field • At least one edge of the focal subject is obscured, preferably two edges • Auditory stimulation from an imperceptible source • Peek-a-boo windows that partially reveal Curving edges • Winding paths **Common features** • Light and shadow • Sound or vibration • Scent • Activity or movement • Artwork or installation • Form and flow • Translucent materials

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Category	Criteria	Design consideration/strategies	Building features/components
	14. Risk/peril	• Risk/Peril design interventions are usually quite deliberate and as such will not be appropriate for all user groups or places • Design strategies that rely on spatial conditions will be easier to implement when incorporated as early as concept design and schematic phases of the design process • The element of safety must protect the user from harm while still permitting the experience of risk	**Spatial Attributes** • Heights • Gravity • Water • Predator–prey role reversal **Common features** • Double-height atrium with balcony or catwalk • Architectural cantilevers • Infinity edges • Façade with floor-to- ceiling transparency • experiences or objects that are perceived to be defying or testing gravity • Transparent railing or floor plane • Passing under, over or through water • Proximity to an active honeybee apiary or predatory animals • Life-sized photography of spiders or snakes

Appendix C
Biophilic Design Framework Used as a Success Matrix

Category	Criteria	Design strategy/building components
Earth	Exposed natural materials	Materials use in natural forms for floors, walls, doors and windows etc. Exposed brick work Natural stone paving
	Low embedded energy natural materials	Use of natural materials with low embedded energy such as timber, clay etc. for floors, cladding and finishes
	Rapidly renewable materials	Rapidly renewable timber use in its natural form Bamboo for cladding and partitions
	Recycled natural materials	Use of materials recycled with low technology such as clay
	Sustainable finishing of materials restoring natural quality	Using finishing techniques to retain natural colours and textures for diversity of experience Use of non-toxic finishing materials
Air	Natural processes for air quality management	Plants for air purification Direct sunlight to avoid stagnant spaces
	Natural ventilation	Openable windows Access to outside space Access to fresh air
	Sensory air flow variation	Use of fragrances Plants responding to natural breeze
	Natural elements for carbon emission offset	Plants for carbon offset Material use for carbon offset
	Low-emitting natural material	Use of materials with low volatile organic compounding

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Category	Criteria	Design strategy/building components
Water	Natural processes for water quality management	Constructed wetland Exposed slow sand filters Solar water purification elements
	Water for thermal comfort	Walls, water features, waterfalls
	Enhanced water area	Water elements in landscaping Visual connection to landscaping
	Water saving in landscaping	Low maintenance plants and trees Hydroponics Wetlands
	Water elements for restoration	Water elements used in indoor and outdoor Use of water sound as a sensory experience Water for psychological comfort Opportunities to touch safe water
Energy	Passive solar heating	Solar for water heating Solar for space heating using glazed area Thermal mass for space heating with natural materials
	Circadian lighting design	Sensory experience of retina of time
	Sensory thermal variation	Glazed areas Access to sun-lit spaces
	Renewable energy use	Use of solar power with visual connection Use of wind power with visual experience
	Natural elements for heat reduction	Green walls Green roofs Plant for shading Water facades Water roofs
Habitat	Restore natural habitat	Reduces building footprint Natural landscaping Indigenous plants Recreating habitat inside
	Restorative natural habitats	Direct access and visual connections
	Bio-diversity	Plant diversity through green walls Indigenous plants Conserve species Mini-forests
	Experience direct nature	Provide visual connections Access to outside Access to water features
	Inter-species connectivity	Animal friendly spaces Animal abodes Animal representations using patterns, forms and textures Aquaponics

Appendix D
Place, Performance and Process Lists for Earth, Air, Water, Energy and Habitat Categories

Place, performance and process lists for Earth

Place criteria	Natural processes	Performance criteria
• Natural material selection • Material connection with nature • Natural material use • Biomimicry • Information richness through material variability • Materials to reflect age, change and patina of time • Place making with earth resources • Visual and non-visual connection with natural materials • Materials for non-rhythmic sensory stimuli • Prospect/refuge • Mystery • Composition of material variability • Sensory variability • Complexity & order in material variability • Biomorphic Forms & Patterns • Fractals using natural materials	• Earth walls for enhanced thermal performance • Sand filters for water purification • Clay as a thermal insulation • Timber as a material for carbon offset • Timber as a rapidly renewable material • Earth as a low embodied energy material	• Material selection • Regional priority • Recycled and reused materials • Enhanced material precaution and transparency • Responsible sourcing of construction products • Designing for durability and resilience • Rapidly renewable materials • Impact management • Low-Emitting Materials • Building life-cycle impact reduction • Net Positive Waste • Hazardous Material Abatement • Site remediation • Reduced pesticide use • Hazardous material reduction • Cleaning products and protocol • Volatile compound reduction • Long-term emission control • Building life cycle assessment (LCA) • Environmental product declarations (EPD)

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Place, performance and process lists for Air

Place criteria	Natural processes	Performance criteria
• Presence of natural air • Spaciousness • Inside outside space connections • Place making with air • Visual connection with natural space • Non-visual connection with space • Connection with natural air systems • Prospect/refuge • Mystery in air through the building • Composition of spatial variability • Sensory experience • Spatial harmony • Space as shape and form • Complexity & order in spatial variability	• Air for power generations • Natural air for ventilation • Flora as carbon storage • Flora for Air purification • Flora for air quality enhancement • Timber as a material for carbon offset	• Air quality management • Healthy interior environment • Enhanced indoor air quality strategies • Low-emitting materials • Air quality monitoring and awareness • Impact management • Pollution infiltration management • Combustion Minimization • Air Filtration • Active VOC Control • Microbe and Mold Control • Tobacco Prevention and Cessation • Humidity Control • Ventilation • Ventilation Effectiveness • Enhanced Ventilation • Operable Windows

Place, performance and process lists for Water

Place criteria	Natural processes	Performance criteria
• Water elements • Information richness • Fractals depicting water • Biomimicry with water • Age, change and patina of time • Place making with water • Visual connection with water • Non-visual connection with water • Connection with water systems and elements • Mystery • Composition of water variability • Sensory variability • Complexity & order in water elements • Sensory comfort	• Solar water heating • Solar water purification • Moisture in air for water generation • Water for power generation • Water for thermal performance • Rain water collection for water use • Flora as a water purifier	• Water Quality • Water contaminants • Legionella control • Enhanced water quality • Water quality consistency • Water use • Net positive water • Drinking water promotion • Moisture management • Handwashing • Onsite non-potable water reuse • Water consumption • Water monitoring • Water leak detection • Water efficient equipment • Flood and surface water management

Place, performance and process lists for Energy

Place criteria	Natural processes	Performance criteria
• Exposed sunlight • Natural light • Light and shadow • Reflected light • Dynamic & diffuse light • Light pools • Warm light • Light as shape and form • Inside outside connecting • Place making • Visual connection in light and energy • non-visual connection in energy • Connection with natural energy systems • Prospect/refuge • Mystery • Risk/peril • Composition • Fractals of light and energy • Complexity & order in light & energy	• Solar space heating • Solar water heating • Solar water purification • Solar energy • Solar lighting • Moisture in air for water generation • Water for power generation • Water for thermal performance • Plant shading for heat gain reduction • Clay as a thermal insulation	• Thermal Performance • Heat island reduction • Enhanced thermal performance • Thermal zoning • Individual thermal control • Thermal comfort monitoring • Lighting • Reduction of night time light pollution • Light exposure and education • Circadian lighting design • Glare control • Enhanced daylight access • Visual balance • Electric light quality • Lighting occupant control and visual comfort • Total energy use • Net positive energy • Renewable energy • Reduction of energy use • Low carbon design • Energy efficient equipment • Optimize energy performance

Place, performance and process lists for Habitat

Place criteria	Natural process inventory	Performance criteria
• Facade greening • Habitats and eco systems • Landscape defining building form • Landscape ecology • Information richness • Age, change and patina of time • Botanical and animal motifs • Tree and columnar support • Shells and tubular forms • Arches vaults domes • Avoiding straight lines • Simulation of natural features • Fractals • Complexity & order in natural elements • Affection and attachment • Attraction and beauty • Prospect/refuge • Exploration and discovery • Sensory variability • Visual and non-visual connection with nature • Mystery	• Flora as a water purifier • Flora for heat gain reduction • Flora for shading • Flora as carbon storage • Flora for Air purification • Flora for air quality enhancement	• Habitat promotion • Restore habitat • Habitat Exchange • Open space • Places of respite • Quality Views • Urban Agriculture • Food Production • Biophilic environment • Access to Nature • Enhanced Access to Nature • Health and wellbeing • Mental health support • Stress support • Restorative opportunities • Restorative spaces • Sleep support