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ROLE OF DESIGN THINKING AND BIOMIMICRY IN LEVERAGING SUSTAINABLE INNOVATION

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Definitions

Biophilic thinking is an approach to solve problems of nature and humankind by applying creative approaches of biophysics and biomimicry designs for conceptualization and developing innovative solutions to improve human well being and sustainability. Biophilia, meaning "love of life or living system" (Fromm 1964), following the term eco-philia translate to as, love of organizations to their natural environment. Eco-philia thinking identifies and improves purposefully design process with overall organizational sustainability including planning for both human and ecology systems. Through the lense of eco-philia design thinking, the creation of sustainable innovation can keep up the corporate sustainability agenda in a larger biophysical, ecological, and human ecosystem.

Introduction

Over the past few years, innovation has turned the wheel in almost every area of life. However, innovation in products and procedures are changing the operational metaphors to achieve sustainability. Green product innovation (GPI) plays an essential part in responding to climate change challenges that have caught the attention of practitioners (Awan et al.,2020). Many nations are still lacking behind these odds; we need more dynamic and fast sustainable innovation procedures to overcome these constraints and challenges. Industrial ecological revolutions are bringing possible analysis of the procedure previous industries have been following (Awan 2020). With the more integrative advance procedure for sustainable innovation, the business model will be able to accelerate the efforts up to present needs in developing sustainable plans and products (Boons et al. 2013). For this endeavor, present study analyzes the whole systematic process of sustainable innovation to understand the lacking feature which business needs to consider for addressing economic, social, and environmental needs simultaneously. Sustainable development still needs more qualities to deal with current challenges (Boons and Howard-Grenville 2009). One of the major aspects of sustainable innovation is knowledge sourcing and management which directly links the innovation acquisition to innovation development (Vitor and Samuel 2016). According to Caloghirou et al. (2004), businesses and organizations need to push the boundaries of interior capabilities with the improved acquirement of external knowledge sourcing in order to provide rapid and efficient innovativeness. an extreme concern of the organization is External Knowledge sourcing to keep track of the environmental limitation and challenges. We have to correct and bring such product and rapid innovativeness which eliminates the major threat of future decline. On one hand, we have global challenges to overcome ,on other hand, we have huge economic crisis in many economics where recourse utilization is not at optimal level and proficiency is compromised. Therefore, this chapter suggests that by utilizing the benefits which external knowledge sourcing can provide us we need to establish new sustainable innovation procedure and framework. First of all, there is a need to understand that in such

major technological breakthrough centuries how human are lacking in many areas, secondly, how external knowledge sourcing can be reformed according to today's needs and how much benefit it can provide to new framework of sustainable innovation. The aim of this paper is to provide a framework of external knowledge sourcing which provide the advantage on many levels to generate fast and efficient sustainable innovation. Current study is analyzing design thinking patterns which have been introduced before to create new space for change in the methodology of design thinking. Many scholars advocate the concept that knowledge generation and design thinking go hand in hand with each other to generate innovativeness. Present study propose in this chapter and try to create the link between external knowledge sourcing and design thinking through biophilia design to achieve sustainable innovation to overcome many challenges current world is going through. Design thinking is a systematic method which supports to generate the external knowledge sourcing phenomena, the more the knowledge is achieved the more ideation and execution of ideation generates which creates the possibility of sustainable innovation dynamically. For example work of Mead (2014) on biologically-inspired design provides the motivation and review for organizations in more ecological aspect where organization can develop a structure or framework to achieve bionics system, biomimetics structure, and biomimicry methods. This paper considers that biomimicry is a productive and efficient tool to install a machinery structure and associate this structure with design thinking as a midstream. But for this, present work trust that external knowledge sourcing is required so organizations can develop new learning mechanisms in order to associate their design thinking pattern with biophilia and biomimicry approaches this will help manufacturing industry to introduce sustainable innovativeness.

External Knowledge sources for Innovation

Major organizational concern toward innovation is how to seek knowledge and how to implement the knowledge to create innovativeness on one platform. the Commercial industries, public and private organization and manufacturing industry has changed the way it used to seek information to promote innovation in product and services in this scenario technological and unconventional mode of knowledge-seeking has been utilized and tested as an effective tool (Laursen and Salter 2006). Over the past years, many researchers have contributed many ideas to introduce frameworks on innovativeness. Leiponen and Helfat (2011) advocated the fact that more the organization seeks for versatility and dimensionality the more knowledge it seeks. Previous literature provides us many pieces of evidence on knowledge sources for innovation as research conducted by Leiponen and Helfat (2010) suggests that organization approaches knowledge through research and development activities, university research, government scientific laboratories, industrial specialized and technical societies not only these are the only sources but also organizations seek knowledge from their customer, competitors, suppliers, producers and stakeholders involved in a supply chain process. Granero and Vega-Jurado (2012) explained in their research that to acquire external knowledge sources from scientific and industrial partners for innovativeness organization are required to build high synchronized mechanism, knowledge incentives and knowledge pattern mechanisms. The focus of external knowledge sources signifies with a bond of networking outside the organization, networking amplifies the procedure and provides considerable incentives to innovativeness (Varis and Littunen 2010). Further, Frenz and Ietto-Gillies (2009) also advocated the concept of external collaboration outside the organization, within an organization, within units and where the transferability is possible between the associates. According to the sources of knowledge starts from and within the organization and expand to outside of the organization. (L. and Petra 2014) discussed that external knowledge sourcing is a way better element to create exploitation and exploration of internal knowledge in the organization. If external knowledge sourcing plays a vital role in an organization's internal knowledge capacity than it is much required to consider external knowledge sourcing at an aggregated level. Shoaib and Kehinde (2019) conducted a study administrating the fact that customers and competitors have been a vital source of providing external knowledge in product innovativeness. They also addressed the fact that manufacturing departments' research activities can flourish if external knowledge has been gained from a customer working in the private and public sectors. Over the years, organizations and manufacturing firm have been introducing very effective key indicators for innovativeness in which external knowledge sourcing has been achieved up to optimal level but with a change in trends and global needs now organizations require to seek new framework while

implementing the innovativeness in material consumption and product development. Globalization is also facing the challenge of scarce resource at an extreme level now which needs to be considered with the development of a new framework of innovativeness. Asimakopoulos et al. (2020) referred that external knowledge sourcing acquisition through external partnership can cause constraints in internal organizational performance. Aggregated mix of traditional methods can be addressed as not effective anymore. It is because organizations are facing new challenges in product manufacturing with climate change and increase in lack of technological methodologies. Therefore, this chapter introduces new ideology to be added in the process of gaining external knowledge sourcing in order to create effective and efficient innovation, which also associates the exploitation and exploration of internal knowledge and resource seeking with additional benefits of better utilization and optimization.

Design thinking and Innovation

Design thinking is the approach to create step by step integrative evidence and prospective based interconnected chain of procedures. Design thinking starts from a systematic analysis of each step in a concurrent procedure of product and services generation. Design thinking is a system that follows the different strategic and operational stages in product development and innovation. Design thinking supports the concept of continuous improvement in the system. The definition of design thinking revolves around the systematic system, which involves many phases of human interaction with consideration of each phase in order to generate practical productivity (Meyer 2015). According to Brown and others (2008) design thinking is “a discipline that uses the designer’s sensibility and methods to match people’s needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity”(P.2). Researchers have monitored many design thinking patterns and stages over the past years to strengthen the innovation and development of products. Design thinking implements the observation of the root cause of the problem with the initiative of the solution and product development as a solution. Design development and thinking theories have been implemented over many years with variation according to the need of time (Beckman and Barry 2007). In the initial stage, the researcher focused on the acquisition of technical and strategic design thinking methodologies on a later stage this is converted into social embedded design thinking patterns (Beckman and Barry 2007). Figure 1. Design thinking adopted from (MIT Sloan Executive Education). Source: Stanford d. School Design Thinking Process. Owen (2007) emphasized that design thinking, as compared to conventional administration strategies, dynamically ignores making preferences for as long as possible to optimize obtaining knowledge and learning as an ambiguity decline approach; learning has long been highlighted as fundamental to the principle of design. The design thinking procedure starts from learning about problems and surroundings to implement it in an integrative phase of operations. Dorst (2011) described very precisely in his study that to reach and develop design thinking researchers always needed to develop a core terminology to grasp a simple stream of design thinking. According to him, challenge generated from need raises the question of ‘what’ and ‘how’ which in response create counter back terminology of interpretation and the breadth of design practice. Frame creation of the design thinking starts from the recombination of problem and enhances with core knowledge and identification of extra elements on the way. This leads us toward value creation and value enhancement in the procedure and design thinking patterns which turn out to be efficient innovativeness. Osorio (2011) introduced the design thinking-based innovation system by defining step by step chain which starts from learning and discovery of creativity proceeds to exploration, execution, and exploitation. In these phases, many obstacles occur in the generation of sustainability of innovation which if reviewed can be solved by the closer framework to natural ideation. This gap calls for a new ideology of design thinking and change in the conventional model of design thinking to achieve persistent, effective sustainable innovation. Liedtka (2015) describe that design thinking tools that start from the imagination of pre ideation, precise interaction with habitats for fact collection, coordinative efforts to put brainstorming, and solid concept development reduces the biasness impact out of procedure. Then this paradigm shifts toward value creation, execution, scalability, and defensibility of discussion, these scenarios push for the need to develop a pilot study of the aspects idealized before and intention of testing the idea leads toward experimentation. Design thinking has been a vital part of innovation and briefly embeds all the factors on one platform. Top technological businesses and organizations are striving for dynamic

sustainable innovations to perceive long term goals which also serve environmental issues. As work in this study have understood from previous literature that design thinking brings more rationalization in recognizing a problem and creating a solution through empathetic solidarity of ideation and testing of ideation now this study proposes in this chapter that if this study put biophilia design as a mandatory element in design thinking it can leads toward more strengthen and rapid sustainable innovativeness. Therefore, in design thinking framework, present study proposes to add biophilia design to generate new shapes and metaphors of sustainable innovation. Changing the internal behavior of industries toward sustainability will be the first step to avail rapid and problem-solving innovation.

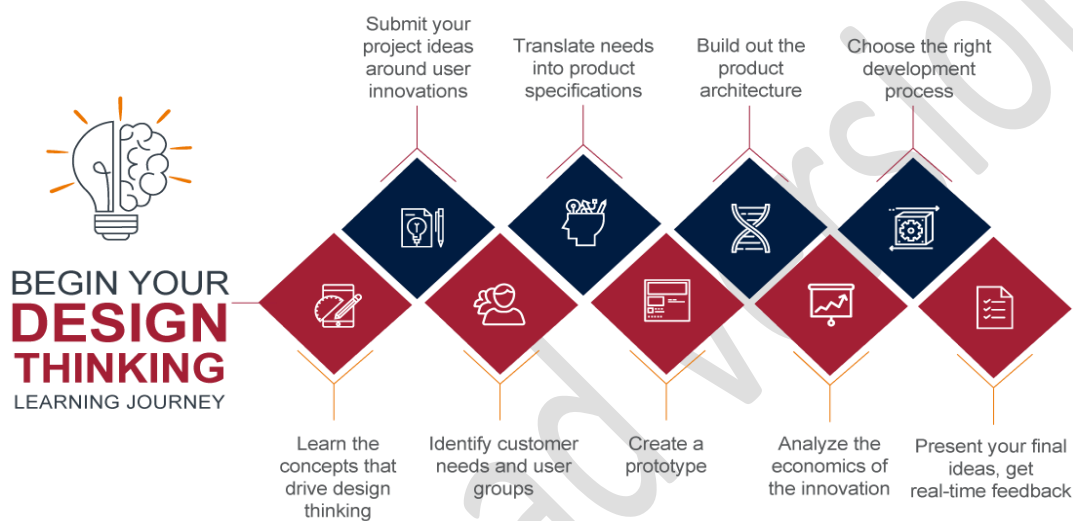


Figure 1. Design thinking adapted from (MIT Sloan Executive Education). Source: Stanford d. School Design Thinking Process

Dimensions and elements of biophilic design

It is very important to understand what is biophilia design. Biophilia design has been introduced in the 1980s by Edward Osborne Wilson where he introduced the concept of human affiliation and needs to be in nature. The concept revolves around that human can be close to nature even in high technological globalized and urbanization era. Natural patterns have their way of working there just need to turn these benefits outside in for close association. Biophilia design is not just a concept to include nature in human lives but also is the concept of initiating a cycle for humans to increase the quality of life while working in urbanized society. Biophilic design can be implemented not only in homes, offices, and other places but also in this design can help to improve human health and the human sense of lacking in many areas. Biophilic design is among recent approaches to improve the interactions and positive relationships between human beings and nature (Parsae et al. 2019).

Bioproducts are now becoming more trendy in many people’s lives but this study are not able to innovate a massive amount of bioproduction of feed and facilitate the underprivileged societies (Kellert & Calabrese,2015.). Here a question raises that if humans are doing well with technological innovations why there is a need for better design, to answer this question. Nabhan et al. (1993) presented the fact that it has been needed of human to inseminate with nature but because of a high amount of production and

technological changes has caused effective damage to humankind and nature where species are in extinction and human life, health, and climate is moving one step back. The dimensions and elements of biophilic design aim to introduce new dynamics design, which provide a solution for environmental damage and many other problems. There are many dimensions and elements as explained by (Kellert 2008), which participate in biophilia design; one of the basic dimensions according to him is naturalistic which are also called direct experience, this dimension occur through straight connect with natural elements like water, air, fire, light, plants, animals, weather, natural ecosystem, and soil. The second basic dimension he mentioned in his study of biophilia design is the place-based or vernacular dimension containing indirect connection with natural elements and includes the features of images of nature, natural resources, natural colors, simulating natural light and air, naturalistic shapes, and forms, inducing nature, information prosperity, maturity, modification, and the glaze of the occasion, natural geometries, biomimicry. The third basic dimension of biophilia design is space and place experience which includes the features of viewpoint and sanctuary, structured complication, an amalgamation of parts to wholes, intermediary spaces, mobility and technical result, edifying and environmental attachment to place(Kellert 2008). These dimensions work under various elements whether it works directly, indirectly, and intermediately party between nature and its procedures. These elements usually are based on environmental features, natural shapes, and forms, natural patterns and processes, light and space, place-based relationships, and evolved human-nature relationships(Kellert 2008). Other binding element includes tree and columnar supports, shells, and spirals, egg, oval, and tubular appearance, curve, crypt, dome form resisting instant lines and right outlook in the setting of the place and infrastructure, Sensory variability also fall in the category of contributive elements of biophilic designs (Kellert 2008). All these natural environmental shapes and forms help the human psyche for the development of sustainable plans close to nature and more effective for their surroundings. All the dimensions and elements provided by nature gives a clue to human development that there is a more sustainable plan mankind can achieve in their industrial revolutions. Figure 2. The biophilic design approach adopted from (Kellert and Calabrese, 2015).



Figure 2. The biophilic design approach adopted from (Kellert and Calabrese, 2015)

Biomimicry for Innovation and importance of Biophilia Thinking

Benyus (1997) defined biomimicry as studies nature’s models and then imitates or takes inspiration from these designs and processes to solve human problems. Biomimicry from biophilia design provides the ideation from

patterns and shapes of natural metaphors (Rossin 2010). Figure 3 illustrates the biomimicry steps adopted from (Shedroff 2009). These natural metaphors help the architect to design the shapes and patterns of products, buildings, and industrial commodities close to the natural design to avoid the deficiencies in human-made designs. Biomimicry is defined as imitating or taking inspiration from nature's forms and processes to solve problems for humans (Klein 2009). Passino (2005) proved the point that biomimicry optimizes the cycle of sustainability by utilizing patterns and forms of the environment around mankind. Gallo, Mauro and van der Wielen (2019) defined that biomimicry establishes a structure orientation for innovation which starts from problem identification toward problem solution, on the way there are many steps of knowledge gaining and learning from biomimicry utilizing animal, plant and bio microbes patterns creates sustainable innovations. Biomimicry demonstrates different patterns and forms through which nature has developed the structure of plants, animals, and other natural well beings. For example, the shape of sharks and dolphins in the sea gives the idea of soundless movement in water new products that can be developed through utilizing these shapes in innovative products. Besides these many chemicals which have been used by industries that caused a high risk of climate change and environmental threat can be changed by using natural elements from plants and other natural well beings. In medical infrastructure biomimicry and also in construction biomimicry can do the wonders by utilizing the natural architectural design. For human health the design and interior design of buildings, offices and hospitals can be designed close to nature so human can be more exposed and closer to natural dynamics this innovation and more innovative design can be introduced while learning biomimicry. It has been observed over some time that biomimicry as a dimension of biophilia has many incentives when it comes to the construction of nature-oriented places. For example, Green (2012) follows design plan from environment-friendly places and buildings construction they provide the close to nature options and also introduces such plans which contribute to sustainable innovations according to their observation biophilia designs provide financial benefit and cost reduction not only this but also long term financial cost cuts and effective management of economic matters. Biophilia design contributes economically in developing the structure of design as its close to nature and manufacturing of artificial substance requires high-cost investments. Biophilia designs can be the reason for reducing stress on workplaces, can enhance creativity in the workforce, and can support the ideation of the employees to come up with new solutions and innovations. Ryan et al. (2014) advocated the benefits of implementation of biophilic design on many levels of human health and well beings of sick patients. Therefore biophilia design has been endeavored to implement in hospitals and health facilities. Biophilia design is not only important for external factors around people but turning toward biophilia design boost the better life for people when it comes to age, health, and management of life balance as people are less surrounded by artificial and harmful objects. Biophilia design also promises a better production of products which is a more pure and sustainable structure. Another important feature of biophilic design is to develop the products according to the natural design which is less harmful to the environment and high temperature in climate. Implementing biophilic design as part of a strategy in the organization lessens the chances for people exposed to external damages which technological and industrial chemical drainage causes in the environment. Evolving the biophilia design and human bond in one place creates a rapid learning procedure. Learning procedure creates knowledge and generation of knowledge paves the way toward efficient innovation. Biophilia design is important to track and monitor the human biological observation and feedback as the outcome, generated from patterns of biophilic design for progress and innovative development especially when the perception of human productivity differs because of distinguished culture, climate, age, gender, landscape character, immigrant status, mental health, and genetic inclinations. This field is evolving in daily life but at a very slow pace. The importance of biophilic design can flourish the innovation industry to the next level because observation of biophilia design unfolds new patterns along the way and make the possibility of the discovery of new features of the environment. Biophilia design has major benefits for health it can create a resilient structure for humans as humans are now more exposed to external damages.

Principles of biophilia thinking

In order to implement an effective and proficient biophilia design, few principals need to be focused while implementing biophilia thinking in working and daily life environment. Kellert et al. (2011) discussed a very important concept that to be close to natural human needs to regenerate habitual biological organic design

in a highly technological environment. There are few principal need to be followed to implement biophilia thinking. According to Kellert and Calabrese (2015) first principle of biophilia thinking is to be in contact with nature on regular basis this means practicing the measure provided by nature on daily basis, for example, having plants in the hospital and working places this is a minor example. But being in habitual contact with nature humans can start developing biophilia thinking which can later lead toward strategic biophilia design on high scale projects. Other principal of biophilia thinking includes a sense of adoption from humans toward natural ways in the high evolutionary environment.

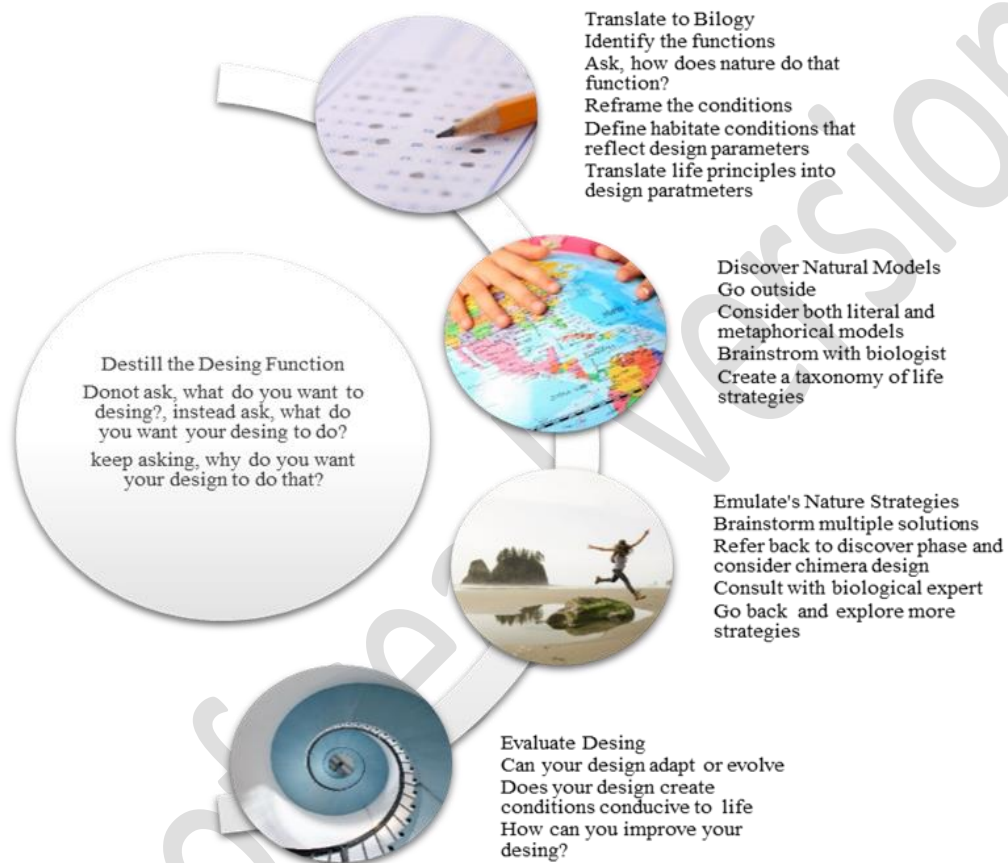


Figure 3. Illustration courtesy of Biomimcry Guild adopted by (Shedroff 2009)

This principle connects with previous connect where only habitually practicing biophilia practices are not enough human needs to adopt the facilities a biophilia design can provide. Furthermore, the principle of biophilia design requires emotional attachment toward the concept, this is considered that if humankind does not want to overcome problems of climate change it very difficult to change the behavior of industrial innovativeness, therefore, it's a mandatory metaphor to have a sentimental connection of biophilia thinking. For example, Zimring et al. (2004) demonstrated in their study that physical environmental change in the infrastructure of a hospital can lessen the stress for staff and patients, overall quality of health, and comfortability for all. Therefore, psychological improvement can occur due to physical environment change, and attachment toward the idea is important.

Buchanan (1992) revealed in their study long ago that design thinking needs definition change with the passage of time and also the connection of the members with design thinking definition. With revolutionary incentives, overtime period change is required now globalization is coping with climate threats and other challenges. Research also present lacking in taking rapid steps, therefore this study endeavored to present a model connecting dynamics of design thinking with biophilia design through biomimicry and biophilic thinking. HOYOS and Fiorentino (2016) suggested that bio-inspired design thinking is built in the approach of nature affiliated with how sustainability occurs in daily life but there is a need for strong biophilic thinking. If officials and civilians are not having a sense of responsibility to sustain the biophilia design in hospitals, offices, industries, and homes than developing biophilia thinking in the system is a hard task to achieve. Moreover, to promote the biophilia design in the system there is a need for shared reinforcing, interrelated, and incorporated architectural resolutions. Biophilic thinking added design inquires implementation of sustainable output, functioning, and flexibility of natural systems overtime on common places and in the daily life of a human. This principle requires persistence in behavior after implementation of biophilia design because nature-based projections require consistent maintains and care. Another principle of biophilia thinking is to make the concept of biophilic design common by getting acceptance from the majority of people. If manufacturing and industrial evolutions are not providing options to people to adopt eco-philia thinking then there is the existence of complexity in achieving positive behaviour of people towards eco-philia design. This study also considers initiatives taken by the governing body can also help to achieve eco-philia thinking in people to regenerate biophilia design at large scale because climate issue requires a change in behaviour at larger figures. Eco-Philic describes as a field of practices of being attracted to involvement in environmental practices. Eco-Philic thinking in the broadest sense is an approach to problems of nature and humankind by applying creative approaches of biophysics and biomimicry designs for conceptualization and developing innovative solutions to improve human well being and sustainability.

The previous discussion in the literature provided an opportunity to introduce affiliation of bio-inspired design thinking with biophilia thinking for sustainable innovation. Based on this prominent and supportive literature on different design development approaches, and review of literature, eco-Phila thinking identifies and improves purposefully design process with overall organizational sustainability including planning for both human and ecology system. Through the lense of Eco-philia design thinking, the creation of sustainable innovation can keep up the corporate sustainability agenda in a larger biophysical, ecological, and Human ecosystem. Eco-philia design also requires the principal of rapid-learning about the environment and space which is required to implement the biophilia design and learning is associated with knowledge acquisition. Learning also generates knowledge and common availability of knowledge increases and doubles the procedure of learning so if this principle is followed eco-philia thinking can promote at commercial, industrial, official, and individual levels. Eco-philia design seeks conscious observation and analysis of natural patterns and shapes to design the products close to nature with environmental benefits. Based on the previously discussed literature, the proposed conceptualization framework is shown in Figure 4.

As literature reveals that supporting facets of innovation such as design thinking, biomimicry, and biophilic design are not mutually exclusive, and can be mutually reinforcing to achieve sustainable innovations, shown in Figure 1. Sustainable innovation is defined as “develop new ideas, behavior, products, and processes, apply or introduce them and which contribute to a reduction of environmental burdens or too ecologically specified sustainability targets” (Rennings 2000)(p.322). For example, organizations can use biophilia design and design thinking as a strategy to achieve innovation, thus it is suggested that biophilic design and design thinking could provide an opportunity to develop products that are inclined to expand a sense of belongingness and responsibility for nature and human. Further, design thinking and biomimicry aspects of the innovation can extend beyond an organization’s boundary that helps guide an organization to design in a way that creates solutions for sustainable design. Eco-philia thinking is good for the organization in many ways, it informs human-environment interactions. It addresses the natural environment demand for a common sustainability objective. It is hoped that current study proposed framework will invigorate additional system building and conceptualizations development of various steps of eco-philia design within the various supply chain and

strategic management discipline. the eco-philía thinking framework created to better understand how sustainable innovation is created and sustained. The framework provides a holistic view of design strategies. Eco-philía thinking identifies and improves purposefully design process with overall organizational sustainability including planning for both human and ecology systems. Through the lense of Eco-philía design thinking, the creation of sustainable innovation can keep up the corporate sustainability agenda in a larger biophysical, ecological, and human ecosystem.

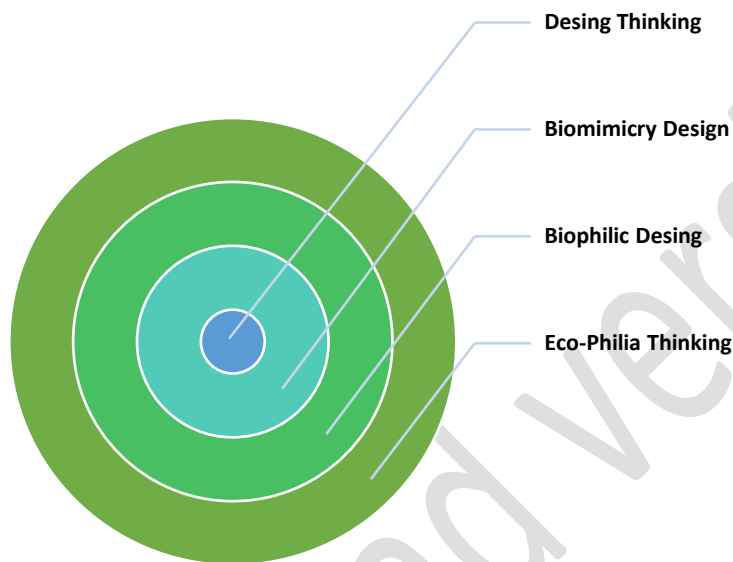


Figure 4 Eco-Philía Thinking Framework for sustainable innovation. Source authors.

Conclusion

Sustainable innovation increasingly attracting the attention of scholars, both as phenomena that provide an understanding of the for the natural resource management. The application of design thinking and biomimicry plays a key role in the implementation of the United Nations SDG9 for the effective attainment of sustainable innovation in green product and process innovation. The conceptual framework proposed in this study began to extend the call for increasing the robustness of bio-inspired design in achieving sustainability goals (Mead 2014) in the innovation management literature. Although there are numerous examples of connections between the design thinking approach and the Biomimicry thinking approach, however, a quantifiable and relative measure has yet to develop. This study has brought to ling the diverse relationships among biophilia design, Biomimicry, and design thinking to meet the goals of sustainable development at multiple levels. This study has proposed a new conceptual framework (Figure 4) for sustainable innovation to consider when utilizing sustainability objectives. This study proposed multiple layers of a conceptual framework for organizations to frame their sustainable innovation management practices for their contribution to the greater common good. Eco-philía thinking is defined as “identifies and improves purposefully design process with overall organizational sustainability including planning for both human and ecology systems”. Through the lense of eco-philía design thinking, the creation of sustainable innovation can keep up the corporate sustainability agenda in a larger biophysical, ecological, and human ecosystem. If eco-philía thinking is successfully implemented by the organizations, sustainable innovation can unlock its full potential to achieve other interlocked UN SDGs. The term eco-philía translates to the love of organizations to their environment. Eco-Philía describes as a field of practice of being attracted to involvement in environmental practices.

Design thinking, biomimicry and eco-philosophy design approaches together with eco-philosophy thinking may bring about sustainable changes in product and process design for circular economy. Eco-Philosophy thinking in the broadest sense is an approach to problems of nature and humankind by applying creative approaches of biophysics and biomimicry designs for conceptualization and developing innovative solutions to improve human well being and sustainability. Sustainable innovation is embedded in a persistent combination of Biomimicry design, design thinking, and biophilosophy design, which is necessary to support organizational sustainability objectives in the industry 4.0. If organizational is to contribute to sustainable innovation, the pursuit of eco-philosophy thinking must always be considered in process-product design to support circular economy initiatives.

Reference

- Asimakopoulou G, Revilla AJ, Slavova K (2020) External knowledge sourcing and firm innovation efficiency. *Br J Manag* 31:123–140
- Awan U, Nauman S, Sroufe R. (2020). Exploring the Effect of Buyer Engagement on Green Product Innovation: Empirical Evidence from Manufacturers, *Bus. Strateg. Environ.*, DOI: 10.1002/bse.2631 (article in press)
- Awan U (2020) Industrial Ecology in Support of Sustainable Development Goals. In: Leal Filho W, Azul AM, Brandli L, et al. (eds) *Responsible Consumption and Production*. Springer International Publishing, Cham, pp 370–380
- Beckman SL, Barry M (2007) Innovation as a learning process: Embedding design thinking. *Calif Manage Rev* 50:25–56
- Benyus JM (1997) *Biomimicry: Innovation inspired by nature*
- Boons F, Howard-Grenville JA (2009) *The social embeddedness of industrial ecology*. Edward Elgar Publishing
- Boons F, Montalvo C, Quist J, Wagner M (2013) Sustainable innovation, business models, and economic performance: an overview. *J Clean Prod* 45:1–8
- Brown T, others (2008) Design thinking. *Harv Bus Rev* 86:84
- Buchanan R (1992) Wicked problems in design thinking. *Des issues* 8:5–21
- Caloghirou Y, Kastelli I, Tsakanikas A (2004) Internal capabilities and external knowledge sources: complements or substitutes for innovative performance? *Technovation* 24:29–39
- Dorst K (2011) The core of ‘design thinking’ and its application. *Des Stud* 32:521–532
- Frenz M, Letto-Gillies G (2009) The impact on innovation performance of different sources of knowledge: Evidence from the UK Community Innovation Survey. *Res Policy* 38:1125–1135
- Fromm E (1964) *The Heart of Man: His Genius for Good and Evil* New York
- Gallo, Mauro and van der Wielen S (2019) *Biomimicry: transformative learning for sustainable solutions*
- Granero AG, Vega-Jurado J (2012) External knowledge sourcing and innovation performance: the role of managerial practices. *Knowl Acquis* 52:68–82
- Green TB (2012) *The Economics of Biophilia: Why designing with nature in mind makes financial sense*. 40pp
- HOYOS CM, Fiorentino C (2016) Bio-utilization, bio-inspiration, and bio-affiliation in design for sustainability: Biotechnology, biomimicry, and biophilic design. *Int J Des Objects* 10:1–18
- Kellert, S., Calabrese, E., 2015. *The practice of biophilic design*. Retrieved from <http://www.bullfrogfilms.com/guides/biodguide.pdf>
- Kellert SR (2008) Dimensions, elements, and attributes of biophilic design. *Biophilic Des theory, Sci Pract bringing Build to life* 3–19
- Kellert SR, Heerwagen J, Mador M (2011) *Biophilic design: the theory, science and practice of bringing buildings to life*. John Wiley & Sons
- Klein L (2009) *A phenomenological interpretation of Biomimicry and its potential value for sustainable design*. Kansas State University
- L. D-DN, Petra de SP (2014) *The interaction between external and internal knowledge sources: an open*

-
- innovation view. *J Knowl Manag* 18:430–446. doi: 10.1108/JKM-07-2013-0257
- Laursen K, Salter A (2006) Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms. *Strateg Manag J* 27:131–150
- Leiponen A, Helfat CE (2011) Location, decentralization, and knowledge sources for innovation. *Organ Sci* 22:641–658
- Leiponen A, Helfat CE (2010) Innovation objectives, knowledge sources, and the benefits of breadth. *Strateg Manag J* 31:224–236
- Liedtka J (2015) Perspective: Linking design thinking with innovation outcomes through cognitive bias reduction. *J Prod Innov Manag* 32:925–938
- Mead TL (2014) Biologically-inspired innovation in large companies: A path for corporate participation in biophysical systems? *Int J Des Nat ecodynamics* 9:216–229
- Meyer E (2015) When culture doesn't translate. *Harv Bus Rev* 93:66–72
- Nabhan GP, St Antoine S, Kellert S, Wilson E (1993) The loss of floral and faunal story: The extinction of experience. *The biophilia hypothesis* 229–250
- Osorio C (2011) Design Thinking-based Innovation: how to do it, and how to teach it. In: BALAS Annual Conference. pp 1–28
- Owen C (2007) Design thinking: Notes on its nature and use. *Des Res Q* 2:16–27
- Passino KM (2005) Biomimicry for optimization, control, and automation. Springer Science & Business Media
- Rennings K (2000) Redefining innovation—eco-innovation research and the contribution from ecological economics. *Ecol Econ* 32:319–332
- Rossin KJ (2010) Biomimicry: nature's design process versus the designer's process. *WIT Trans Ecol Environ* 138:559–570
- Ryan CO, Browning WD, Clancy JO, et al (2014) Biophilic design patterns: emerging nature-based parameters for health and well-being in the built environment. *ArchNet-IJAR Int J Archit Res* 8:62
- Shedroff N (2009) Design is the problem: the future of design must be sustainable. Rosenfeld Media
- Shoaib AB, Kehinde M (2019) The diversity of knowledge sources and its impact on firm-level innovation: Evidence from Germany. *Eur J Innov Manag* 22:681–714. doi: 10.1108/EJIM-10-2018-0232
- Varis M, Littunen H (2010) Types of innovation, sources of information and performance in entrepreneurial SMEs. *Eur J Innov Manag* 13:128–154
- Vítor C, Samuel M (2016) Key knowledge management processes for innovation: a systematic literature review. *VINE J Inf Knowl Manag Syst* 46:386–410. doi: 10.1108/VJIKMS-02-2015-0017
- Zimring C, Joseph A, Choudhary R (2004) The role of the physical environment in the hospital of the 21st century: A once-in-a-lifetime opportunity
- MIT Sloan Executive Education. [https://executive-ed.mit.edu/mastering-design-thinking.php?utm_source=Google&utm_medium=c&utm_campaign=B-365D_ROW_GG_SE_MDT_Jun_20_Core&utm_content=Design_Thinking&utm_term=design thinking&gclid=Cj0KCQjws_r0BRCwARIsAMxfDRiQL6e2OhS6FZI7rmK_2wXY9e4GYE73kFWQ](https://executive-ed.mit.edu/mastering-design-thinking.php?utm_source=Google&utm_medium=c&utm_campaign=B-365D_ROW_GG_SE_MDT_Jun_20_Core&utm_content=Design_Thinking&utm_term=design%20thinking&gclid=Cj0KCQjws_r0BRCwARIsAMxfDRiQL6e2OhS6FZI7rmK_2wXY9e4GYE73kFWQ)