

REPUBLIC OF TURKEY
YILDIZ TECHNICAL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED
SCIENCES

IN-BETWEEN LIVING AND MANUFACTURED:
AN EXPLORATORY STUDY ON BIOBUILDING
COMPONENTS FOR BUILDING DESIGN

Berrak KIRBAŞ AKYÜREK

DOCTOR OF PHILOSOPHY THESIS

Department of Architecture

Building Research and Planning Program

Advisor

Prof. Dr. Ayşen CIRAVOĞLU

Co-Advisor

Prof. Dr. Masi MOHAMMADI

January, 2021

REPUBLIC OF TURKEY
YILDIZ TECHNICAL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

**IN-BETWEEN LIVING AND MANUFACTURED:
AN EXPLORATORY STUDY ON BIOBUILDING
COMPONENTS FOR BUILDING DESIGN**

A thesis submitted by Berrak KIRBAŞ AKYÜREK in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY is approved by the committee on 19.01.2021 in Department of Architecture, Building Research and Planning Program.

Prof. Dr. Ayşen CİRAVOĞLU

Yıldız Technical University

Advisor

Prof. Dr. Masi MOHAMMADI

Eindhoven Technical University

Co-Advisor

Approved By the Examining Committee

Prof. Dr. Ayşen CİRAVOĞLU, Advisor

Yıldız Technical University

Assoc. Prof. Dr. Feride Pınar ARABACIOĞLU, Member

Yıldız Technical University

Asst. Prof. Dr. Fulya ÖZSEL AKİPEK, Member

Istanbul Bilgi University

Assoc. Prof. Dr. Polat DARÇIN, Member

Yıldız Technical University

Assoc. Prof. Dr. Aslihan ŞENEL, Member

İstanbul Technical University

I hereby declare that I have obtained the required legal permissions during data collection and exploitation procedures, that I have made the in-text citations and cited the references properly, that I haven't falsified and/or fabricated research data and results of the study and that I have abided by the principles of the scientific research and ethics during my Thesis Study under the title of In-Between Living And Manufactured: An Exploratory Study on Biobuilding Components for Building Design supervised by my supervisor, Prof. Dr. Ayşen CİRAVOĞLU. In the case of a discovery of false statement, I am to acknowledge any legal consequence.

Berrak KIRBAŞ AKYÜREK

Signature

This study was supported by the Scientific and Technological Research Council of Turkey (TUBITAK) Grant No: 2211/A.

A Thesis for the free spirits

ACKNOWLEDGMENTS

Foremost, I kindly would like to express my sincere gratitude to the supervisors, Prof. Dr. Aysen CIRAVOGLU, Prof. Dr. ir. Masi MOHAMMADI, and Asst. Prof. Dr. Husnu YEGENOGLU for their guidance, suggestions, valuable feedbacks, constructive and wise criticisms during the Ph.D. process. I would like to thank Prof. Dr. Aysen CIRAVOGLU, as my second promotor at TU/e and the first promotor at Yildiz Technical University, for her faith in our studies and constant support since in the beginning of this Ph.D. in 2014. I would like to thank Prof. Dr. ir. Masi MOHAMMADI, as my first promotor at TU/e and second promoter at Yildiz Technical University, for giving me the opportunity to work at TU/e and included in the Smart Architectural Technologies chair. I would like to thank Asst. Prof. Dr. Husnu YEGENOGLU, as my co-promotor at TU/e and committee member at Yildiz Technical University, for his support and encouragement and for keeping my enthusiasm on the thesis topic.

I would like to thank my committee members at Yildiz Technical University for their efforts and time. I would like to thank Assoc. Prof. Dr. Pinar ARABACIOGLU and Asst. Prof. Dr. Fulya OZSEL AKIPEK, for their valuable comments from the early stages of my study and always creating extra time for me to listen and contribute my work. I would like to thank the members of the Ph.D. committee at YTU Assoc. Prof. Dr. Aslıhan ŞENEL and Assoc. Prof. Dr. Polat DARÇIN for their fruitful remarks. I also would like to thank Prof. Dr. Ayşin SEV and Assoc. Prof. Dr. Aslı SUNGUR.

I would also like to thank the members of the Ph.D. committee at TU/e, Prof. Dr. Ward COTTAAR, Prof. Dr. Jos J.N. LICHTENBERG, and Prof. Dr. Cor WAGENAAR for their fruitful comments, valuable suggestions, efforts, and time. I also have a special thanks to my advisor, Dr. Koert van MENSVOORT. His works were encouraged me to come to the Netherlands in the first place, and I am so happy to see him by reading my thesis and being part of this study.

I would like to thank all the experts participating in my studies, sharing their knowledge, and sparing their precious time. I would like to mention by name: Lloyd ALBERTS, Maurizio MONTALTI, Marina TOETERS, Boris ZEISSER, Natalia ROMERO HERRERA, Ermi van OERS, Henk JONKERS, Wanda KRUIJT, Tjeerd VEENHOVEN, Elvin KARANA, Christiaan BAKKER, Melle JANSSEN, Jordy SENSSEN, Teresa van DONGEN, William MYERS, Stephan WENSVEEN, Nadia JELLOULI-GUACHAT, Frank MARCUS, Tom KOENDERMAN, Raymond CUIJPERS, Michael J. DAWKINS. With their precious contributions, and high level of expertise, this research has transformed into a ‘practical knowledge’.

This thesis is financially supported by TUBITAK (The Scientific and Technological Research Council of Turkey) Ph.D. scholarship entitled 2211/A between 2014-2018. I would like to thank my dearest gratitude to TUBITAK.

A doctor’s title is something you must achieve by yourself, but you never do it alone. A joint Ph.D. was an exhausting and challenging path to follow. I would like to thank everybody who supported me during my Ph.D.: friends, colleagues, and professors at TU/e and Yildiz Technical University.

I want to thank Prof. Dr. Tulin GORGULU for her support, understanding, and kindness, especially on administrative struggles. I would like to thank all my colleagues for their kindness and supports in room 206. I owe special thanks to Nazli ARSLAN, Esin YILMAZ, Hasan TASTAN, Omur KARARMAZ, and Serhat ULUBAY for their friendship, support, and helps on administrative struggles. I also would like to thank Prof. Dr. Deniz ERINSEL ONDER for her friendship and kindness and her help to find my way in academic life.

I would like to thank all members of the Smart Architectural Technologies Chair at TU/e. Thank you for all our discussions and meetings. I owe special thanks to my dear friends, Seyed Morteza HOSSEINI and Linh NGUYEN. I cannot tell how much I missed having coffee breaks with them during these Corona times. I also want to thank Ozlemnur ATAOL, Peyman NAJAFI, Chuan Ma, Leonie van BUUREN, and Anne GRAVE for their friendships. I also would like to thank Dr. Olivia GUERRA-SANTIN for spearing extra time to help my studies.

I present my honest thanks and gratitude to my parents, Hüseyin and Nursel KIRBAŞ, whose love and support I always feel by my side throughout a lifetime.

I owe special thanks to my sisters: Basak BALOGLU and Beril KIRBAS. I am grateful to them, especially for their support, when I got confused and panic. I also would like to thank my dearest and oldest friend Sidika TOPTAS. We have chosen different paths in life but always manage to walk together. I want to thank Alp ESMER for being my brother, always supporting me, encouraging me. Four of you are my ‘rock stones’ who are always there for me. You never let me feel alone. I am so lucky to have you in my life.

Last but not least, I want to thank my husband, Efe AKYUREK, for being my secret supervisor by reading, revising, and critiquing this work. Thank you for believing me even the times I stop believing myself. Without your support, help, love, friendship, and kindness, this study could have never been completed; any thanks would be an understatement. Without you, none of this would matter.

January, 2021

Berrak KIRBAŞ AKYÜREK

TABLE OF CONTENTS

LIST OF FIGURES	xiii
LIST OF TABLES	xvii
ABSTRACT	xv
ÖZET	xix
1 INTRODUCTION.....	1
1.1 Literature Review.....	3
1.1.1 Scope.....	4
1.1.2 Potentials & Problems.....	12
1.2 Objective of Thesis and Research Questions.....	18
1.3 Methodology.....	20
1.4 Original Contribution.....	32
1.5 Structure of the Thesis	34
2 THE CONCEPTS OF NATURE AND TECHNOLOGY IN BUILDING DESIGN.....	37
2.1 Questioning the Concept of Nature	38
2.2 Summary of the Changing Dynamics in Building Design Through the Concept of Nature	41
2.3 Summary of the Changing Dynamics in Building Design through the Development of Technologies.....	48
2.4 Shifting Notions of Nature and Technology in Contemporary Concepts .	56
2.5 Discussion on the Changing Dynamics in Building Design in-between Living and Manufactured	61

2.6 Conclusions.....	71
3 RESEARCH ON TERMINOLOGY OF BIOBUILDING COMPONENTS IN BUILDING DESIGN	73
3.1 Methodology.....	75
3.2 Literature Review.....	76
3.3 Findings and Discussions	79
3.4 Conclusions.....	80
4 DETERMINATION OF BIOBUILDING COMPONENTS IN BUILDING DESIGN.....	83
4.1 Methodology.....	84
4.1.1 Level of Technological Integration	84
4.1.2 Determination of the Relevance with Building Design	85
4.2 Examples of Biobuilding Components	87
4.3 Findings and Discussions	100
4.4 Conclusions.....	111
5 EXPLORING BIOBUILDING COMPONENTS FROM FUTURE ARCHITECTS' VIEWPOINTS	116
5.1 A Building Design Experiment in Building Design Studio.....	117
5.2.1 Methodology.....	118
5.1.2 Phase 01, Warm-Up.....	124
5.1.3 Phase 02, The Experiment.....	128
5.1.4 Final presentations & Key Results.....	131
5.2 Conclusions.....	137
6 EXPLORING BIOBUILDING COMPONENTS FROM PRACTITIONERS' VIEWPOINTS	140

6.1 Interviews with the Practitioners.....	141
6.1.1 Methodology.....	142
6.1.2 Summary of the Interviews	151
6.1.3 Development of Biobuilding Components and their Integration into Building Design.....	171
6.2 Conclusions.....	187
7 CONCLUSIONS AND RECOMMENDATIONS.....	189
7.1 Research Questions Revisited.....	190
7.2 Recommendations.....	200
7.2.1 Recommendations for architects	201
7.2.2 Recommendations for Future Research and Practice.....	203
7.3 Closing Remarks	204
REFERENCES.....	210
A INTERVIEW TRANSCRIPTS	232
B DOUBLE DOCTORATE REQUIREMENTS BY YILDIZ TECHNICAL UNIVERSITY	404
PUBLICATIONS FROM THE THESIS	430

LIST OF FIGURES

Figure 1.1 The Scope of the Thesis	4
Figure 1.2 The Increasing Number of Biobuilding Components	16
Figure 1.3 The Research Model of the Thesis.....	31
Figure 1.4 The Relations Between Chapters and Research Questions.....	34
Figure 2.1 A Summary of the Changing Dynamics in Building Design through the Concept of Nature.....	47
Figure 2.2 House of the Future, by Alison Smithson, 1958 (Alter, 2016)	49
Figure 2.3 Afase Solar House, 1958 (“AFASE Solar House / Scottsdale,” n.d.).	49
Figure 2.4 Future in the Past: Futuristic Imagination from 1979 of a House in 2000 (Gatland, K. and Jefferis, 1979).	50
Figure 2.5 A Short Summary of the Development of Technologies into the Building Environment (Classification of the timeline as mechanization, electrification, automation, adapted from <i>Domotica Kompas. Inzichten uit een decennium slimme zorgprojecten in Nederland</i> (Mohammadi, 2014).....	55
Figure 2.6 The Pyramid of Technology (Table is composed by the author based on the information in the works of Mensvoort, Mensvoort and Grievink, 2012)	59
Figure 2.7 Root Bridges in Meghalaya, India (“Guided Growth When the ‘built’ becomes the ‘born,’” n.d.).....	63
Figure 2.8 Protocells and Future Venice Project Simulation by Christian Kerrigan	64
Figure 2.9 The BIQ (Bio Intelligent Quotient) House, Photos © Colt International, Arup Deutschland, SSC GmbH	65
Figure 2.10 Baubotanik, Building Growing through Living Trees (Ferdinand; Ludwig and Schönle, n.d.)	65
Figure 2.11 Fab Tree Hab Project (Arbona et al., 2003)	66
Figure 2.12 Hy-Fi, The Organic Mushroom-Brick Tower Opens At MoMA’s (Stott, 2014).....	66
Figure 2.13 The Growing Pavilion in Dutch Design Week, October 2019 (personal archive of Peyman Nafai).....	67

Figure 2.14 Silk Pavilion, an Architectural Space Growing with Silkworms (Oxman, 2015).	67
Figure 2.15 Zelfherstellend Paviljoen (Self-healing Building)	68
Figure 2.16 Slime Molds Growing in the z-axis, and the Generation of Growth Patterns of Slime Molds in Building Design Simulation (Gruber & Imhof, 2017a)	69
Figure 2.17 Examples of Questions in the Evolution of Buildings through Technological Developments	70
Figure 3.1 The Scope of the Literature Review on Biobuilding Components ...	75
Figure 3.2 The Structure of the Overview of Terminology on Biobuilding Components	82
Figure 4.1 Level of Integration of Gathered Examples in Thesis	85
Figure 4.2 Building Layers Determined by Brand (1994)	86
Figure 4.3 The Scope of Biobuilding Components Included in Thesis	87
Figure 4.4 Example of Categorization of Biobuilding Components through Building Layers Determined by Brand (1994)	88
Figure 4.5 The Mostly Used Terms in the Determined Biobuilding Components	101
Figure 4.6 Biobuilding Components in the Nested Hierarchy (Based on Geels, 2002).	113
Figure 4.7 Biobuilding Components in the Reconfiguration Pathway (Based on Geels, & Schot, 2007)	114
Figure 5.1 The Weekly Schedule of the Project Course	119
Figure 5.2 The Organization of the Experiment	120
Figure 5.3 Translation of Drop by Drop Project into Different Building Layers: An Example of a Student Answer	121
Figure 5.4 Final Presentations of the Students	121
Figure 5.5 Examples from the Works of Test Group (the biobuilding components shown by the author).	132
Figure 5.6 Examples from the Works of Test Group (the biobuilding components shown by the author).	132
Figure 5.7 Comparison of the Percentage of the Students from the Encoded Protocols of Test and Control Group Students.	132

Figure 6.1 Thematic Approach Analysis Map of the Interviews	172
Figure 6.2 The Iterative Design Process of Biobuilding Components (Based on Roozenburg and Enkels, 1994)	173
Figure 6.3 Superposition of the Design Stages of Biobuilding Components...	183
Figure 6.4 The Dialogue between Industrial and Building Design through Biobuilding Products Becoming Biobuilding Components (Based on Poelman & Kelson, 2008 and Iterative Structure of Design process by Roozenburg and Enkels, 1994)	186

LIST OF TABLES

Table 3.1	Terms in the Literature Exemplifying the Interrelation of Living and Manufactured Components with “bio” in Building Design (Kirbas Akyürek et al., 2020)	78
Table 4.1	Examples of Biobuilding Components.....	91
Table 4.2	Findings from the Determination of Biobuilding Components	112
Table 5.1	Assigned Biobuilding Components to the Students	122
Table 5.2	Students Works on the Abstraction of the Keywords.....	126
Table 5.3	Students works on Redesigning their Design Studio	127
Table 5.4	Integration Stages of Test Group Students.....	129
Table 5.5	Followed Stages of Test Group Students in the Design Process.....	130
Table 5.6	Information Categories and Their Subclasses	133
Table 5.7	Encoded Protocols of All Students into Information Categories	134
Table 6.1	Interviewee List	149
Table 6.2	Questions of the Interviews	147
Table 6.3	Practitioners’ Descriptions of their Professional Practice.....	153
Table 6.4	Motivations behind Practitioners’ Practice	155
Table 6.5	The Novelty of Practitioners’ Practice	157
Table 6.6	Practitioner’s Preferences in the Terminology of Biobuilding Components.....	159
Table 6.7	The Expected Results from Practitioners’ Practice.....	161
Table 6.8	Practitioner’s Existing and Ongoing Studies on User’s Experience .	163
Table 6.9	The Impacts of Biobuilding Components from the Practitioner’s Perspectives	165
Table 6.10	Challenges Experienced by the Practitioners	167
Table 6.11	Future Expectations of the Practitioners	169
Table 6.12	The Recommendations of the Practitioners for Architects	170
Table 6.13	Design Process of the Development of Biobuilding Components and Their Integrations into the Buildings	178
Table 6.14	Demonstration of Design Stages as an Example	184

IN-BETWEEN LIVING AND MANUFACTURED: AN EXPLORATORY STUDY ON BIOBUILDING COMPONENTS FOR BUILDING DESIGN

Berrak KIRBAŞ AKYÜREK

Department of Architecture

Doctor of Philosophy Thesis

Advisor: Prof. Dr. Ayşen CİRAVOĞLU

Co-advisor: Prof. Dr. Masi MOHAMMADI

Living organisms of nature, such as plants and algae, have often provided innovative solutions for buildings within current environmental degradation in relation to the significant matter of the living components in building design since pre-modern to contemporary architecture. Meanwhile, smart technologies such as automation systems, artificial intelligence, and the internet of things (IoT) have taken place in building design, in addition to the integration of a variety of manufactured components from electrical sockets to domestic appliances into buildings since industrialization. At this point, contemporary studies manifest that emerging technological achievements have also enabled the incorporation of living organisms into the design, thereby living and manufactured components tend to grow towards ‘in-between.’ Accordingly, this ‘in-betweenness’ also introduces itself within building design that is expected to alter the design of building components into ‘biobuilding components.’

Within the rapid and comprehensive growth of technology, the number of biobuilding component examples has been increasing gradually and about to infiltrate into everyday lives and surroundings; however, how building design would be affected by biobuilding components is needed to be elaborated in the building design domain. Therefore, this thesis explores the expected impact (s) of biobuilding components with their possible meaning(s) in building design.

The objective of the thesis is to present an explanatory study that yields knowledge of biobuilding components by evaluating their theoretical and practical implications. This leads to exploring the expected impacts of biobuilding components by elaborating on historical, phenomenological, practical, technological, building design, and educational meanings of biobuilding components. While the number of biobuilding components in the industry will increase in the years ahead, this research takes a reliable step forward on this emerging field in the building design domain by enhancing architects' understandings of biobuilding components.

Keywords: biobuilding components, biobuildings, sustainability, smart technologies, building design

YAŞAYAN VE İMAL EDİLEN ARASINDA: BİNA TASARIMINDA BİYO YAPI BİLEŞENLERİ ÜZERİNE BİR ARAŞTIRMA

Berrak KIRBAŞ AKYÜREK

Mimarlık Anabilim Dalı

Doktora Tezi

Danışman: Prof. Dr. Ayşen CİRAVOĞLU

Eş Danışman: Prof. Dr. Masi MOHAMMADI

Bitkiler ve algler gibi doğanın canlı organizmaları, modern öncesinden çağdaş mimariye kadar bina tasarımında yaşayan bileşenlerin önemli maddesi ile ilgili olarak mevcut çevresel bozulma dahilindeki binalar için sıklıkla yenilikçi çözümler sağlamıştır. Bu arada, elektrik prizlerinden ev aletlerine kadar çeşitli üretilen bileşenlerin binalara entegrasyonunun yanı sıra sanayileşmeden bu yana bina tasarımında otomasyon sistemleri, yapay zeka ve nesnelerin interneti (IoT) gibi akıllı teknolojiler yer almıştır. Bu noktada çağdaş teknolojik araştırma ve gelişmeler canlı organizmaların tasarıma dahil edilebildiğini, dolayısıyla canlı ve üretilen bileşenlerin ‘arada’ olma eğiliminde olduğunu ortaya koymuştur. Bu durumun yapı bileşenlerinin tasarımını ‘biyo yapı bileşenlerine’ dönüştürmesi beklenmekte ve dolayısı ile bina tasarımına etkilemesi beklenmektedir.

Teknolojinin hızlı ve kapsamlı büyümesi içinde, biyo-yapı bileşeni örneklerinin sayısı giderek artmakta öyle ki günlük yaşama ve yapılı çevreye sızmak üzeredir. Bu sebeple, bina tasarımının biyo yapı bileşenlerinden nasıl etkileneceği, bina tasarımı alanında ayrıntılı olarak ele alınmalıdır. Böylelikle, bu çalışma biyo yapı bileşenlerinin beklenen etkilerini bina tasarımındaki olası anlamını/anlamlarını ile araştırmaktadır.

Tezin amacı, teorik ve pratik çıkarımlarını değerlendirerek biyo yapı bileşenleri hakkında bilgi veren açıklayıcı bir çalışma sunmaktır. Bu, biyolojik bina bileşenlerinin tarihsel, fenomenolojik, pratik, teknolojik, bina tasarımı ve eğitimsel anlamlarını detaylandırarak biyo yapı bileşenlerinin beklenen etkilerinin araştırılmasına araştırılmasına ve tartışılmasına olanak sağlar. Önümüzdeki yıllarda sektördeki biyo yapı bileşenlerinin sayısı artacağı varsayımı ile, bu araştırma, mimarların biyo yapı bileşenlerine ilişkin anlayış ve yaklaşımlarını geliştirerek bina tasarımı alanında gelişmekte olan bu alandaki mevcut bilgi eksikliğinin giderilmesinde önemli ve özgün bir katkı sağlamaktadır.

Anahtar Kelimeler: biyo yapı bileşenleri, biyo bina, sürdürülebilirlik, akıllı teknolojiler, bina tasarımı

Within the rapid and comprehensive growth of technology, a variety of innovations incorporated with living organisms could be applied as building components (i.e., wall, façade panel, interior element, etc.) in a building such as: algae-filled walls (e.g., BIQ house in Hamburg/Germany, Poerbo et al., 2018), façade panels grown from mushrooms and mycelium (e.g., Growing Pavilion, Klarenbeek, 2019), and flowerpots cleaning the air with plants (e.g., Clairry project, Masi et al., 2015). Such innovations position themselves in-between ‘living and manufactured’ by manifesting a ‘radical’ design approach thanks to the latest technological advancements enabling us to design together with living organisms such as biotechnology and bioengineering, biofabrication, and biomaterial production (Myers, 2018).

The topic of the thesis emerges from studying these ‘in-between’ innovations in the building design domain. Within the thesis framework, these innovations are entitled ‘biobuilding components’ (as introduced in Section 1.1.1 and further elucidated in Chapter 3), and the aim of the thesis is determined as follows:

To explore the expected impact(s) of biobuilding components with their possible meaning(s) in building design.

To accomplish this aim, initially, the thesis approaches its topic by embracing a perspectivist way of thinking, inspired by Nietzsche’s perspectivism. In his own words, Nietzsche outlines his idea as follows:

“In so far as the word ‘knowledge’ has any meaning, the world is knowable; but it is interpretable [emphasis in original] otherwise, it has no meaning

behind it, but countless meanings – “Perspectivism,” Translation: Walter Kaufman.¹”

From my point of view, Nietzsche criticizes the concept of indispensable ‘truth’ by underlining that knowledge relies on multiple perspectival interpretations, not objective facts. Nietzsche’s perspectivism as a philosophical approach depends on a visual metaphor which implies that our eyes capture things from a particular perspective with certain limitations, and these specific viewpoints trigger different interpretations in which knowledge is constituted (Anderson, 1998; Atwell, 1981; Berry, 2005; Nola, 1987; Welshon, 2009). With this metaphor, Nietzsche emphasizes the ‘subjectivity’ in human perception and discards the possibility of knowing a subject without any subjectivity (Atwell, 1981; Berry, 2005; Gilmour. J. C., 1990; Stewart, 1986). In this regard, a single perspective is always problematic with a single point of view; therefore, perspectivism suggests a plurality, since different perspectives ensure epistemic values such as ‘simplicity,’ ‘plausibility,’ and ‘empirical adequacy’ in terms of evaluating theories and interpretations (Anderson, 2007). That’s why, in this book *Human, All-Too-Human: A Book for Free Spirits* (Nietzsche, 1910), Nietzsche repeatedly refers to perspectives as plural; thus he stresses the value of different understandings, and advocates that ‘becoming aware of the perspectival nature of knowledge is itself an improvement in knowledge’(Atwell, 1981).

From my aspect, the perspectivist way of thinking brings an approach for this technology-driven research suggesting the discussion of different, even contradicting studies, theories, and statements altogether. In my opinion, perspectivism inspires me to establish the theoretical background of the study by including different classifications, concepts, and theories as a result of approaching the thesis topic from multiple angles (Chapter 2, Chapter 3).

¹ Original German: *Soweit überhaupt das Wort “Erkenntniß” Sinn hat, ist die Welt erkennbar: aber sie ist anders deutbar, sie hat keinen Sinn hinter sich, sondern unzählige Sinne. – “Perspektivismus”.* Nietzsche. See: Nietzsche, F. W. (1906/1987). *Der Wille zur Macht*. Nr.481 (M. Rehfuss, Ed.). Wensin: Verlag.

Moreover, it encourages understanding and analyzing the expected impact(s) of biobuilding components by determining multiple examples (Chapter 4), considering different interpretations and understandings of different actors from multiple disciplines (Chapter 5, Chapter 6).

The Introduction Chapter explains how the thesis will proceed to achieve its aim. Firstly, the *Literature Review*² section provides a comprehensive understanding of the thesis topic by clarifying the scope of the investigation (Figure 1.1) and the problem field. Secondly, the following section identifies the key objectives related to the research's disciplinary boundaries by presenting *Objective of the Thesis and Research Questions*. Thirdly, the *Methodology* section explains the research approach and methods (in literature research, data collection, and analysis) to seek answers to the research questions. The research model of the thesis is presented in this section (Figure 1.3). Fourthly, the *Original Contribution* section offers the novelty of the thesis in the existing literature. Lastly, the *Structure of the Thesis* section presents a brief explanation of each chapter. The relations between research questions, research models, and chapters are demonstrated as a reading guide at the end of the Introduction (Figure 1.4.).

1.1 Literature Review

A literature review highlighting fundamental studies, concepts, approaches, theories, and examples, which introduces firstly *Scope* and secondly, *Potentials & Problems* of the thesis. In this way, this part of the study identifies the research's disciplinary boundaries by explaining the definition of the biobuilding component.

² Regarding the agreed joint degree protocol between two universities: Eindhoven University of Technology (TU/e), Eindhoven/the Netherlands and Yildiz Technical University (YTU), Istanbul/Turkey, the thesis template must follow the rules of Graduate School of Science and Engineering of Yildiz Technical University. For further information, please see: <http://www.fbe.yildiz.edu.tr/page/GRADUATION/THESIS-SPELLING-INSTRUCTIONS-and-MANUAL/361>

It then describes the problem field of the research within the established boundaries.

1.1.1 Scope

This section of the study provides inquiries on the accurate determinations of ‘living,’ ‘manufactured,’ and ‘building’ components, and their intersections as ‘bio-components’ and ‘biobuilding components.’ From this thesis point of view, these determinations introduce the basis for this thesis. This thesis positions itself in-between living and manufactured, and this ‘in-betweenness’ emerges within the intersection of “the concept of nature”³ and the development of technology. Figure 1.1 demonstrates the scope of the thesis, and each determination is furtherly explained in the below sub-sections. They are formulated by thoroughly understanding, digesting, and analyzing the literature on the interrelations between the comprehensive concept of nature, development of technology, and building design.

LIVING COMPONENTS :

Living and growing organisms in nature.

MANUFACTURED COMPONENTS:

Man-made productions.

BUILDING COMPONENTS :

Building design elements influencing building design.

“BIO” COMPONENTS:

All innovations at the intersection of living and manufactured components.

“BIOBUILDING” COMPONENTS

The interrelation of living and manufactured components as building components.

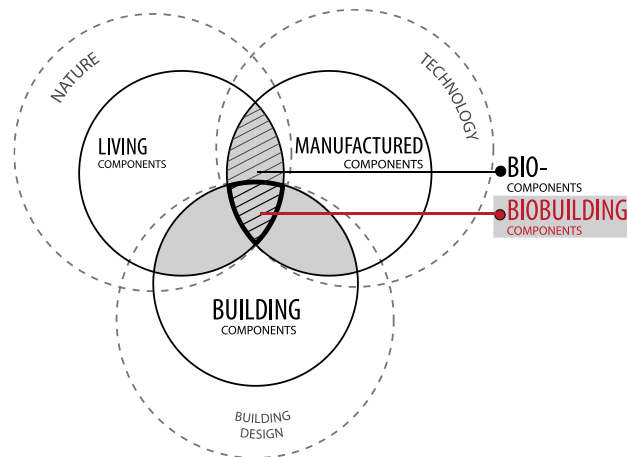


Figure 1.1 The Scope of the Thesis

³ Nature needed to be discussed as “the concept of nature,” since its meaning relies on the altering understandings constituted by humans (Collingwood, 1945; Andreas Roepstorff and Bubandt, 2003; Soper, 1995). This argument furtherly elucidated in *Chapter 2, Section 2.1.1 Questioning the Concept of Nature*.

This research's key subject is the 'interrelation' of living and manufactured components by incorporating living organisms into the design. *Living components* point out the use of living organisms within the "concept of nature" by representing the 'natural,' 'living,' 'growing,' side of this interrelation. By this means, the term of living is used as corresponding to its biological essence instead of its common use in technology within the descriptions of dynamic and interactive objects. On the other hand, *manufactured components* indicate the man-made interference that makes this incorporation possible within technology developments. Thus, they can be connotated with the 'artificial,' 'technical,' or 'non-natural' side of this interrelation. From this study's point of view, living and manufactured components indicate two different poles entirely different from each other. However, due to new technological abilities enabling us to design with living organisms, the gap between the living and the manufactured seems to be closed within bio-derived concepts, such as biomimicry (Benyus, 1997), biophilia (Kellert & Winslow, 1993), biodesign (Myers, 2018), and bioarchitecture (Ripley & Bhushan, 2016). Concerning these bio-derived concepts, the intersection of living and manufactured components is entitled as bio-components, which indicates both. Accordingly, the main focus of the thesis is specified as biobuilding components, referring to particular bio-components being used as building components within the building design domain. In that sense, biobuilding components are positioned at the intersection of the concepts of nature, technology, and building design by encompassing living, manufactured, and building components.

In my opinion, the explanations of these determinations in an example can provide a better understanding before elucidating them in detail. For instance, in the project of Mogu initiated by Maurizio Montalti (Appels et al., 2019), acoustic panels grown from mycelium are accepted as a biobuilding component considering the potential role of an acoustic panel in the design of a building. In this case, mycelium is the living component. The man-made technique to grow mycelium in the demanded form, and added artificial materials such as polishing material are accepted as manufactured components. Since bio-component

represents a general term regardless of the relevancy of a product with building design, any other innovation developed with mycelium could be entitled as bio-component (e.g., a food container or a bottle grown from mycelium, Camere & Karana, 2017).

To define biobuilding components, primarily, it is essential to explain the determinations of living, manufactured, and building, and then bio-components in detail.

Living Components in the Concept of Nature

The concern of the thesis in the concept of nature determined as 'living components,' and specified accordingly:

Living components encompass any singular or plural living organisms such as plants, animals, humans, fungi, protists, and bacteria by giving an equal importance to all forms of life in the ecosystem (Enger and Smith, 2006; Taylor, 1986).

In its origin, the word nature comes from the Latin term *natura* and is related to “born” and directly connected to life. However, due to its etymological richness and conceptual breadth in various contexts, the term nature is one of the most “complex” words in the language (Proctor, 1998; Andreas Roepstorff & Bubandt, 2003; Soper, 1995). That’s why studies in the literature suggest different understandings towards the concept of nature (e.g., Bookchin, 1996; Descola et al., 2014; Gissen, 2012; Lähde, 2006; Mittelstraß, 2014). Meanwhile, establishing the relationship between nature and humans, either as they are distinguished or united, separates these interpretations into two different poles (i.e., Western nature-culture dualism and non-Western and contemporary approaches as explained in Section 2.1). Therefore, it is important to stress that this research needs to specify its understanding of the different interpretations of the concept of nature and its approach towards the relations between humans and nature.

In my opinion, this determination as living components contributes to the understanding of this thesis in two advantages. Firstly, it helps to instrumentalize

the concept of nature by keeping the main focus on the practical use of living organisms, thus narrowing down the scope of the study by excluding the discussions on the non-living elements of nature (e.g., air, soil, light, wind, etc.). Secondly, this determination implies a “biocentric” approach by accepting humans as part of the natural environment like other life forms such as bacteria, algae, animals, and plants.⁴ In this way, the study determines its attitude towards the relationship between nature and humans by taking into account alternative concepts encompassing human, human-made, and living elements of nature all together (e.g., the works of Descola, Bookchin, Haila, and the concepts like; *Next Nature*, *Subnature*, *Dark Nature*, as elaborated in Section 2.4).

Manufactured Components in the Development of Technology

The concern of the thesis in the concept of technology determined as ‘manufactured components,’ and specified accordingly:

Manufactured components encompass “man-made” technologies, which are associated with the term “artificial” or “non-natural” in academic debates (e.g., Bader et al., 2016; Heinrich et al., 2019; Myers, 2018; Mensvoort and Grievink, 2012).

The word technology originates from a combination of two Greek words: *techne* and *logos*. *Techne* means “technique, art, craft, or skill”; *logos* means “to speak of.” In this way, the term technology initially covers any man-made practice in various domains, scales, and disciplines among an endless number of applications, from humankind’s first developed tools to the newest innovations. However, similar to the concept of nature, technology implies a vast concept with different understandings; thus, various definitions by many scholars (Poelman, 2005). For example, according to Schön & Rein (1994), technology indicates a tool,

⁴ The “biocentric” approach, also called “life-centered environmental ethics,” respects all forms of life by giving an equal moral right and value. Different attitudes could be found regarding the biocentric approach, while ‘biocentric egalitarians’ like Taylor (1986) believes that humans are not superior over other life forms (Enger and Smith, 2006).

technique, and process. Rouse (1993) explains technology as the application of scientific knowledge resulting in practical implications. Moreover, it is also possible to come up with certain distinctions on technology in both academic (i.e., scholarly sources like articles, books, official websites) and popular literature (i.e., social media, unofficial websites), such as ‘low-tech’ (simple, often tradition, and easily practicable technologies using little energy and sources), and ‘hi-tech’ (opposite to low-tech, the latest technology available) (Falk and Lyson, 1988). Furthermore, lately, ‘smart’ is widely used to describe technologies with a level of intelligence by means of being connected with internet networks, such as automation systems, IoT, and sensors (e.g., Balta-Ozkan et al., 2013; Kasier, 2015; Marikyan et al., 2019). Thus, this research needs to be careful about its approach regarding technology by avoiding any misunderstandings.

In my opinion, this determination as manufactured components contributes to the understanding of this thesis in two advantages. Firstly, it helps to instrumentalize technology by avoiding misunderstandings through altering determinations towards technology concepts. Secondly, this determination brings a neutral position by not limiting the study with terms like ‘hi-tech,’ ‘smart’ and ‘intelligent.’ At this point, one could argue that everything around us is already manufactured including even gardening, agriculture, in fact, the concept of time. This study is not against this idea; in fact, it embraces any man-made interference, including smart technologies, and non-smart ones in common sense as well. What is focused on here is technology allowing the incorporation of living organisms. For example, wearable technologies (e.g., smartwatches, clothing, bracelets) are smart technologies. They can be known as ‘biosmart’ by indicating an interrelation between a living component (the human body) and a technological apparatus. On the other hand, for example, self-growing furniture made from mushrooms seems irrelevant to the term ‘smart,’ even though it offers a smart way of approaching the production system (e.g., Appels et al., 2019; Klarenbeek, 2019; Stott, 2014). In this way, ‘smartness’ is already included within manufactured component determinations by implying that modern technologies must be covered. However, this determination chooses to emphasize man-made interference in a general

sense to retain the study's focus on incorporating living organisms, regardless of classifications of their technology (i.e., smart, high-tech, low-tech) or domains, functions, scales, or purposes.

Building Components in Building Design

The focus of the thesis in building design determined as 'building components' and specified accordingly:

Building components implies a 'conventional' term frequently used in building design to describe various building design elements such as; walls, columns, stairs, and many more.

Before determining biobuilding components, from my view, it is essential to stress how this thesis outlines building components in building design. A building can be regarded as a composition with its internal and external parts assembled from segmented levels corresponding to different scales (Brand, 1994; Duffy, 1990; Leupen, 2004). Concerning the combination of different components in a building, building design incorporates various extents, not only in design and practice but also in history and theory, by crossing multiple disciplines such as industrial design (Phocas, 2015; Poelman, 2008), engineering (Gibson, 2012), and urban design (Ratti & Claudel, 2016). In this thesis, to embrace buildings as a combination of individual but connected products as building components eases our attempts to trace their impact(s) on building design. Moreover, this study narrows down its focus by determining building components as products (objects or systems) that could be integrated into buildings by excluding the factors related to urban context from its scope.

Bio-Components

In academic and popular literature, the prevailing descriptions of the innovations incorporated with living organisms are: "bio," "smart," "intelligent," "living," "growing," "eco," and "organic" (e.g., Imani et al., 2017; Ivanić et al., 2015; Oguntona and Aigbavboa, 2017; Speck et al., 2017; Shu et al., 2011; Valdecasas and Wheeler, 2018; Mensvoort and Grievink, 2012). Among those terms and

prefixes, it seems possible to grasp two prevailing categories. Living, growing, eco, and organic can be associated with nature-based concepts by means of describing the living side of the interrelation with the characteristics of natural elements. On the other hand, “smart” is a blanket term for innovative technologies with some degree of artificial intelligence (Alam et al., 2012; Arunvivek et al., 2015; Dawid et al., 2017; Hong et al., 2016; Marikyan et al., 2019). Therefore, it represents the current understanding in the literature describing the manufactured side of innovations.

At this point, the term “bio” mediates the descriptions of both living components (living, growing, eco, organic) and manufactured components (smart, intelligent). That is because, with the help of technological advancements, a wide range of bio-derived concepts explains the various ways to connect, inspire, utilize and merge with nature as such; “biodesign” (Myers, 2018), “biomimesis” (Benyus, 1997), “bioinspiration,” (Gruber, 2013), “bionics” (Wahl, 2006), “biophilia” (Caperna, 2017), “biocentric” (Mathews, 2011), and “bioarchitecture” (Ripley & Bhushan, 2016). As mentioned here, each term represents a different discipline, and therefore various scopes and approaches. However, despite the number of bio-derived concepts, there is a lack of a blanket term specified on the interrelation of living and manufactured components in the existing literature (Deuerling et al., 2018; Kirbas Akyürek et al., 2020; Shu et al., 2011). Therefore, this study puts forward its own determination on the intersection of living and manufactured components as ‘bio-components,’ and specifies accordingly:

The innovations (objects or systems) are incorporated with living organisms in all scales, domains, functions, and disciplines.

The reasons behind focusing on the terms with “bio” shall be further critiqued as the study unfolds in the following chapters (Chapter 3, Chapter 4, Chapter 6).

Biobuilding Components

The focus of the thesis is the use of biobuilding components (instead of conventional building components) in building design, specified accordingly:

Biobuilding components address bio-components that could be used as building components in different building parts.

Among the number of terms and definitions with “bio” (Chapter 3 explains the similarities and differences within these concepts and their use in building design, Table 3.1 demonstrates the approach and scope of each concept), there are a limited number of transformed terminologies in building design, by means of the configuration of terms and concepts related to architectural discipline. Indeed, there is no determination like ‘biobuilding’ or ‘biospace’ in the existing literature (Kirbas Akyürek et al., 2020). “Biodesign” and “bioarchitecture” might seem relevant for this study at first. Bioarchitecture embraces bioinspired design by converging architecture, engineering, and art, and encompasses solutions and opportunities presented by living and non-living components of nature (Eryildiz and Mezini, 2012; Pourjafar and Branch, 2011; Ripley and Bhushan, 2016). Thus, bioarchitecture is not suitable to underline the incorporation of living organisms by means of focusing on certain analogies between architecture and nature (e.g., formal, historical), not practical aspects. “Biodesign” might seem more relevant to the incorporation of living organisms. In his book, William Myers (2018) demonstrates the incorporation of living organisms with several examples (including buildings, products like furniture, clothing, etc.) However, the term indicates a more extensive approach suitable for all design disciplines, as Myers stated in his own words in the interview (Appendix A Interview transcripts). Furthermore, to adapt a well-known term like biomimicry and then to stress the practical use of living organisms would seem to be an option. However, this can also cause misunderstandings. Therefore, none of the bio-derived terms seems appropriate to express the focus of the study on the incorporation of living organisms.

That’s why, I embraced the term biobuilding components in this thesis scope. The following opinions and attitudes can be made from here. The combination of ‘bio’ and ‘building components’ provides an explicit emphasis. By staying connected with bio-derived concepts, the term leads us to discuss ‘bio’ products, which can be found in discussions within both living and manufactured building components

in building design. Moreover, this definition will also be elaborated on in the following Chapters (Chapter 3, Chapter 4, Chapter 6). Furthermore, concerning the vast and unpredictable number of innovations that could be accepted as a biobuilding component, selection criteria for the examples in the study are explained in-depth in Chapter 4, Section 4.1.

All in all, in my opinion, the issues clarified above help me to signify the precise framework of the thesis. They also deliver an understanding of the used terminology for the following part of the thesis. Moreover, this helps to increase the strength of the thesis's understanding within complex terminology of the emerging field. The next section explains the problem field of the thesis.

1.1.2 Potentials & Problems

By representing innovative products incorporated with living organisms finding a place in building design, biobuilding components arise in the knowledge gap in-between living and manufactured building components. Accordingly, the problem field of the thesis entails two significant academic debates in the literature: firstly, the key benefits of using living organisms for buildings; secondly, smart technologies finding a place in buildings. The main potential that this study established is the tendency of these two different backgrounds to 'grow' towards each other gradually in building design with biobuilding components.

First of all, to understand the importance of biobuilding components, it is essential to look into the use of living organisms as building components in building design in contemporary architecture. Living organisms have often provided smart and sustainable solutions for buildings by considering the demands of Western society (e.g., energy efficiency, renewable resources, managing and reducing waste) (Oguntona & Aigbavboa, 2017; Pawlyn, 2011; Pedersen Zari & Storey, 2007; Vincent, 2016). That's why living organisms have often been utilized for resolving the environmental challenges of today with an increasing need for energy, resources, and raw materials from the developing world (Farmer, 1999; Koelman, 2004; Winn et al., 2012). For this argument, wooden structures could be given as a very conventional example, since utilizing plants for wood, and timber

production determines a renewable resource and provides well-known benefits by reducing CO₂ emissions and fossil fuel energy consumption in buildings (Buchanan, 2007; Gosselin et al., 2016).

Moreover, design principles could be emulated from living organisms by learning from their biological forms, processes, and systems and implementing design strategies into the buildings (Marshall & Lozeva, 2009; Pawlyn, 2011; Pedersen Zari & Storey, 2007; Vincent, 2016). Thus, the embracement of the logic of nature within living organisms (i.e., growth, self-repair, adaptability) in building design could create harmony with the environment (Eu, 2019; Nkandu and Alibaba, 2018; Vallas and Courard, 2017). In that sense, with the help of bio-derived concepts and computational technology, buildings have been designed as living, dynamic, and fluent forms and structures inspired by natural elements in the last decades (Heinrich et al., 2019; Ratti and Claudel, 2016). For example, applications in building scale, especially in office buildings, such as in a responsive façade providing daylight control in Al-bahar Towers in Abu Dhabi (2012), take an important place in existing construction practice as well as in literature (Hosseini et al., 2019). Likewise, in the case of Waterloo International Terminal (1994) in London, designed by Nicholas Grimshaw & Partners, the flexible scale arrangement of the Pangolin is mimicked in the glass panel fixings so that they can move in response to the imposed air pressure forces (Aldersey-Williams, 2003). As another example, the “breathing skin” of Eastgate Building (1996) in Harare, Zimbabwe, provides an energy-efficient air ventilation system based on the principles and methods abstracted from termites and termite mounds (ElDin et al., 2016).

At this moment, the key benefits of living organisms for building design are as mentioned here, especially from a practical point of view. Still, they are also driven by an alternative awareness and learning in the domain of building design and construction based on the studies in theory on the bonds between nature concept and buildings (Armstrong, 2015; Gruber, 2011; Ratti and Claudel, 2016; Ripley and Bhushan, 2016; Vallas and Courard, 2017). A rich history lies behind bonding living organisms in nature with buildings, since the (symbolic, analogic, and

metaphorical) meaning(s) of nature for the production of space is one of the critical aspects of architecture's disciplinary conditions from pre-modern to contemporary architecture (i.e., imitation, mimesis, metabolism) (e.g., the works of Marc-Antoine Laugier, Quatremere de Quincy, Frank Lloyd Wright, and Kisho Kurokawa, as examined in Section 2.2., Figure 2.1). Therefore, it seems that living components have already been adapted as 'living building components' in building design depending on both practical and theoretical bonds with the concept of nature and building design.

Second of all, to understand the importance of biobuilding components, it is essential to look into the integration of smart technologies in contemporary building design. The advances in computational technology have accelerated the developments of technologies, thereby resulting in 'smart' technologies becoming tools for supporting the quality of daily lives in the built environment (Desolda et al., 2017; Wolter and Kirsch, 2017; Yang et al., 2008). In this way, the physical world can be united with digital systems with the design of smart environments by promising to ease daily tasks, housing chores (Allameh, 2016; Hong et al., 2016; Marikyan et al., 2019), etc. Accordingly, smart technologies have motivated architects to design smart environments, buildings, especially smart offices and smart homes (Aldrich, 2003; Alam et al., 2011; Arunvivek et al., 2015; Dawid et al., 2017; Mohammadi and Hammink, 2015). Thus, the term 'smart' has become a 'buzzword' of studies in building design discussing user-friendly industrial products empowering the interaction between people and their surroundings (e.g., Arunvivek et al., 2015; Balta-Ozkan et al., 2013; Hammink et al., 2019; Hong et al., 2016).

Moreover, in building design, a variety of projects (e.g., showcases, installations, living labs) have introduced visions of the future of everyday life by foreseeing the success of various (smart) technologies (Mohammadi, 2014; Vegesack, A. and Eisenbrand, 2006). Many of the experimental technologies of that time have been presented in buildings that can now be seen as very conventional or even outdated (e.g., microwave in Dymaxion House, 1927, solar systems in House of Tomorrow, 1933, see Section 2.4). In contemporary buildings, having smart technologies like

security, HVAC, wireless and surveillance systems, and controlling them by smartphones has become frequent and omnipresent (see: Section 2.2, Figure 2.2). Furthermore, the internet of things, big data, pervasive and mobile computing, sensor networking, and artificial intelligence have often found a place within contemporary discussions in building design (Cook and Das, 2007; Coosje Hammink et al., 2019; Lavirotte et al., 2015). However, just a couple of decades ago, wired homes resembled ‘science fiction’; only the ‘hobbyists’ were envisioned as having them (Harper, 2003). Indeed, ordinary home technologies of today like washing machines, electric razors, kettles, and cookers were uncommon before the 1960s. Likewise, the first rise of domestic appliances like fridges, dishwashers, and vacuum cleaners started in the 1920s (Aldrich, 2003). For this reason, it seems that manufactured components have already been adapted as ‘manufactured building components’ in contemporary building design. More technologies are expected to be integrated into the near future.

At this juncture in building design, the emerging praxis of incorporating living organisms arises at the intersection of these two studies. By this means, technological developments in the industry have manifested a variety of innovative products in which living and manufactured components have been intertwined with an increasing momentum (i.e., technologies in the fields of biomaterial production, biotechnology, bioengineering, etc.) (Bernabei and Power, 2016; Camere and Karana, 2017; Dunne and Raby, 2013; Ginsberg et al., 2014; Karafyllis, 2006; Kleinert, 2018; Koivunen, 2005).

Among these innovations, various could be applied as building components such as walls, facades, and structural and interior elements (Myers, 2018; Ripley and Bhushan, 2016). In this way, this interrelation with living organisms embraces environmental responsibility by carrying out a wide range of sustainable solutions for buildings (Vallas and Courard, 2017), and smartness by providing alternative solutions to new questions in the midst of uncertainty (Gruber, 2011). For example, self-healing concrete with bacteria (Jonkers, 2007), a lamp generating energy through the photosynthetic process of the plant (Living Light-Lamp, van Oers, 2016), acoustic panels growing biodegradable products through mushroom

and mycelium (Appels et al., 2019), and living wall systems supporting the HVAC systems of buildings (“Green Wall - Cloud Garden - Circular wall system,” 2018) are now on the product market and can be applied as alternatives to conventional building components.

In this context, biobuilding components are becoming highly relevant for market conditions, as notions like sustainability, smartness, and environmental responsibility are becoming key subjects which appeal to the ‘value system’ of consumers and get instrumentalized for economic strategies. In other words, biobuilding components are already introduced to society and in the growth phase of the ‘industry life cycle,’ therefore they might reach ‘maturity’ in the near future considering the well-known concept of the innovation S-curve (Rogers, 2003) (Figure 1.2).

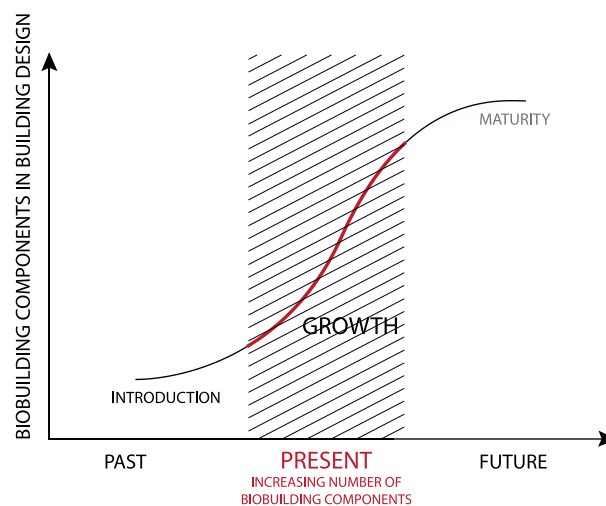


Figure 1.2 The Increasing Number of Biobuilding Components

In this regard, the number of biobuilding components has been increasing gradually and is about to infiltrate into our everyday lives and surroundings, affecting the built environment. Therefore, it seems possible to discuss the evolution of the research questions related to the integration of technological developments in building design, shifting its focus from smart technologies to biobuilding components (Figure 2.17). Indeed, designing with living organisms seems to have become a topic of interest over the past years in building design.

Possible examples could be the design experiments, publications, conferences, and exhibitions initiated by the Mediated Matter Group at Massachusetts Institute of Technology (MIT) (Oxman, 2015), the book of William Myers (2018), *Biodesign: Nature+Science+Creativity*, and design exhibitions curated by him, such as *Biodesign: From Inspiration to Integration* held between August 24 and September 27, 2018, in Rhode Island, USA. Furthermore, *Growing Pavilion* in Dutch Design Week 2019 and *Circular Garden Installation*, Milan Design Week 2019, could also be examples of design exhibitions with such installations.

Moreover, many studies have already sought to enhance technical features and beneficial attributes of innovative materials and construction techniques to incorporate living organisms (Gruber et al., 2018; Joachim, 2010; Oxman, 2015). In *GrAB Growing As Building Project*, Barbara Imhof and Petra Gruber explore the potential of slime molds (unrelated eukaryotic organisms) in building design by experimenting with their growth through the grid structure and building design simulation (Gruber & Imhof, 2017a; Imhof & Gruber, 2015). In the Mediated Matter Group of Massachusetts Institute of Technology (MIT), Neri Oxman designs *Silk Pavilion* as a 3D space fabricated with silk together with digitally-aided silkworms (Oxman, 2015; Oxman et al., 2012). In the *Fab Tree Hab* project, Michelle Joachim seeks to find a way to “grow” a building through plants by adapting a gardening method called “pleaching” into building design and construction (Arbona et al., 2003; Joachim, 2010). Similar to the innovative housing projects (as elaborated in Section 2.4), these experiments have introduced visions of the recent technological developments. They explore the interrelation of living and manufactured components in building design and provide answers to their advantages for biodegradability, growth, and self-repair. Henceforth, within the rapid and comprehensive growth of technology, the numbers of biobuilding components have increased exponentially in the product market (Figure 1.3). Accordingly, many aforementioned studies have already presented the advantages, innovative solutions, and possible uses of biobuilding components in the academic and popular literature, along with the experimental

studies in building design. Despite the importance of this experimental research, much uncertainty still exists about the relation between biobuilding components and building design. In my opinion regarding my findings in the literature review, the connections between the two facets of biobuilding components (living and manufactured) seem to be missing in the existing literature. Moreover, the studies in the building design domain (e.g., GrAB, Baubotanik, Silk Pavilion as discussed in examples above) mostly stay within a single perspective by discovering the advantages, technical attributes, and possibilities of a particular type of living organism, thus specific biobuilding components. In this sense, there is a need for further studies in building design that will create knowledge and overall understanding by looking into different perspectives (i.e., different studies, different biobuilding component examples, different living organisms).

Accordingly, from my view, this thesis is formulated to provide contributions to fill this gap in the literature. The research objectives and research questions are explained below and how this problem field shall be researched is presented in the methodology section.

1.2 Objective of Thesis and Research Questions

The objective of this study is to yield knowledge of biobuilding components through their theoretical and practical implications which lead us to deliberate their expected impacts on building design. It is also to provide recommendations for architects and future research and practice in the building design domain. Accordingly, the main research question of the thesis is determined as follows:

How would building design be affected by biobuilding components?

This thesis focuses on bringing knowledge in this emerging praxis of the incorporation of living and manufactured components in the building design domain, thereby bringing consciousness and profound comprehension by looking through both theoretical and practical points of view. With this view, this study seeks to empower architects and designers' consciousness in building design

practice rather than developing a design theory. For this reason, this main research question is twofold: 'Why' and 'How.' The first question should be 'Why,' otherwise especially for this technology-driven topic in an emerging field, 'how' questions cannot be appropriately answered.

RQ01: Why building design would be affected by biobuilding components?

This first question seeks answers to the reasons that make biobuilding components a critical subject for building design. This fundamental 'why' question has been broken down into two (2) sub-questions:

RQ1.1 Why biobuilding components could affect building design by addressing both living and manufactured components? (Chapter 2)

RQ1.2 Why the integration of biobuilding components could affect building design? (Chapter 4, Chapter 5, Chapter 6)

In this way, RQ1.1 seeks to provide a better understanding of the meaning(s) of biobuilding components for building design from a theoretical point of view; thereby, establishing a theoretical basis for the study. RQ 1.2 seeks to understand biobuilding components from a practical point of view by providing answers for the motive behind their integration into building design.

RQ02: How could biobuilding components find a place within the current building design practice?

This second question seeks to determine the examples of biobuilding components through their expected use in the current practice and theory in building design.

The sub-questions are:

RQ2.1 What are the concepts, terms, and methodological approaches related to biobuilding components in the building design domain? (Chapter 3)

RQ2.2 What are the characteristics of biobuilding components along with their relevancy to the building design? (Chapter 4)

Overall, RQ2 and its sub-questions (RQ2.1, 2.2) seek to provide an overview of biobuilding components by evaluating the biobuilding examples, terminology (RQ2.1), and possible use(s) in the building design domain (RQ2.2).

RQ03: How biobuilding components could be integrated into the buildings?

This third question seeks to bridge findings in theory and practice by analyzing the integration of biobuilding components into building design. The sub-questions are:

RQ3.1 What are the opportunities and barriers that can affect the integration of biobuilding components into building design? (Chapter 5, Chapter 6)

RQ3.2 What is the current design process of the integration of biobuilding components into building design? (Chapter 6)

In this way, RQ03 and its sub-questions (RQ3.1, 3.2) seek to provide answers on the possible ways to integrate biobuilding components into building design by revealing the design process, opportunities, and barriers.

The following section elucidates the methodology of the thesis and shows the research model of the study (Figure 1.3) applied to provide answers to the research questions mentioned above. At the end of the Introduction Chapter, Figure 1.4 demonstrates the connections between research questions, the chapters, and the research model.

1.3 Methodology

This thesis carries out an exploratory study by embracing different general and practical aspects of building components by combining multiple disciplines and methods. Firstly, this section of the study explains the research model of the thesis in connection with the theoretical framework. It elucidates in detail what variables are being studied, which methods are used, and how they are connected to operationalize the aforementioned Research Questions (Section 1.2).

This thesis applies the research model below (Figure 1.3) and presents itself as threefold: *Background* (Chapter 2), *Overview* (Chapter 3, Chapter 4), and *Analysis* (Chapter 5, Chapter 6). The *Background* part of the thesis provides comprehensive literature research by approaching biobuilding components from different angles (i.e., a systematic combination of multiple literature reviews regarding the relationships between nature, technology, and building design). Thus, it underpins the interrelation of living and manufactured components from a broader perspective. Then establishes a theoretical basis of the study by elaborating on the shifting notions of nature and technology. Further on, the *Overview* part of the thesis looks into the current design practices of biobuilding components in the industry. It encompasses data gathering, including a literature review on related concepts, terms, definitions, methodological approaches on biobuilding components, and examining different examples (i.e., determining biobuilding components from multiple domains such as fashion and textile, energy, light, building design). On the theoretical basis established in *Background* and the findings of the *Overview*, the *Analysis* part of the study concentrates on the integration of biobuilding components into buildings by carrying out two studies that apply qualitative research methods: a design experiment with architecture students, and interviews with practitioners. It then gives an understanding of the design process of the integration through the translations of biobuilding components from industrial to building design by revealing the opportunities and barriers. Accordingly, the findings in the *Analysis* part lead us to present recommendations for architects and future studies for the building design domain. Overall, that is how the different parts of the study are connected to its theoretical framework.

The *Background* part of the study provides answers to RQ1.1 by looking into different relations in the literature; firstly, nature-building design; secondly, technology-building design; thirdly, nature-technology; fourthly, nature, technology, and building design. Scholarly databases, Jstor, ScienceDirect, Scopus, and Google Scholar, were used to find relevant sources, including books, academic and popular articles, booklets of exhibitions and demonstrations, and

conference papers, in addition to printed publications. Different keywords, limitations, and scopes are determined in each section, as shall be explained individually.

Initially, Chapter 2 needs to start with giving information on the concept(s) of nature (Section 2.1) to underpin studies exploring the relationships between nature and building design (Section 2.2), nature and technology (Section 2.4), and nature, technology, and building design (Section 2.5). Thus, Section 2.1 presents an introduction that embraces studies from social sciences found with the following keywords and their combinations: *nature concept*, *nature and culture dualism*, *nature and human*, *human and non-human*, *philosophy of nature*, *social determinism*, *biological determinism*. However, these keywords indicate a comprehensive bibliography out of the focus of the thesis; therefore, this part of the study is limited to inquiries highlighting the complexity of the nature concept with altering understandings and different interpretations on the relations between nature and humans (e.g., the ‘Western’ dualistic way of thinking on nature and culture, and alternative non-Western approaches).

Section 2.2 presents a literature summary of the changing dynamics in building design through the concept of nature. This summary is a historical literature review focusing on the meaning of the living organisms in building design concerning the concept of nature. It starts from the critical example in architectural history, Primitive Hut by Marc-Antoine Laugier, then traces the evolution of the (analogical, symbolic, and metaphorical) meaning(s) of nature within buildings design examples (e.g., mimesis approach of Quatremère de Quincy, Organic architecture by Frank Lloyd Wright, Metabolism Movement by Kisho Kurokawa) (Figure 2.1). This part of the study determines that the impact of the concept of nature on building design has a long tradition, by evaluating the historical, phenomenological, and practical meanings of living components in the building design examples. The examples were chosen with the help of different combinations of three keywords in three main categories: first, the ways of bonding with nature; *inspiration*, *mimesis*, *imitation*, *mimicry*, *analogy**, *symbolic**,

*metaphoric**; second, an emphasis on *living components* such as *natural elements*, *living*, *living elements*, *living organisms*; third, the related discipline, *architecture*, *architectural design*, *buildings*, *building design*. Within that vast and comprehensive bibliography, only one specific, well-known example (e.g., Falling Water House, Sydney Opera House) is further evaluated to discuss different understandings of nature in building design. Meanwhile, examples related to the urban context and the impact of non-living elements of nature (e.g., sun, air, wind, etc.) are excluded.

Section 2.3 presents a literature summary of the changing dynamics in building design through the development of technologies. This summary is also a historical literature review, starting from the arrival of electricity into the built environment to the integration of current smart technologies into building design. It discusses the rise of time-saving technologies in the early 20th century (domestic technologies such as the vacuum cleaner, electric kettle, etc.), time-consuming ones in the 1960s (televisions, personal computers), and smart technologies since the 1980s (home automation systems, internet, VR systems, etc.) (Figure 2.5). The studies included in the scope of this section were found with the following keywords: *smart*, *smart home*, *smart environment*, *smart building*, *smart technologies*, *smart home technologies*, *innovative housing projects*. Studies related to *smart construction systems* and the *smart grid* are left behind the scope of the review. This part of the study discusses that the impact of technological developments, especially the practical meanings of small-scale technologies, on building design has a long tradition. This leads us to underline the changes in the phenomenological meanings that technologies, once defined as ‘futuristic,’ ‘odd’ technologies (e.g., the microwave), are now fully integrated into buildings. Meanwhile, the works of Vegesack, A. and Eisenbrand, J. (2006), Aldrich (2003), and Mohammadi (2014) play important roles to underpin this argument by arguing the changing dynamics in building design through the integration of technologies.

Section 2.4 investigates contemporary studies focusing on the shifting notions of nature and technology (e.g., Descola et al., 2014b, Gissen, 2012, Mensvoort and Grievink, 2012). The studies in this part are included regarding their contents by means of their possible contribution to a better understanding of the praxis of design with living organisms. Thus, this part of the study leads us to underpin the interrelation of living and manufactured components through contemporary concepts that bring new understandings to the concept of nature, thus providing an introduction to the following Section 2.5.

Section 2.5 presents a discussion on the changing dynamics in building design with the interrelation of living and manufactured components. This discussion is conducted with the examples in building design, presented in the current decade, exploring the incorporation of living organisms in building design. It shows the evaluation research questions of the experimental studies under the influence of technological developments in the building design domain by synthesizing the findings from literature research (Figure 2.17).

Overall, Chapter 2 constitutes the *Background* of the study by evaluating the different meanings (historical, phenomenological, philosophical, practical) of the interrelation of living and manufactured components with comprehensive literature research. Thus, it concludes with a hypothesis, as an answer to RQ1.1, that incorporating living organisms into design seems significant in the discipline of building design with the expected impacts of biobuilding components considering the relationships between nature, technology, and building design. In this way, the *Background* part of the study provides answers to RQ1 by giving insights on the meanings of biobuilding components in theory; RQ1.2 seeks to find answers from a practical point of view. Therefore, RQ1.2 is answered along with the findings in the *Overview* and *Analysis* parts.

The *Overview* part elaborates on the practical aspects of the interrelation of living and manufactured components to answer RQ2. It gives information on the concepts and methodological approach currently used to determine biobuilding

components; it also presents a data collection of biobuilding components met with the determined criteria (Figure 4.2).

To begin, by providing answers to RQ2.1, Chapter 3 presents a literature review by determining its focus on the most-used bio-derived terms and definitions on biobuilding components (e.g., “biodesign,” “biomimicry,” “biophilia,” etc.) (Figure 3.1). In this way, this part of the study plays a mediator role between the *Background* and *Overview* part by giving information on the resonance of biobuilding components in the existing literature (Table 3.1). However, the literature review seems too limited to provide accurate terms and definitions. Therefore, this part of the study suggests a research terminology (Figure 3.2), including exploration of terminology in the gathered examples (Figure 4.5), and the most-used terms of the experts working with biobuilding components (Table 6.6).

Additionally, by seeking to provide answers to RQ2.2, the thesis carries out data gathering in Chapter 4 to give an overall understanding of biobuilding components in building design within current academic and popular literature. For this reason, the study includes both academic (e.g., scholarly articles, books, and published research papers) and non-academic (e.g., non-scientific platforms such as; official company websites, news, non-academic articles) sources, since non-academic sources help us to collect up-to-date information on the examples in the current practice. They must exemplify the interrelation of living and manufactured components; they are not limited through their domains, disciplines, or keywords. Certainly, it is not feasible to compose all biobuilding examples due to their endless spectrum and large number. Therefore, the examples, indicating the incorporation of living organisms, are filtered through two steps (Section 4.1.1). Firstly, the examples are limited by addressing prototypes at *envisioned*, *operational*, and *applied* levels based on the technological level of integration in the Pyramid of Technology by Mensvoort (2013a). The Pyramid of Technology offers certain levels of technology (“envisioned,” “operational,” “applied,” “accepted,” “vital,” “invisible,” and finally “natural”) with a claim that by following these steps, any technology can become a natural part

of daily life (Mensvoort, 2013a). As a starting point, The Pyramid of Technology (Mensvoort, 2013a) helps to limit the examples (Figure 2.6) by evaluating the existing and prospected relationship between the biobuilding components in society and our daily lives as well. Secondly, the examples are limited with certain building layers: “structure,” “skin,” “service,” “space plan,” “stuff,” and “servant”; by adopting the theory of Brand (1994) as an assistive tool (Figure 4.2). In this way, Brand’s layers (1994) enable us to determine the relationship between biobuilding components and building design, thereby looking through the architects’ viewpoints on the expected building design impacts. Accordingly, the scope of the examples is determined (Figure 4.2). Then, 70 biobuilding components are examined and presented in Table 4.2 with their necessary information (name, year, initiator, domain), their main characteristics along with their practical implications (‘goals,’ ‘objectives,’ ‘implementations’), and their relevancy to building design (integration layers). Meanwhile, the key findings from the determination of biobuilding components are summarized in Table 4.3 and further discussed.

Moreover, as the conclusion of the *Overview*, multi-level perspective (MLP), an analytical tool, leads us to evaluate biobuilding components by delivering knowledge of the connection between different scales of impacts (micro, meso, and macro). This tool emphasizes the social aspects of technological transition through the contribution of multiple actors such as scientists, policymakers, users, and special-interest groups to the patterning of technological development (Geels and Schot, 2007). By embracing MLP as a filter, Chapter 4 discusses the connection between biobuilding components (micro), building design (meso), and environment (macro) (Figure 4.6, Figure 4.7). By this means, we can better express the technological meanings of biobuilding components within social and technological change along with the key findings of the *Overview*, thereby providing answers to RQ1.2.

The *Analysis* part carries out two qualitative studies by seeking to provide answers to RQ3. The expected impacts of biobuilding components through their

integrations into building design are explored with two groups of actors: architecture students (future architects); and practitioners (architects, interior designers, product designers/developers, biologists, academicians, engineers, fashion designers, i.e., experts working with biobuilding components as found in the *Overview* part).

Firstly, design experiments are conducted as a combination of various design tasks in two phases: ‘warm-up’ and ‘research,’; and also with an auxiliary survey. They were held from September 2018 to January 2019 with a gender-equal group of sixteen (16) first-year architecture undergraduate students as a part of the first-year design studio project at Yildiz Technical University, Istanbul-Turkey. The qualitative data was gathered as the transcriptions of the verbal data of the presentations of the students. This data was analyzed with the Protocol Analysis (PA) method as retrospective reports allowing the encoding of the cognitive approaches and problem-solving abilities of designers (Cross, 2001; Dorst and Dijkhuis, 1995; Lawson, 2005; Suwa and Tversky, 1997). Moreover, the tasks of the students, sketches, systematic observations of the author, and retrospective reports, were examined as the research findings. Working with architecture students leads us to conduct a research experiment that is empowered through their free minds which are not limited to the conventional architectural norms (Caglar and Uludag, 2006). This experiment was conducted with first-year students, considering them to be more open-minded and freer from the restricted codes of architectural design compared to others. If the design experiment were to provide fruitful results, other design experiments would continue with the students in different years. However, the design experiment offers limited information on the design process of the integration of biobuilding components into building design, since architecture students have limited knowledge of biobuilding components, and during the experiment, it was not possible to work on real biobuilding components. The experiment reveals the opportunities and barriers to biobuilding components in building design through future architects’ perspectives by providing answers to RQ3.1, but it seems insufficient to provide

further answers to RQ3.2. Therefore, the *Analysis* part of the study conducts interviews to look from another perspective with different actors and methods.

The sampling group of the interviews addressed practitioners as the experts working on biobuilding components in different professions: ‘architects,’ ‘interior designers,’ ‘product designers/developers,’ ‘biologists,’ ‘academicians,’ ‘engineers,’ and ‘fashion designers.’ A “chain referral sampling” strategy was applied for the selection of the interviewees. With this, the practitioners already mentioned in the subjected biobuilding components were reached out to, and their suggestions were taken into consideration to reach other practitioners (Table 6.1). This part of the study urged the creation of knowledge of biobuilding components by validating the literature and data gathering findings through the practitioners’ distinct ways of thinking. In this regard, the oral history method was adopted to prepare the questions and conduct the interviews. The use of the oral history method in this study is not to gather information on history but to get insight into the subjects that are not mentioned in ‘official’ sources by recording the experience of people (Beard, 2017; Federer, 2015; Hesse-Biber and Leavy, 2005; Miller-Rosser et al., 2009; Thomson, 2015). Meanwhile, the analysis of individual narratives can provide disciplinary, collective, or social patterns and specific kinds of individual habits that don’t fit into any classification (Miller-Rosser et al., 2009; Portelli, 2009). Accordingly, the interviews were conducted in-depth, preferably face-to-face with multiple actors, motivating interviewees to tell their story with semi-structured open-ended questions and probing questions.⁵ To draw a neutral tone by leading them to express their ideas with their terminology seems crucial. For this reason, the questions were prepared without using or referring to any terms, concepts, or specifications (Table 6.2). During the interviews, these specific

⁵ The interviews are preferred to be conducted face-to-face, but because of the experts’ busy schedules, one interview was conducted by phone, and another one was conducted via Skype. Although the interviewer did not notice any particular differences in terms of the answers given to the questions, the lack of physical connection resulted in experts’ answering only the given questions instead of providing life stories, and experiences which are critical for the method (i.e., oral history) for this study.

terms were used only after the interviewees mentioned them first to express their ideas (Appendix A Interview transcripts)

After concluding twenty (20) interviews with twenty-one (21) practitioners, it was decided that the saturation point had been reached.⁶ Further on, the verbal data of each interview is transcribed into the text, as shown in the Appendix A Interview transcripts (excluding those that are not included upon the special request of the interviewee). Firstly, the findings of the interviews are summarized by explaining the practitioners' answers to each question. This summary leads us to present additional information on biobuilding components that do not currently exist in the official sources, thereby contributing to the answers for RQ2 (RQ2.1 and RQ2.2) and RQ1.2 by delivering the practical meanings of biobuilding components from practitioners' viewpoints. Secondly, by seeking to provide answers to RQ3.2, the theoretical "thematic approach analysis" method is chosen to analyze the interviews' transcriptions. Thematic approach analysis is a flexible method of identifying patterns or themes within qualitative data (Braun and Clarke, 2006; Clarke and Braun, 2013; Evans and Lewis, 2017; Jodi, 1994; Lynass et al., 2012). This method leads us to determine four design stages; "realization," "production," "exploration," and "translation," indicating the design process of the biobuilding components' development and their integration into building design (Table 6.13). Meanwhile, the design process determined by Roozenburg and Enkels (1994) helps us to determine the relationships between these design stages (Figure 6.2). Moreover, these design stages are further discussed through three examples (both examined in the *Overview* and within interviews) (Table 6.14).

After answering all the research questions, the thesis presents different meanings (theoretical, practical, technological, architectural, educational) of biobuilding

⁶ In qualitative data analysis, saturation point or how many interviews are enough relies on the quality of the data along with the researcher's insights instead of the quantity of the interviews. However, the studies show that new information is rarely presented after eighteen (18) interviews as in Guest, 2006, or after 17 as in Hennink, 2016.

components. Then, it elaborates on the expected impacts of biobuilding components concerning these meanings of biobuilding components.

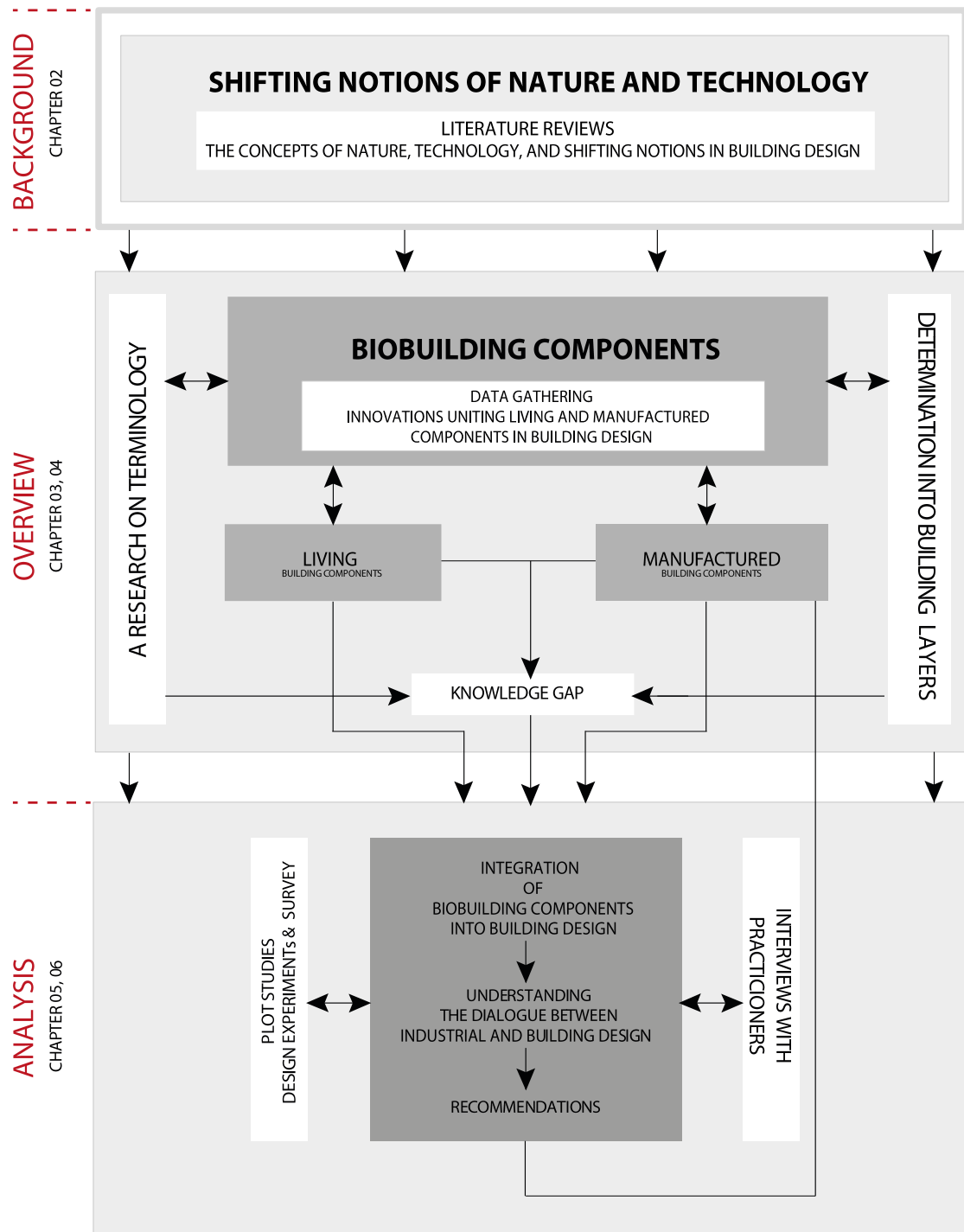


Figure 1.3 The Research Model of the Thesis

In summary, as shown in Figure 1.3, the *Background* part gives a better understanding of the historical, phenomenological, and practical meanings of the interrelation of living and manufactured components looking through a theoretical perspective. The *Overview* part explores existing biobuilding

components and the current terminology in theory and determination, thereby providing discussions from a more practical point of view. The *Analysis* part allows the creation of bridges between theory and practice by exploring how biobuilding components could be integrated into buildings, thereby providing insights for the building design domain.

1.4 Original Contribution

With the growing number of biobuilding components in the industry (Figure 1.2), a large number of aforementioned studies have presented the advantages, innovative solutions, and possible uses of biobuilding components concerning multiple domains (e.g., social sciences, industrial design, energy, light, building design) and multiple actors (e.g., architects, products developers, engineers) as well, in the academic and popular literature. At this point, this thesis embraces a perspectivist way of thinking to yield knowledge of the biobuilding components in building design. Perspectivism brings a novel approach to this technology-driven topic with an urge to embrace the plurality of different, even contradictory, studies, examples, and viewpoints through the value of subjectivity and plurality in creating knowledge. This leads to exploring the expected impacts of biobuilding components by elaborating on the historical, phenomenological, practical, technological, architectural, and educational meanings of biobuilding components all together.

The study examines the motive behind the interrelation of living and manufactured components in building design by showing the changes in the historical, phenomenological, and practical meanings of living and manufactured components initiated from the *Background* part. By this means, this thesis contributes to the current stage of knowledge on biobuilding components in the literature research and gives insights on their architectural impacts in theory. Introducing and examining a variety of biobuilding components in the *Overview* part of the study contributes to the current stage through their practical meanings in the industry (i.e., their use in multiple domains) and building design (i.e.,

relevancy to building design). In this way, this part of the study gives an understanding of the expected architectural impacts of biobuilding components by their relation to different building parts, multiple functions, uses, and advantages. Moreover, this part of the study evaluates the connections between different scales (micro, meso, macro). Thus it reveals the technological meanings of biobuilding components related to their societal impacts. Firstly, the *Analysis* part contributes to the current stage of knowledge on biobuilding components with the findings of the design experiment in the scope of an architectural design studio. Secondly, the interviews with practitioners lead us to present information on biobuilding components by gathering and examining different, even contradictory viewpoints all together. Thus the *Analysis* part of the study contributes to the literature by adding practitioners' and future architects' visions and prospects on the expected architectural and societal impacts of biobuilding components.

From my point of view, this thesis stresses the importance of biobuilding components for building design by revealing their 'multi-perspective impact' by looking through different viewpoints. By this means, each perspective might discuss another meaning and expected impact of biobuilding components. Within this multi-perspective view of biobuilding components, this research enlightens their architectural impacts with their theoretical and practical understandings, different uses, and advantages in building design along with related domains and actors in addition to their specific technological benefits. It then discusses possible social impacts of biobuilding components on building design and vice versa. Thus, this thesis is expected to inspire architects by empowering their knowledge of biobuilding components, thereby aiding them in making decisions to include or exclude them in their designs.

1.5 Structure of the Thesis

All in all, the chapters of the thesis is structured as follows. Figure 1.4 below demonstrates the reading guide of the thesis.

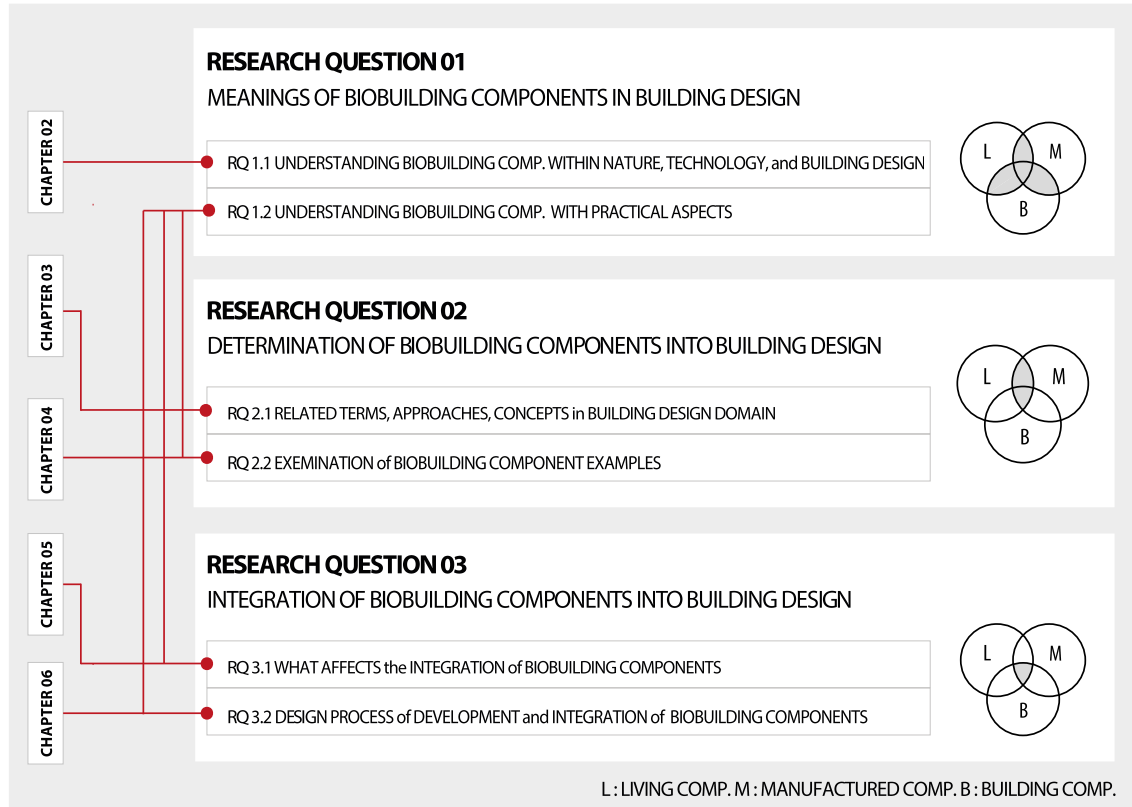


Figure 1.4 The Relations Between Chapters and Research Questions

Chapter 2, The Concepts of Nature and Technology in Building Design

The first chapter of the thesis presents a theoretical background of the study that underpins the problem field. Literature reviews (nature and building design, technology and building design, nature and technology, nature and technology, and building design) lead us to elucidate the broader aspects of biobuilding components in theory by giving a better understanding of the following Chapters. This chapter concludes with a hypothesis that incorporating living organisms into the design has significantly influenced building design. Thus, this phenomenon needs to be discussed in building design with biobuilding components concerning contemporary studies indicating shifting notions of nature and technology.

Chapter 3, Research on Terminology of Biobuilding Components in Building Design

This part of the study presents a literature review on “bio” derived concepts, terms, and definitions in the existing literature. This chapter is concluded that there is a lack of accurate terminology on biobuilding components in the current literature. For this reason, the study suggests research on terminology in the thesis by examining the definitions and terms in biobuilding examples and practitioners’ preferences on terminology.

Chapter 4, Determination of Biobuilding Components in Building Design

In this chapter, the examples of biobuilding components are presented and examined. This chapter provides information about biobuilding components, thus leading us to compose the following analysis part of the study.

Chapter 5, Exploring Biobuilding Components from Future Architects’ Viewpoints

The building design experiment was conducted with future architects; architecture students, analyzing the relationship between biobuilding components and building design, are elaborated in this chapter. This chapter concluded that biobuilding components could be integrated into building design, while the design approach plays a critical role.

Chapter 6, Exploring Biobuilding Components from Practitioner’s Viewpoints

The interviews with practitioners are explained in this chapter, along with the Appendix A showing each interview's transcriptions (excluding two of them kept confidential upon request). This part of the thesis reveals the design process on how biobuilding components are developed and could be integrated into building design. This chapter plays a critical role in the thesis by providing answers on the bridges between industrial and building design.

Chapter 7, Conclusion and Recommendations

This Chapter presents answers to each research question and offers recommendations for architects and future studies in the building design domain based on the key findings of the thesis. Finally, the thesis ends with closing

remarks with hypothetical conclusions indicating my own deductions and future prospects for biobuilding components in the building design domain.

THE CONCEPTS OF NATURE AND TECHNOLOGY IN BUILDING DESIGN

The theoretical background of the thesis is introduced by giving an understanding of the intersections between living, manufactured, and building components within the relationships between nature, technology, and building design. This part of the study delivers answers to the aforementioned RQ1 and associated two (2) sub-questions by encompassing comprehensive literature research involving historical and current studies and various discussions from different angles. The goals of the chapter could be summarized as follows:

- To deliberate the meanings of the interrelation of living and manufactured components in the building design domain by evaluating historical and contemporary studies focusing on the connections between nature, technology, and building design.
- To give insights into the expected impacts of biobuilding components on building design by providing inquiries upon the impacts of nature and technology on building design.

In the scope of the Chapter, to begin with, the concept of nature is introduced through the disputes in the social and behavioral sciences. Thus, better comprehension is provided to the following sections on the variability and subjectivity of nature concept and the contemporary studies putting forward unique approaches towards the relationship between nature and technology. Further on, firstly, a summary of the changing dynamics in building design is presented by explaining the ever-transforming and time-bounded understandings of nature concept through the altering approaches and building examples from pre-modern times to today in the architectural discipline. Secondly, another summary debates the impacts of technological developments on building design by revealing the roles of small-scale products for buildings since industrialization

to contemporary architecture. Thirdly, contemporary concepts manifesting shifting notions of nature and technology are explained and discussed. Fourthly, a discussion part deliberates the changing dynamics in building design through the interrelation of living and manufactured components with contemporary examples in relation to the findings of the literature summaries.

All in all, in my opinion, these way of structuring the literature part of the study provides to give an introductory idea of the expected potentials of biobuilding components through reviewing the relationships between nature, technology, and building design in a systematical and analytical way. These summaries lead us to evaluate historical, phenomenological, and philosophical meanings of biobuilding components, thereby providing insights into the contemporary examples exemplifying the interrelation of living and manufactured components in the building design domain.

2.1 Questioning the Concept of Nature

What is nature? Whose concept of nature must be acknowledged?

The social and behavioral sciences have often entered into discussions on nature by calling these questions (Soper, 1995). This is critical since the term of nature has been altered fundamentally based on the “idea” of nature (Collingwood, 1945). What is highlighted here is that nature is an “unstable concept, prone to change dependent on the cultural and historical context” (Andreas Roepstorff and Bubandt, 2003). In this regard, this part of the study offers significant insights into the ‘open-ended’ debates on the concept of nature from a broader vision.

The term nature is one of the most “complex” words in the language due to its ubiquity in a wide range of contexts (Soper, 1995; 1). The word nature itself is etymologically rich, presenting its conceptual breadth over time (Proctor, 1998). Originally, nature term comes from the Latin term *natura* and has related to “born” and directly connected to life. On the other hand, the Greek word for nature is *physis*, related to “growth.” In addition, through time, three senses have been

embodied within the word nature in English (Williams, 1980). The term nature has represented “mortality” from the thirteenth century. At the beginning of the fourteenth century, nature has been connotated with the inherent force controlling the world and human beings. In the seventeenth century, nature term has also started to indicate the physical world as a whole that might refer to the current understanding of the world of nature today in the English language (Proctor, 1998).

Throughout history, thinking about the concepts of nature has raised several critical philosophical and theoretical issues which constitute the background of the epistemology of nature (Proctor, 1998). “Nature is not a simple concept,” as Jürgen Mittelstraß (2014) manifests, and explains three reasons by revising the altered philosophical views of nature from Plato to Einstein. Firstly, the meaning of nature encompasses the physical universe through biological evolution. Secondly, nature has different meanings in different cultures; as such, Greek tradition distinguishes between creative nature and created nature, meanwhile living in harmony with nature has been an integral part of Indian culture. Today, under the influence of the modern sciences, historically divergent concepts of nature have lost their scientific significance and “universalism.” Thirdly, in the beginning, nature could be identified with the pure world without any impact of man; however, today, a great extent of nature has already become a part of an artificial world built by technology and science (Mittelstraß, 2014).

The concepts of nature do not only emerge for seeking what nature is but also developed through the concern of nature-human relations (Williams 1980). In recent studies, environmental psychologists have shown interest in the concept of nature with an assumption that it might help to mitigate environmental problems (Tam, 2013). Ultimately, two leading positions have come forward for the current debates; one as the human distinctiveness from nature and the unity of humans with nature (Proctor, 1998). For instance, in the non-Western indigenous studies, the relationship between humans and non-humans seemed to be favored (Kawaguchi and Guimarães, 2019). On the contrary, in Western thought, humans

and non-humans were divided by considering nature and “culture” as two separate poles (Daly Bezerra de Melo, 2012; Andreas Roepstorff and Bubandt, 2003).

The so-called Western nature-culture dualism has been elaborated in many studies by numerous authors (Collingwood, 1945; Glacken, 1967; Haraway, 2015; Merchant, 1990; Passmore, 1974; Plumwood, 1993; Smith and Harvey, 1990; Williams, 1980). The concept of “culture” has often been defined with connotations to “human,” “social,” and any “man-made” artifact, while nature mainly referred to the external environment except humans. Moreover, a “hierarchal perspective” is also constructed between nature and culture as “first” and “second nature” (Bookchin, 1996). The first nature includes what is “natural” as biological and non-human; meanwhile, the second nature refers to the development of technology and science, and all humans’ abilities advanced from the primitive one. The first nature signifies primitive and wild, but pure and non-human, whereas the second nature encompasses what is human, social, and furtherly developed. What remarkable here is that the division of nature and culture become part of the inquiry, not the solution (Daly Bezerra de Melo, 2012).

The hierarchical definitions, natural as primitive and man-made as evolved, do not bring any solution to the demands of the contemporary society either (Bookchin, 1996; Haila, 2000; Lähde, 2006). Nevertheless, indeed nature-culture dualism implicit in this era of environmental change by leading scholars to highlight the contextuality and specificity of the concept of nature (Roepstorff, A., & Bubandt, N., 2003). Meanwhile, environmental ethicists have developed concepts over whether concern for nature is connected to culture (anthropocentrism) or nature (ecocentrism and biocentrism) (Hagan, 2001).

In my opinion, this part of the study provides me to stress the ‘subjectivity’ in the concept of nature by means of altering approaches such as western and non-western thoughts. Although what has been covered above is admittedly limited within the enormous bibliography, this section underpins the reasons of ever-transforming and time-bounded impacts of the concept of nature on building

design (as discussed in Section 2.2), and the emergence of new approaches connecting nature and technology (as discussed in Section 2.4).

2.2 Summary of the Changing Dynamics in Building Design Through the Concept of Nature

This section summarizes time-bonded and altering reflections of the concept of nature from pre-modern to contemporary architecture through various examples in building design. Evaluating the impacts of the concept of nature on building design gives an understanding of the possible meaning(s) of incorporating living organisms in building design.

Since pre-modern architecture, symbolic, analogic, and metaphoric meanings of living and non-living elements of nature have taken place in architectural discourse (Özdemir and Selcuk, 2016). The notion of nature and its scientific and philosophical debates throughout history have continuously been associated with building design's critical aspects (Davies, 2011; Guy, 2010; Hagan, 2001; Owen, 2008). The understandings of 'nature' and 'natural' have been transcribed into architectural meanings, and these comprehensions gained spatial implications and materialized as spaces (Davies, 2011). In this section, these arguments are demonstrated, critiqued through several examples in building design, as highlighted in Figure 2.1.

Different aspects within this comprehensive and vast bibliography could be primarily exemplified with the depiction in *Primitive Hut* by Marc Antoine Laugier in the 18th century. Laugier explains the 'origin' of architecture by exploring the anthropological relationship between man and the natural environment (Laugier, 1755). Primitive hut was 'natural' in the sense of abstracting principles of a basic shelter by favoring intrinsic and natural forms in architecture, just like the abstraction of proportional relationships from nature by Leon Battista Alberti (Hagan, 2001).

In the case of *Cenotaph for Sir Isaac Newton* in 1784, Étienne-Louis Boullée was inspired by the pure forms of nature. Meanwhile, the sphere analogically symbolizes the globe of the World; the starry sky in the sphere could also be interpreted as evidence of the desire to control nature (Gössel and Leuthauser, 1991). In this way, Étienne-Louis Boullée had explored the possibilities in architecture to embrace its fundamental principles from nature (Kaufmann, 1939).

On the other hand, Quatremère de Quincy offered the imitation of the ideas from nature rather than particular forms by seeing geometrical principles as the abstracted forms derived from nature (Hendrix, 2012). In his words, he explained his approach as follows:

“It is nature itself in its abstract essence which is taken as a model. It is the order of nature which becomes its archetype and genius.” (Quatremère de Quincy in Quatremère de Quincy & Younés, 1999)

In other words, the abstraction of nature was already embedded in the geometrical abstractions, similarly to the abstracted forms of plants by Christopher Dresser in the book *The Grammar of Ornament* of Owen Jones in 1859 (Brett, 1995, p. 40). *Mimesis* idea here referred to mimicking the “productive process of nature” instead of the reproduction of natural forms (Blumenberg and Wertz, 2000).

Furthermore, in the late 19th century and the early 20th century, the combination of art was introduced as an international movement known as “Art Nouveau.” In architectural design, early examples could be seen in the works of Louis Sullivan, which signified one of the pioneers of modern architecture. Sullivan also explained his well-known phrase as “form follows function,” underpinned by natural law on the connection between aesthetical expressions and functionality in the elements of nature (Grady, 1955). With this crucial motto in architecture, Sullivan implies for a natural architecture, especially how some forms can come from research around natural phenomena by seeking to examine how the connections between form and function in architecture can achieve great formal results.

Later on, the nature-inspired works of Antoni Gaudi demonstrated a way of mimicking nature in building design by aiming to emulate the aesthetics of the protection and comfort of nature (Rawlings et al., 2012). For example, Gaudi inspired by the structural form of sequoia trees, as can be seen in the supporting structure of the *Sagrada Familia*, 1882, in Barcelona, Spain.

In the 20th century, along with the ongoing examples of art nouveau and the rise of modernism in architecture, different ways of bonding with nature had been developed in building design, parallel to the technological developments in the global industry (Jencks, 1995, p. 109). In early 1908, Frank Lloyd Wright introduced the word ‘organic’ into his philosophy of architecture as an extension of the teachings of his mentor Louis Sullivan (Mumford, 1989). Organic architecture implies a firm biological analogy between the building and the natural environment (Gieselmann, 1996). Moreover, the articulation of technology into building structure in an environmentally friendly way is described as ‘organi-tech’ (Jencks, 2002, pp. 229–234). The examples of organic architecture could be seen in very well-known buildings in architecture, for example, *Casa Milla* by Antoni Gaudi and *Falling Water House* by Frank Lloyd Wright. Furthermore, the *Sydney Opera House* could be one example of biological analogies in architecture with its roof that protects the inner parts of a living organism, opera hall (Johnson, 1994, p. 419). In addition, the designs of Santiago Calatrava, nature have often been an inspiration in the sense of structural organization; thereby, it seems possible to discover more examples in his works and sketches (Lyall, 1992).

Later on, the “Metabolist movement” connotated the city with the metaphor of the human body while its elements can be born, grow, and die (Pernice, 2004). The *Nakagin Capsule Tower*, designed by Kisho Kurokawa in 1972 (Kurokawa, 1987), seems to be a clear demonstration of ‘metabolism’ in architecture. In the meantime, the need for buildings and the city to reconnect with the natural environment has received renewed interest in modern discourse with increasing demand for energy, resources, and raw materials from the developing world

(Winn et al., 2012). Thus, living and non-living components of nature have become the tools for resolving the environmental problems of today due to the increasing demand for energy, resources, and raw materials from the developing world (Farmer, 1999; Marshall and Lozeva, 2009). *Nakagin Capsule Tower* was inspired by the cellular discoveries of the time, cellular organization, replication, and efficiency of function, aiming to fulfill the essential living requirements with the scaled-up, interconnected blocks as living capsules (Ripley and Bhushan, 2016).

Moreover, technological developments have brought new design possibilities as promising solutions for environmental degradation. In this regard, various concepts discovering how technology learns from nature (bio-derived concepts as such; “biomimicry,” “bioinspiration,” “biomorphology,” “biophilia,”) have been put forward by a large number of researchers. Each concept explains how to connect, inspire, utilize, and merge with nature, and favors particular techniques and approaches as well. Within numerous bio-derived concepts resonated in architecture, “biomimicry” could be seen as the most well-known technique extensively practiced by innovators in building design (e.g., Bhushan, 2009; Gruber and Jeronimidis, 2012; Pawlyn, 2011; Ratti and Claudel, 2016). The origin of the word biomimicry comes from the Greek words *bios* (life) and *mimesis* (imitation) (Benyus, 1997). The fundamental idea is to learn from nature and imitate it in the sense of ecological concerns similar to historical studies (Vincent, 2016). In building design, biomimicry suggests applying forms, processes, and systems of nature as sustainable solutions (Pawlyn, 2011). Biomimicry was adopted into building design through different interpretations such as the levels of “organism,” “behavior,” and “ecosystem” (Aziz and El sherif, 2015). According to Aziz & El Sherif (2016), the organism level indicates the mimicking of a particular organism, either as a part of the whole, behavior-level indicates mimicking of the behavior of a particular organism, while ecosystem-level refers to the mimicking of the whole ecosystem. For instance, *Waterloo International Terminal*, designed by Nicholas Grimshaw & Partners, demonstrates an example of biomimicry at the organism-level (Yedeki Arslan, 2014). The Pangolin’s flexible

scale arrangement is mimicked in the glass panel fixings mimic so that they can move in response to the imposed air pressure forces (Aldersey-Williams, 2003). The example of biomimicry in behavior level could be seen in *The Council House 2*, Melbourne CH2, with inspiration from the bronchi of the tree (Radwan and Osama, 2016). In addition, John and Nancy Todd's *Living or Eco Machines* exemplifies the biomimicry at the ecosystem level with its wastewater systems designed to mimic plants (Todd and Todd, 1994). Likewise, many more existing and conceptual examples indicate the different natural elements' mimicking in different ways. What remarkable here is that biomimicry has only recently gained its popularity with the development of contemporary technological abilities, particularly with the rise of computer technology (Ratti and Claudel, 2016).

As shown in the aforementioned examples in history, like the works of Quatremère de Quincy, Frank Lloyd Wright, and Kisho Kurokawa, to bond with nature is not a new phenomenon in advance of technology nor architectural discourse. However, Ratti and Claudel (2016) highlight that the rise of computer technology plays a critical role in designing buildings as living, dynamic, and fluent forms and structures inspired by natural elements. In this sense, technological advancements seem to be relevant to bring further design possibilities, such as new forms and structural designs to building design. In other words, symbolic, analogic, and metaphoric meanings of nature in history could be transformed into technological practice by means of the development of building elements with mimicking natural elements. For example, *Falling Water House* creates a harmony with its site by connecting interior and exterior spaces, while this harmony analogically represents the relationship between human and nature. Likewise, the *Nakagin Capsule Tower* expresses the metaphorical meanings of the human body. On the other hand, the examples of biomimicry in building design like *Waterloo International Terminal* exemplify the practical meanings of bonding natural and building elements (as façade panels in this particular example) to bring environmental degradation solutions.

Nowadays, living organisms can be incorporated into different building parts by acting as another design tool (Myers, 2018; Ripley and Bhushan, 2016). In the case of Algae powered ‘biointelligent’ building in Hamburg/Germany, *The BIQ (Bio Intelligent Quotient) house*, the required building energy is supplied through algae in the façade panels (Stelline, 2013). The bio-reactive façade, called “SolarLeaf,” produces renewable energy from solar thermal and algal biomass heat. Likewise, the *Biomilano* project BY Stefano Boeri Architecture envisions the skin of a building acting as a vertical forest attached to the buildings’ gray water circulation system (Myers, 2018; 42-45). Moreover, as in the example of the *Baubotanik* project, Ferdinand Ludwig uses living trees as load-bearing construction elements (Ludwig et al., 2012). In this way, “to reach beyond biomimicry becomes possible” in building design, in the sense of creating design together with living organisms, not just inspiring from them (Myers, 2018).

In conclusion, there are always more buildings to tell. What remarkable here is that altering approaches towards the concept of nature has always been resonated within architecture, thereby affecting building design in many ways. Meanwhile, technological developments have often presented alternative ways to connect the building and natural environment by meeting the demands of contemporary society. To follow the reflections of the concept of nature and the alternative ways technology presented to create bonds between a building and natural environment drive us to deliberate the possible consequences of today’s ongoing interest in the incorporation of living organisms in building design.

So far, this section reviews the impacts of the concept of nature on building design. The following section continues by reviewing the impacts of the development of technologies on building design.

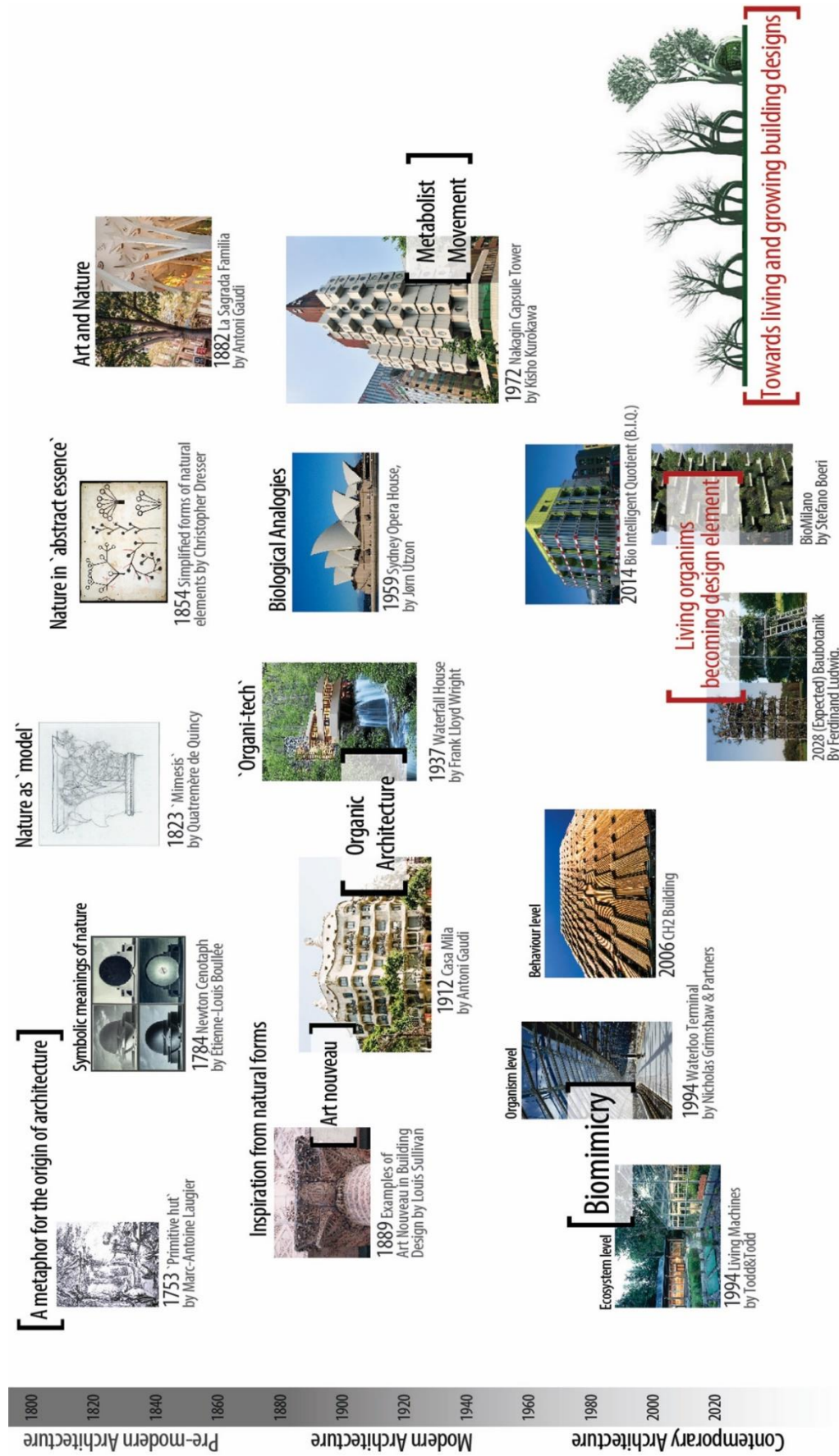


Figure 2.1 A Summary of the Changing Dynamics in Building Design through the Concept of Nature

2.3 Summary of the Changing Dynamics in Building Design through the Development of Technologies

This section summarizes the changing dynamics in building design through the development of technologies by discussing the consequences of the infiltration of small-scale technologies into the building environment. In this way, this section gives a better understanding of the critical role of technological developments in building design.

The impacts of the developments of technology have often experimented with building design. Numerous technologies in multiple scales, domains, and functions have already been integrated into buildings since industrialization. Today, this integration continues through the exponential growth of technology, as demonstrated in Figure 2.5.

In parallel to the developments of technologies and their integrations into the buildings, several building design attempts, mainly known as innovative housing projects, tried to give insights on the impact of the latest technologies on building designs (Kirbas Akyurek et al., 2018).⁷ Admittedly, there are more examples in other typologies, such as office buildings. However, housing projects seem to give a better understanding of technological developments within the building environment and the impact of technologies on everyday life.

What is noteworthy in these projects, many technologies have been presented in that buildings can be seen as very conventional or even outdated. For example, the ‘Dymaxion house’ (1927) and the ‘House of the Tomorrow’ (1933) explores how electricity based technology can be integrated into the home environment (Mohammadi, 2014; Vegesack, A. and Eisenbrand, 2006). The “House of the future” (1956) by Alison Smithson demonstrates intercom systems as an

⁷ As a side study of the thesis, technological integration of thirty-eight housing buildings, between the period from 1927 to 2008, are examined, please see: Kirbas Akyürek, B., Kortekaas, S., Fisscher, J. L., & Mohammadi, M. (2018). Technological integration of the ‘house of the future’. In J. Veuger (Ed.), *Barometer Public Real Estate Special Issue 2018* (Issue 2018, pp. 127–144). Spry Real Estate Academy En Bariet Ten Brink.

innovative technology along with several ideas, such as electrically heated beds without blankets (Alter, 2016) (Figure 2.2).



Figure 2.2 House of the Future, by Alison Smithson, 1958 (Alter, 2016).

The article above published in *Mechanix Illustrated* presents the pushing buttons to control radio and television as something “innovative,” new, and different in the House of Future project. The main goal of the House of Future was to generate discussion on how a future house would look like by providing solutions for ease of daily life. Moreover, in *MIT Solar House I* (1939) and *Afase Solar House* (1958), solar technology have been presented as innovative; in fact, futuristic (Figure 2.3).

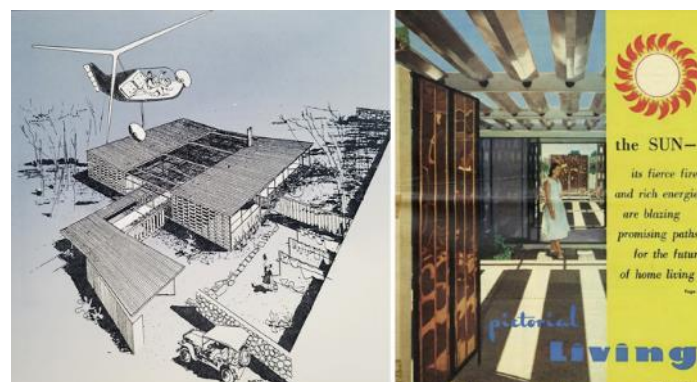


Figure 2.3 Afase Solar House, 1958 (“AFASE Solar House / Scottsdale,” n.d.).

Furthermore, in the 1970s computers, and having wired homes was ‘fiction’ that only the hobbyists were interested in (Figure 2.4).



Figure 2.4 Future in the Past: Futuristic Imagination from 1979 of a House in 2000 (Gatland, K. and Jefferis, 1979).

It seems that the innovations finding discussions in building design just a few decades ago are now infiltrated into daily lives and embraced in the building environment. Therefore, a summary of the development of technologies through the debates of their resonances into building design leads us to provide insights into the possible impacts of the upcoming technologies on building design.

Two significant leaps in technology come as foundations for technology interference into daily life and the buildings (Aldrich, 2003). Firstly, the arrival of electricity into the home environment in the first quarter of the 20th century triggered the rise of domestic appliances, and subsequently, HVAC systems in the buildings. Secondly, in the last quarter of the 20th century, developments in information technology were encouraged to explore the possibility of exchanging information between people and household appliances, systems, and networks, inside and outside the home (Mohammadi and Hammink, 2015).

In the 1900s, the fundamental purpose of electricity was only considered the lighting in the building environment. The anecdote of Adrian Forty (1986) tells the story of two elderly ladies who attempted to prevent electricity from leaking from the sockets. This anecdote highlights electricity at home was indeed extraordinary and new only about a century ago. At that time, houses were mostly placed with one socket since people could not see any use for adding more (Harper, 2003). Between 1920-1940, the advertisement of domestic technologies promising less housework resulted in houses having more electric sockets, which increased the integration of technologies into daily activities as well as the home

environment (Aldrich, 2003). Accordingly, house designs have begun to take shape around the advantages of the growing number of domestic appliances (Gann et al., 1999). These domestic technologies majorly affected daily lives, but somehow in an unexpected way. “Time-saving” technologies increased hygiene standards and resulted in women to spend more time at home (Bowden and Offer, 1994; Cowan, 1983).

In the 1940s, the buildings' heating systems with “mechanical core” allowed architects to develop their designs independently from the heating source. Thanks to interior climate control and artificial lighting, the layout of the office buildings freed from windows, and the height of the stories could be diminished. By the 1940s, air-condition in office buildings became a standard feature in the USA's design (Eisenbrand, 2006). Moreover, these technological abilities enabled architects to refine the building envelope using thermopane (insulated) glass panels. By the 1950s, office buildings and spaces were “more mechanized” through the spread of computers at workplaces, which also triggered the process of automation and the field of information technology. Afterward, all of the technologies in the workplace were transferred to the home environment (Mohammadi and Hammink, 2015). Herewith, Eisenbrand (2006) claims that household mechanization with the increasing number of domestic technologies affected buildings limitedly, however utilities as electricity, plumbing, and heating had a much more crucial impact on building designs and layouts.

In the 1960s, time-saving technologies, washing machines, electric razors, sewing machines, kettles, cookers became omnipresent, while the implementation of central heating and thermostats was also widespread at homes (Aldrich, 2003). Further on, another domestic technology stream started to rise oriented to increase the comfort of the user (Mohammadi and Hammink, 2015). So-called “time-consuming” technologies such as television, radio, cinema, computer spread rapidly. This rapid growth led to hobbyists trying to connect these technologies in their homes as “wired homes” as the early concepts of “smart homes” (Harper in Aldrich, 2003). For example, The Xanadu house (1983) presents a showcase by

exploring to design a home with an integrated computer system to shift people's idea of a house, which should be more than a passive shelter (Mohammadi, 2014). In the 1980s, with the rise of developments in computing and information technology, computers were moved from workplace to house by blurring the distinction between home and work environment (Aldrich, 2003). Following the growing potential of digital systems in daily activities, the term "Smart Home" was first used in 1984 by the American Association of House Builders (Harper in Aldrich 2003; Solaimani et al., 2011). At this point, the home was attributed as being smart, not for its construction techniques or sustainable features; it was smart by including interactive and intelligent technologies (Venkatesh et al., 2003). Afterward, the advantages of technologies in the built environment have raised an interest in smart homes by both academics and practitioners (Marikyan et al., 2019). The 'TRON intelligent house' (1989) is the first experimental lab of the study, which addresses the possibilities of the 'smart home' (Vegesack, A. and Eisenbrand, 2006). "Smart" has become an "umbrella term" for innovative technologies with some degree of artificial intelligence, while smart homes are inseparably bonded with smart technologies (Alam et al., 2012; Arunvivek et al., 2015; Dawid et al., 2017; Hong et al., 2016; Marikyan et al., 2019). In the meanwhile, projects continued to be developed in order to experience new technologies in the building design, since the technology can only successfully be implemented when the technologies adjust to the actual needs of people instead of human suiting to the limits of the technology (Mohammadi and Hammink, 2015; Slaats, 2017). Therefore, projects like Living Home Tomorrow (2003) have experienced the reflections of the development of smart technologies on building design (Vegesack, A. and Eisenbrand, 2006).

Nowadays, the physical world can be united with digital systems with the design of smart environments. Meanwhile, home automation systems have been a rapidly growing area in developing a modern home (Arunvivek et al., 2015). For decades, to design a smart, interactive environment was just a dream, but recent advances enable this desire to come through (Cook and Das, 2007, p. 3). To make this dream more vivid, the researchers focused on solving relatively minor problems

such as; the low adaptation and diffusion rate despite their potential advantages (Anderson, 2007; Balta-Ozkan et al., 2013; Chan et al., 2009; Ehrenhard et al., 2014; Jacobsson et al., 2016; Yang et al., 2008). Subsequently, current studies have started to examine the technological, financial, ethical, and legal and psychological barriers of smart home acceptance and adoption from users' perspectives (Marikyan et al., 2019). Thus, architects have driven with the idea to design smart environments, homes, and buildings that centered around the perception of a human; experience, emotions, and feelings (Mohammadi et al., 2019).

Briefly, Mohammadi and Hammink explain the development of technology in the building environment until today as 'mechanization,' 'electrification,' and 'automation' (Mohammadi and Hammink, 2015). In the early 1900s, the process of mechanization allowed for faster and cheaper production of goods (mass production). Further on, electrification by means of adaptation of electricity into the home environment led to boost domestic technologies in combination with mass production.

The combination of income, the changing role of the housewife, and further evolvement of the technology consolidated the adoption of domestic electrical technology like washing machines, toasters, coffee makers, etc. Furthermore, the efficiency movement in the interbellum and 1950s encouraged the use of automated electric appliances in the home, inspired by the usage of automated machines in the workplace. What is essential in these examples is that technologies can affect building design regardless of their scales; thus, architects can develop their projects accordingly, as in the cases of Innovative House projects. For example, Open the House Project inspires from the innovative climate clothing. The innovative clothing system leads humans to have their own thermal comfort by allowing architects to open the house by means of independence from climatic conditions and necessary heating and ventilation systems (Vegesack, A. and Eisenbrand, 2006).

All in all, technological developments have often made drastic changes in building design alongside the societal and cultural aspects. While technology surrounds every aspect of our lives with an increasing number of innovations, daily activities always remained at the focus of various design disciplines (e.g., product design, fashion design, building design). Nowadays, the recent technologies have been developed under the influence of designing with biology (e.g., furniture grown through mushrooms, clothes made from bacteria, lamps lighted via photosynthesis energy) (Myers, 2018). In fact, contemporary designers like the Modern Meadow group entitle the current stage of time as ‘biofabrication’ to emphasize the impact of biology on contemporary material and product development (Modern Meadow, 2017).

The following part discusses contemporary studies on the shifting notions of nature and technology that might be relevant to understand the development of technologies by incorporating living organisms.



Figure 2.5 A Short Summary of the Development of Technologies into the Building Environment (Classification of the timeline as mechanization, electrification, automation, adapted from *Domotica Kompas. Inzichten uit een decennium slimme zorgprojecten in Nederland* (Mohammadi, 2014))

2.4 Shifting Notions of Nature and Technology in Contemporary Concepts

This section deliberates contemporary concepts that lead us to understand the shifting notions of nature and technology in relation to the debates on nature and culture, as discussed in Section 2.1. By relying on the changing dynamics in building design through the concept of nature (Section 2.2), and technological developments (Section 2.3), these concepts and studies seem relevant to understand the interrelation of living and manufactured components.

Contemporary studies point out the fading boundaries between nature and technology by arguing nature and culture; natural and man-made can no longer be distinguished. In his ethnographic work among an Amazonian community, the Achuar Tribe, anthropologist Philippe Descola found out that although the opposite is tempting, Amazon Forest is not untouched, pure, or wild. Since the flora and the distribution of the species have transformed and majorly changed by people through the thousand years, the forest has evolved under the influence of mankind (Descola et al., 2014). Regarding the research, he criticizes the nature-culture duality in his book (Descola et al., 2014). He states that nature evolves and alters through physical and chemical human activity, so it cannot exist independently from both human and non-human (Descola et al., 2014). In this regard, Descola attempts to reach “relative universalism” by rejecting the universal comprehension of nature and culture distinction, which was invented in the 17th naturalism in the West (SAHLINS, 2014). Descola draws attention to the subjectivity on the definition and interpretation of nature by revealing the facts that people’s effects on this World are beyond imagination and assumption. Likewise, Roepstorff and Bubandt (2003) state as follows: “Nature is no longer what it used to be, [b]ut neither is culture,” therefore now it is “almost impossible” to discuss nature without culture.

Bookchin (1996) also claims that the hierarchical definitions, natural as primitive and man-made as evolved, do not bring any solution to the demands of contemporary society. Since culture develops on the process, not on ‘untouched

nature,' the sharp distinctions are inadequate to meet the changing needs of the World (Lähde, 2006).

According to Haila (Haila, 2000), by considering nature as an 'external object,' the environment transformed into 'utilizing subject.' In this way, nature, referring to non-human, pure, and untouched, has been considered tamed, dominated, and controlled by people in modern thought (Haila, 2016; Uggla, 2009). At this point, Bruno Latour (1993) stresses that 'we have never been modern,' and suggests a hybrid perspective as a mixture of nature and culture opposition to the dichotomy which he disabuses. He criticizes modern societies by 'purification' the concept of nature among humans and society, and he claims that they were 'created together' and 'reinforce' each other (Latour, 1993; 31).

Many designers still consider nature as its idealized perfection and distinguish any design activity from the natural environment (Kleinert, 2018). However, concepts like 'subnature' (Gissen, 2012), 'dark nature' (Michael, 2011), 'next nature' criticize the idealized concept of nature by underlining subjectivity within its common understanding. David Gissen (2012) claims that he uncovers the story of the subnatural in architecture and discusses the denigrated forms of nature by naming them as "subnature." Indeed, nothing is unwanted or unpleasant in nature; the way we see them depends on our early assignments and prejudices. Nature is not what we imagine and idealize; therefore, the comprehension of subnature is useful to motivate and develop building programs (Gissen, 2012). Similar to the holistic approach of Gissen's by means of embracing nature with its 'undesired' entities, dark nature also indicates criticisms towards excluding anything from nature with aesthetical concerns (Michael, 2011). Furthermore, Koert van Mensvoort claims that the roman interpretation of nature has dominated our notion of nature by considering nature as born, culture as man-made. However, we should approach nature through its Greek interpretation of 'growth' (Mensvoort et al., 2012; 5). "Nature changes along with us," as he (2012) declares, and regardless of born or man-made, human or non-human, nothing is unnatural or outside of nature. In this sense, Mensvoort introduces a unique concept entitled: "Next Nature." This concept signifies a novel approach motivated

by the fading boundaries between nature and technology within various industrial products in several such as; health, food, and textile (these examples could be followed in Nano Supermarket, *Nanosupermarket*, n.d.). According to Mensvoort (2015), the merge of natural and manufactured elements may sound ‘futuristic’ first, but pieces of evidence from everyday life insist that the bridges were already established.

The Next Nature concept challenges the perfected and scared assumptions attached to the concept of nature (Kleinert, 2018). Despite its futurist essence and the name starting with “next,” the idea mainly refers to today and discusses the potential changes in the near future. As in Mensvoort’s (2015) words: “We live in next nature, the next is today, but since we got accustomed, it is hard to notice it.” In this way, to observe and evaluate this integration in-between nature and technology, Mensvoort explains how any technological product can be ‘natural’ by means of fully integrated into everyday life with their approach as ‘The Pyramid of Technology’ (Mensvoort, 2013).

The Pyramid of Technology is identified as a ‘method’ which demonstrates the possibility of any technological product to be naturalized through seven steps; ‘envisioned,’ ‘operational,’ ‘applied,’ ‘accepted,’ ‘vital,’ ‘invisible’ and finally ‘natural’ (Mensvoort, 2013a) (Figure. 2.6). This pyramid yields a holistic overlook of technology by presenting a ‘tool’ for developing ‘better technology’ that can be used by scientists, inventors, engineers, designers, and entrepreneurs (Mensvoort, 2013a).

The term technology is commonly associated with developing innovations that need more time to be part of our daily lives (Mensvoort, 2013a). On the other hand, technology does not only include the latest electrical and electronic apparatuses. From wearing clothes to writing, clocks to money, buildings to roads, several familiarized things as natural in everyday life are, in fact, technological. For instance, a human can be seemed all-natural at first glance. However, as remembering our clothes, glasses, watches, smartphones, and any other products strictly glued on our daily habits, it is evident that we as humans are captured by

technology more than we realized. In this regard, this pyramid puts forward a criticism towards accepting technology only as high-tech by means of newly developed, advanced technology.

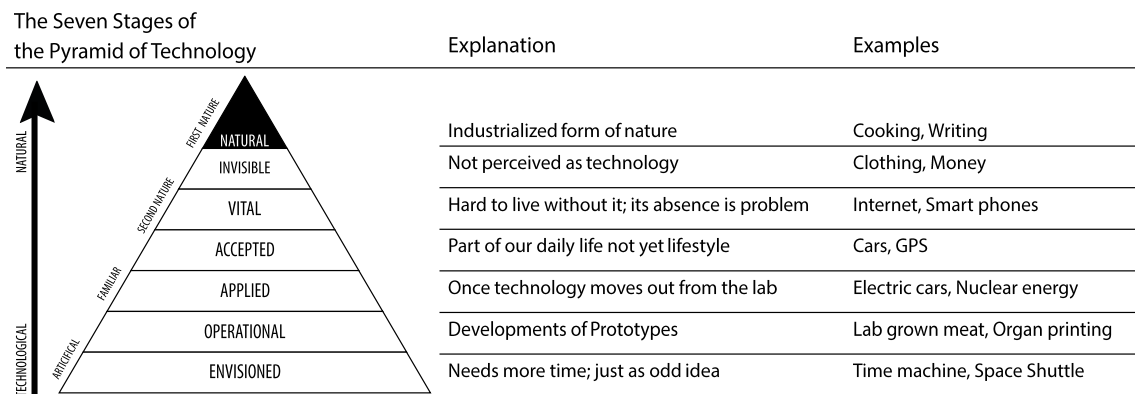


Figure 2.6 The Pyramid of Technology (Table is composed by the author based on the information in the works of Mensvoort, Mensvoort and Grievink, 2012).

Based on this pyramid, architecture; buildings and city in general is considered at the stage of vital. However, Mensvoort also underlines that these steps can be a part of discussion. The examples in Figure 2.6 is open to discussion, and there are no concrete lines amongst those stages. While one may consider the internet as invisible, the other may also say it is accepted highly depending on people's life quality. However, this uncertainty does not refute this model but strengthens it. For instance, just before one or two decades ago, using a mobile phone was a remote and impossible idea, but now a cell has almost become an "apparatus" of a body (Mensvoort, 2013a). In this way, the achievability for any technology to become vital for humans and then invisible is underlined. Technological products are always in the process of these stages. The technologies at the lower part of the seven stages may be considered as artificial, unreachable, in fact, impossible. Nevertheless, at a specific point in time, all the technologies were all begun at this earliest stage, just as an odd idea.

Despite the futuristic, artificial perception of the technologies at the lower stages, technologies at the top are all-natural and deeply integrated into daily life

(Mensvoort, 2013a). The innovations at the lower part of the seven stages may be criticized as being artificial, unreachable, impossible. Nevertheless, one should remember that at a specific point in time, all the technologies today were all begun at this “lowest” and “most primary” stage. Likewise, Poelman (2010) explains the ‘diffusion of technology’ by saying ‘what is may become ought,’ emphasizing any technology to become vital and necessary. In some cases, technologies can instantly be applied right after their initial idea, but also, this stage can last an indefinite time. The lowest stages of the pyramid are mainly related to the initial achievability of the technology, but from the accepted phase, the upper stages are mostly engaged with the perception of users. Moreover, technologies can slide down to lower stages as well as they climb up. Technologies moving up from lower stages to the accepted level are seen as new, unfamiliar, and artificial. Moving down technologies from upper levels are mainly considered outdated and nostalgic (ex. fax machine) (Mensvoort, 2013a).

In conclusion, this section underlines the shifting notions of nature and technology by addressing contradictory debates on human and man-made, natural, and cultural bonds as well. The inquires on the concept of nature (e.g., by Bookchin, Gissen, Latour) stress the subjectivity and time-boundness from different points of view by showing the fading boundaries between humans and man-made. The Next Nature concept (Mensvoort and Grievink, 2012) has come one step forward to understand the interrelation of living and manufactured components, among the other concepts (e.g., Subnature, Dark Nature) by elaborating on the concept of nature in connection with technological developments. Furthermore, The Pyramid of Technology claims any man-made products could be accustomed to society and could become routine in that sense. This pyramid seems relevant to highlight the possibility of biobuilding components to be integrated into daily life by evaluating their expected societal impacts in the following part of the study (Chapter 4). But before that, the following section presents an overview by discussing contemporary examples in building design with the findings of all these literature summaries (Section 2.2, 2.3, 2.4).

2.5 Discussion on the Changing Dynamics in Building Design in-between Living and Manufactured

This section discusses contemporary examples in building design that exemplify the interrelation of living and manufactured components by experiencing in building scale. Thus, this part of the study provides an overview of changing dynamics in building design by offering insights into the expected impacts of biobuilding components and discussing contemporary examples with the findings in the literature summaries. In this way, it underpins the connections between the theoretical studies about nature and technology with building design.

Indeed, many studies in building design explore the possible solutions to the current demands of society and construction systems through the incorporation of living organisms and discussed in the literature with an emphasis on their 'living' features, in fact in some studies as 'living buildings' (Armstrong, 2014; Birkeland, 2015; Gale, 2011; Heinrich et al., 2019; Imhof and Gruber, 2015; F. Ludwig et al., 2012). Many of these examples were already demonstrated as a showcase in design exhibitions and research platforms (e.g., Dutch Design Week 2009, Biodesign Exhibition), or the concepts were furtherly evaluated in academic and non-academic publications (e.g., (Gruber and Imhof, 2017; "Terreform," 2020; Vegesack, A. and Eisenbrand, 2006). The examples evaluated in this section are the prototypes in building scale (as single building construction or concept) that their expected results, aim, and scope could be found in-detail within scholarly sources as such articles, books, official websites in the academic databases (i.e., Scopus, Jstor, and Sciencedirect). To discuss these examples provides an overall understanding of the interrelation of living and manufactured components in building design.

These examples address building components such as façade elements, structural materials, and interior elements, thereby demonstrating the interrelations between living and manufactured components in different building design ways. In that sense, they represent the ways to connect with nature, and at the same time, the adaptation of new technological developments with the incorporation of

living organisms. Regarding the literature summary in Section 2.3, these examples point out the transformation of historical and philosophical meanings of living components (as in symbolical, analogical, and metaphorical interpretations of the concept of nature) into practical meanings by providing another approach rather than mimesis, imitation, mimicry. Regarding the connections between technological developments and building design, the literature summary in Section 2.4, it is also possible to evaluate these examples with the impact of technological developments on building design. They demonstrate how to embrace new technological advancements with the incorporation of living components and tries to answer how buildings can be designed with living organisms (Figure 2.17). This question can be accepted as providing further answers to RQ1 in addition to the discussions in Section 2.4.

Foremost, the root bridges in Meghalaya, India, seems to be a significant example that we can learn from nature through its ‘guided growth’ even before the construction of buildings from blueprints and components (Mensvoort and Grievink, 2012; Myers, 2018) (Figure 2.7). These bridges are made with the secondary roots of the *Ficus elastica* tree (Middleton et al., 2020). Rachel Armstrong emphasizes that “they are the most effective way to ‘heal’ a stressed ecology may be to construct living buildings” (Armstrong, 2010). In that sense, before deliberating current studies in highly developed Western societies, root bridges in Meghalaya, India, reminds us that there is much to learn from non-Western cultures and the growth of nature in which outcome is ‘unpredictable,’ but context-dependent.



Figure 2.7 Root Bridges in Meghalaya, India (“Guided Growth When the ‘built’ becomes the ‘born,’” n.d.)

The way we built buildings and cities is not “sustainable,” as Armstrong (2010) argues. There is a need for the right “language” to find a way to homes and cities connecting with the surroundings (Armstrong, (2010). Through advanced technological materials, architectural design may turn into communicating and interacting living organisms in nature, more than just the arrangement of physical aspects of our surroundings. Nevertheless, according to Armstrong (2010), the fundamental problem here is the construction process, design, manufacture, and build. The usage of the same accustomed materials in architecture should be renewed with the current technology’s assistance (Armstrong, 2010). Accordingly, she approaches growing a building on the self-reparability advantages of materials created via synthetic biology. In the project, Future Venice, she suggests growing a synthetic limestone reef under the city’s foundations to prevent the city’s foundations from being eroded (Armstrong, 2016) (Figure 2.8). She offers that due to the constant water requirement, metabolic materials will challenge the assumptions we have about architectural building processes by bringing useful solutions to the cities having trouble with water, such as Venice (Armstrong, 2015). In this way, she introduces new approaches with new (protocells) biological materials (metabolic) with an envision that these technologies will develop further through the upcoming years (Bedau, 2009).



Figure 2.8 Protocells and Future Venice Project Simulation by Christian Kerrigan (Hobson, 2014)

Protocells and metabolic materials are not on the market right now; however, the aforementioned example, algae powered ‘biointelligent’ building in Hamburg/Germany, *The BIQ (Bio Intelligent Quotient) house*, already exemplifies the interrelation of living and manufactured components with algae-filled façade panels (Figure 2.9). This particular example presents a novel way of energy harvesting, and it also acts as mobile shading devices for the building interior (Heinrich et al., 2019). In that sense, it is possible to underline the added value of the living components as a building façade and also interior elements. In that sense, in addition to philosophical meanings of the concept of nature, it seems new phenomenological meanings of nature are also added by means of triggering different senses by creating a novel interior atmosphere by creating diverse connections with nature. In my opinion, this leads us to discuss the connections between different examples in buildings design. For example, the early examples in Art Nouveau in building design, the figures, and ornaments on buildings as such in the works of Antoni Gaudi bring associations with the elements of nature by creating visual connections. Moreover, the examples in modern architecture like Falling Water House lead us to discuss the bonds between nature and buildings by creating a harmonious relationship between the building site. *The BIQ (Bio Intelligent Quotient) house*, on the other hand, creates a visual connection by utilizing algae within the building façade and leads us to connotate sustainability with the concept of nature by providing energy-efficient solutions with living organisms.

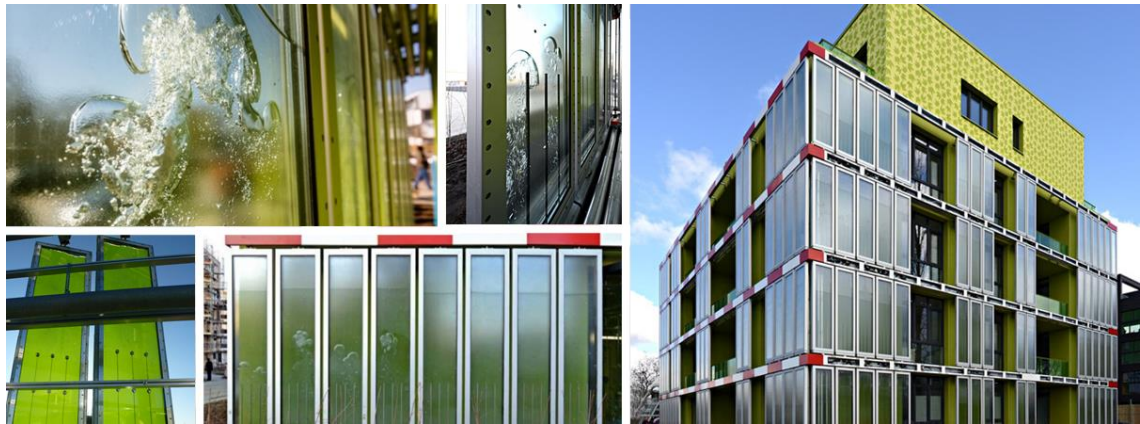


Figure 2.9 The BIQ (Bio Intelligent Quotient) House, Photos © Colt International, Arup Deutschland, SSC GmbH

While algae can continue to procreate, it seems possible to talk about a symbiotic relationship between the living and manufactured components and mimicking the logic of nature as in the examples of biomimicry in architecture. Similarly, in the *Baubotanik* project, Ferdinand Ludwig uses living trees as construction elements aiming to blur the boundaries between the differences between the man-made and the natural, nature, and technology (Ludwig et al., 2012) (Figure 2.10).



Figure 2.10 Baubotanik, Building Growing through Living Trees (Ferdinand; Ludwig and Schönle, n.d.)

Baubotanik project demonstrates a mutual relationship between the living and manufactured components by raising the construction simultaneously with plants' growth (F. Ludwig, 2016). Like the *Baubotanik* project, Joachim approaches from a conceptual perspective by seeking to find a way to 'grow' a building through the Fab Tree Hab project. The method that used in this project is new to architectural

construction but very old and familiar in gardening, “pleaching.” Despite the requirement of a longer time period of building these homes, the alive structure can renew itself through the seasonal cycles by preserving its ecological benefits (Arbona et al., 2003) (Figure 2.11).



Figure 2.11 Fab Tree Hab Project (Arbona et al., 2003)

In addition, the adaptation of plants, The Organic Mushroom-Brick Tower, at MoMA’s PS1 Courtyard in 2014, demonstrates the interrelation of living and manufactured components with the incorporation of mushrooms (Figure 2.12).



Figure 2.12 Hy-Fi, The Organic Mushroom-Brick Tower Opens At MoMA’s (Stott, 2014)

As another example, The Growing Pavilion in Dutch Design Week 2019 represents a ‘smart’ way of decreasing the harmful environmental impacts of the construction industry, while panels were grown from mushrooms (Klarenbeek, 2019) (Figure 2.13). In the example of Hi-fi, the building is stable, yet the bricks are produced with growing mushrooms. The mushrooms in the Growing Pavilion, on the other

hand, continues to grow. This led us to discuss different phenomenological meanings of the interrelation of living and manufactured components with different practices of living components.



Figure 2.13 The Growing Pavilion in Dutch Design Week, October 2019 (personal archive of Peyman Nafai).

Moreover, the Silk Pavilion is a clear demonstration of incorporating living organisms differently (Figure 2.14). The Silk Pavilion discovers the relationship between digital and biological fabrication on product and architectural scales by inspiring the ability of silkworms to create 3D space. In this example, it is possible to mention a more distanced relationship with living organisms, which acted as the ‘co-designers’ of the architectural space (Oxman, 2015).



Figure 2.14 Silk Pavilion, an Architectural Space Growing with Silkworms (Oxman, 2015).

In some examples, interrelation could be more ‘hidden’ in a way to notice the incorporation of living organisms, such as in the example of Zelfherstellend

Paviljoen. Self-healing concrete with bacteria targets to reduce the costs of concrete production and maintenance, as well as CO₂ emissions (Jonkers, 2007) (Figure 2.15). In this project, bacteria play a crucial role; in another project, it has also tried to find solutions to the problem of CO₂ emission through biological concrete for constructing ‘living’ building materials with lichens, mosses (Universitat Politècnica de Catalunya (UPC), 2012).



Figure 2.15 Zelfherstellend Paviljoen (Self-healing Building) (“zelfherstellend paviljoen,” n.d.)

These examples demonstrate the interrelation of living and manufactured components in building design with full-scale prototypes. In GrAB Growing As Building Project, Barbara Imhof and Petra Gruber explore the potential of slime molds (unrelated eukaryotic organisms) in building design by experimenting with their growth through the grid structure and building design simulation (Gruber & Imhof, 2017a; Imhof & Gruber, 2015) (Figure 2.16). The project aims to examine the ability of slime mold to grow three-dimensionally by growing in three-dimensional grids, both vertically and horizontally. At first, it studies to observe the behavior of slime molds and prove that volumes can be created in the guided paths (Gruber & Imhof, 2017a). Secondly, it explores the potential of slime molds to become the co-designer through simulating slime molds to generate growth patterns within unexpected forms.

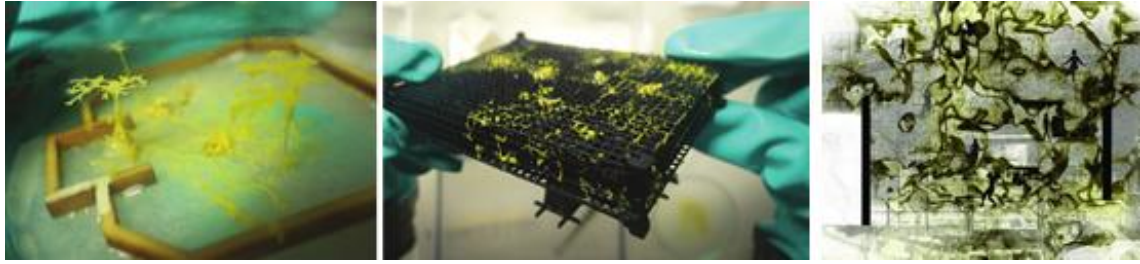


Figure 2.16 Slime Molds Growing in the z-axis, and the Generation of Growth Patterns of Slime Molds in Building Design Simulation (Gruber & Imhof, 2017a)

These examples led us to discover different practical meanings of the interrelation of living and manufactured components by creating different bonds with the concepts of nature, thus also bringing new phenomenological and philosophical meanings in addition to examples with the approaches of mimesis, imitation, mimicry. On the one hand, examples like *The Hi-fi*, *Silk Pavilion*, *Self-healing pavilion* offer possible innovative and sustainable solutions to environmental degradation with biobuilding components by inspiring architects and informing society on the possible benefits and ways of use of the living organisms in building designs. On the other hand, the examples of *The BIQ (Bio Intelligent Quotient) house*, *Growing pavilion*, *Baubotanik*, *Fab tree lab*, *GrAB* demonstrate how to grow buildings and living components by promising a dynamic, harmonical, symbiotic relationship between living organisms and the building itself. Admittedly, these dynamics promise to create a new relationship and interaction with the user as well. This presented new senses, new phenomenological, and philosophical meanings of the interrelation of living and manufactured components, which need to be further discovered in the building design domain. These examples lead us to discuss that the current, in fact, ‘mechanical’ thinking of components is changing by means of addressing the possibility of their ‘growth’ instead of ‘production.’

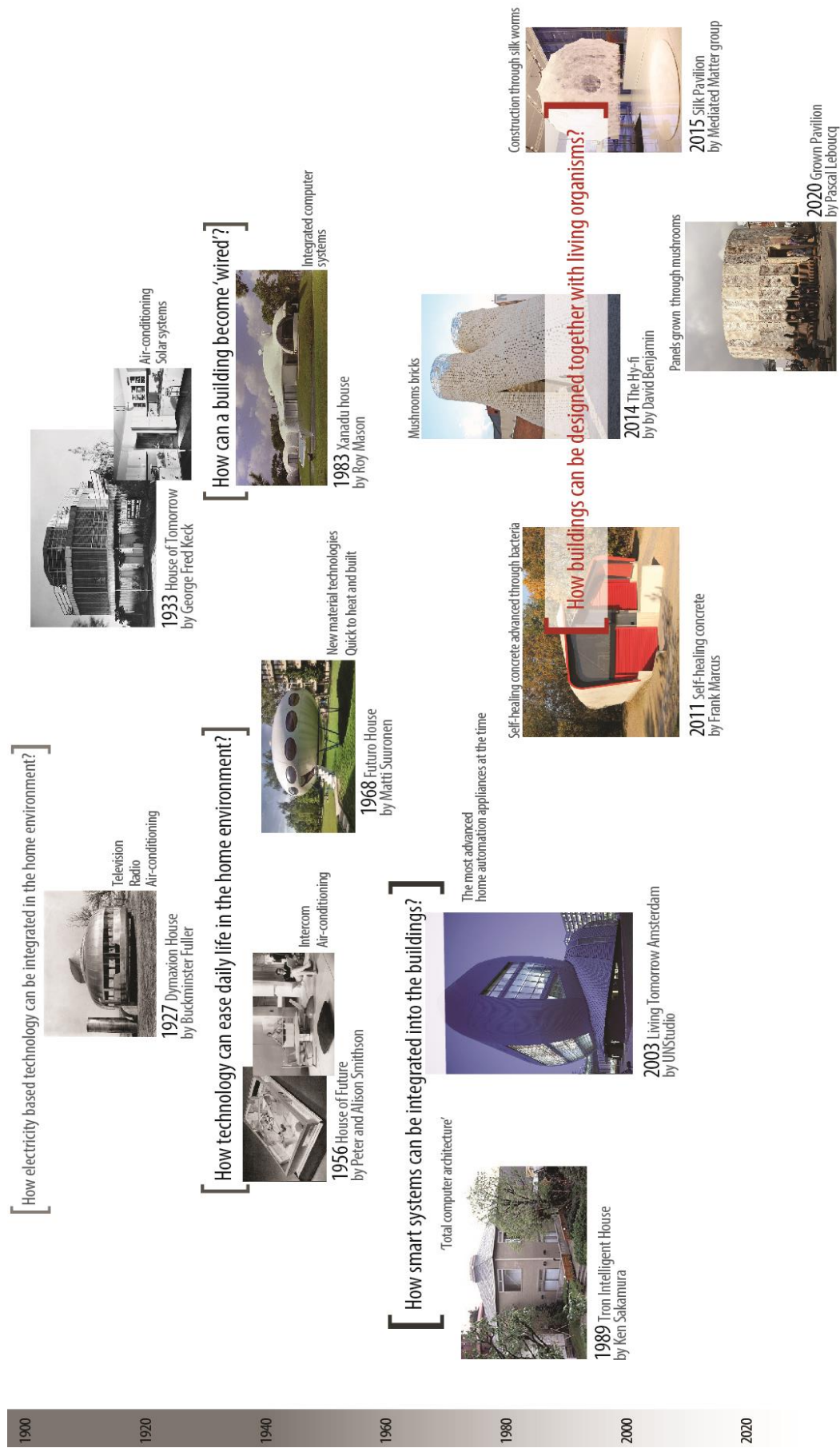


Figure 2.17 Examples of Questions in the Evolution of Buildings through Technological Developments

2.6 Conclusions

This Chapter confirms that connecting with nature and adapting to technological developments have always remained at the core of building design throughout history. The influences of the concept of nature and the development of technology on building design lead us to underpin the potential meaning of incorporating living organisms into building design through its bonds between nature and technology.

While the concept of nature has maintained its significance as a matter of discussion in the scope of building design in architectural discipline, its evolving relationship with technology emerges to focus on contemporary examples. Section 2.3 evaluates the impact of the concept of nature on technology altering through the understandings of the concept of nature. Meanwhile, technological developments have often resonated in building design through the infiltration of industrial products in multiple scales, functions, and purposes. Furthermore, contemporary studies have led us to underpin the growing number of researches discussing the in-betweenness of nature and technology, living and manufactured. Ongoing examples in building design exemplifying the use of biobuilding components encourage us to focus on elaborating their potentials in building design.

Admittedly, the literature studies could be extended with more examples (i.e., with more buildings) or further information (e.g., further discussions on construction techniques and conceptual designs). In addition, instead of Western examples (i.e., exemplified buildings in Europe), non-Western architectural examples such as Japanese and Indian Architecture, traditional Chinese architecture could also be evaluated in-depth. On the one hand, vernacular architecture examples can bring different understandings and clarifications. For instance, examples like Living root bridges in India might lead further studies to learn from regenerative aspects of living organisms (e.g., (Middleton et al., 2020)).

However, it is more important to underline the necessity to elaborate biobuilding components through its bonds with nature and technology. Only in this way the theoretical meaning of the intersection of living and manufactured, thereby biobuilding components could be understood.

In my opinion, this part of the study grasps the emergence of biobuilding components in building design. Moreover, it stresses the increasing number of studies in the building design domain. Meanwhile, the number of biobuilding component examples has been increasing gradually and about to infiltrate into everyday lives and surroundings; however, building design would be affected by biobuilding components is needed to be elaborated in the building design domain. From my point of view, the systematic organization of literature review part of the thesis leads us to hypothesize that the praxis of incorporating living organisms into design seems critically significant in the discipline of building design. Meanwhile, contemporary concepts indicating shifting notions of nature and technology might ease understanding of the meanings of biobuilding components for buildings and society. Thus, biobuilding components shall be understood and explored in an analytical manner.

RESEARCH ON TERMINOLOGY OF BIOBUILDING COMPONENTS IN BUILDING DESIGN

This Chapter introduces research on terminology by carrying out a literature review specified on bio-derived concepts and provides answers to RQ 2.1. The goals of this part of the study could be summarized as follows:

- To examine concepts and methodological approaches related to the incorporation of living organisms in building design.
- To determine relevant terms and definitions that could be adopted to describe the interrelation of living and manufactured components in the scope of the thesis, building design as well.

In this way, this part of the study gives a better understanding of the praxis of incorporating living organisms in building design by elucidating the terms and definitions already found a place in the existing literature. This prevents any misunderstandings towards the ambiguity and complexity of terminology regarding the description of biobuilding components.

In the framework of the Chapter, the following sections are presented, respectively: *Methodology*, *Literature review*, *Findings and Discussions*, and *Conclusions*. In the literature review, bio-derived concepts are evaluated through their main *approaches* and *scopes* to deliver concise information of the related concepts.

Moreover, the literature review focuses on popular terms and concepts on biobuilding components limited to the “bio” prefix. Innovations incorporated with living organisms could be found entitled with many terms as such “bio,” “smart,” “living,” “growing,” “eco,” and “organic,” and many more in the existing academic

and popular literature(Kirbas Akyürek et al., 2020).⁸ Within those terms, “bio” seems to come one step forward among the others for the scope of the thesis firstly by simply indicating biology, and with a large number of bio-derived concepts establishing various ways to bond between the elements of nature and technology. For example, the term “smart” is often used as “smart technologies,” “smart materials,” “smart sensors,” “smart systems,” while the incorporation of living organisms clearly not the issue all the time. “Living” could be used to describe some level of dynamism or resemblance to biological systems, thereby do not have to be related to actual living organisms⁹. “Organic’ and “eco” seem more relevant debates ever since the 1960s on “green,” “organic,” “ecological design,” and “sustainability,” which seems not suitable to highlight the focus of the study.¹⁰ Notably, the concept of sustainability has already been presented in ongoing discussions in building design since the 1960s with numerous concepts, terms, definitions, along with several dilemmas towards the relationships between nature and technology (Ciravoğlu, 2008). Therefore, using these terms can cause further misunderstandings to explain the interrelation of living and manufactured components.

All in all, this Chapter clarifies the ambiguity in terminology, thereby ensures the semantical comprehensibility of the thesis. This part of the study reveals appropriate terms and definitions and avoids certain concepts, thus eases us to determine examples of biobuilding components in the following Chapter.

⁸ These terms are found out in the descriptions of the gathered examples of biobuilding components in the following Chapter.

⁹ For example, Ratti and Claudel (2016) claim that due to powerful computation technology now turned into rational and gridded forms that are easily replaced by organic and complex forms. Thus, designers explore the possibilities of designing “vibrant, dynamic and living” structures.

¹⁰ For further information on the debates on “green,” “ecology,” and “sustainability” please see: Madge, P. (1993) Design, Ecology, Technology: A historiographical Review, Journal of Design History, Vol. 6, No. 3, pp. 149-166, UK: Oxford University Press. And also, Madge, P. (1997) Ecological Design: A New Critique, Design Issues, Vol. 13, No. 2, pp. 44-54, USA: The MIT Press.

3.1 Methodology

Academic and popular literature overloaded with a variety of concepts derived with “bio” suggesting methods and approaches on technological developments together with living organisms (Deuerling et al., 2018; Ivanić et al., 2015; Speck et al., 2017).

Figure 3.1 demonstrates the scope of the literature review by aiming to give an overview of terminology on the specified scope within the comprehensive, ambiguous, and complex bibliography.

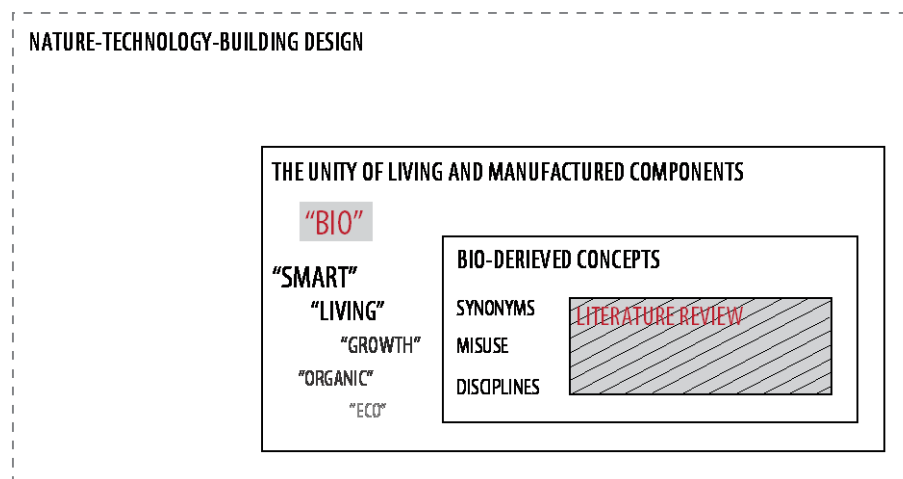


Figure 3.1 The Scope of the Literature Review on Biobuilding Components

This diversity in the terminology motivates us to begin with eliminating certain concepts within the categories of *synonyms*, *disciplines*, and *misuse*. Afterward, the determinations relevant to the scope of the research were defined and furtherly elaborated.¹¹

¹¹ One could suggest to conduct a systematic review on “bio”. Therefore, it is necessary to emphasize that this study do not carry out a literature review on “bio”. It focuses on “bio-derived” concepts in the scope of building design in order to explain the incorporation of living organisms. This lead to be more selective within the a large number of studies in multiple disciplines.

3.2 Literature Review

To start by filtering terms and definitions that are out-of-scope leads us to present a detailed literature review, thereby guides us to highlight related concepts explicitly.

Synonyms

The terms with the “bio” prefix have presented numerous studies along with many synonyms. For instance, the common synonyms of “biomimicry” are “biomimesis,” “biomimetic,” “bionics,” “biognosis,” “biomimetic design,” “bioanalogous” design,” “bioinspired,” “bioinspiration,” and “biologically inspired design” (Shu et al., 2011). Indeed, minor differences could also be found between these synonyms. For example, bioinspiration indicates the transfer of aesthetic and morphological aspects, whereas, in biomimetics, functional aspects play a key role (Gruber, 2013). Likewise, “bionics,” often used similar to biomimetics, is more related to “cybernetics” (Papanek, 1974) and artificial intelligence (Vogel, 2000). In the scope of the research, only the terms of “biomimicry,” “bioinspiration,” and “bionics” were included, while the minor differences between the other terms were disregarded and discussed under the “biomimicry” term.

Disciplines

The disciplines bordering with biological studies have been respected with “bio” prefix as such “bioengineering,” “biogenetics,” “biomedical,” “biomechanics,” “biomedical engineering,” “biological engineering,” “biotechnical engineering,” “bioarchitecture,” and many more. These terms were excluded since they represent the intersection of specific domains with the advantages of biology. Only “bioarchitecture” was further elaborated as if it might be suitable for the research scope.

Misuses

Confusingly, it seems possible to encounter common misuses both in academic and popular literature. For example, “biomorphology” or “biomorphic design,” and “biomorphism” are more related to the imitation of the forms in nature

(Speck, 2017), yet the terms could be mistakenly used as “biomimicry.” In addition, the term “biotechnology” might sound like a combination of biology and technology; therefore, it might seem suitable to describe the interrelation of living and manufactured components. However, biotechnology means any technological application that uses biological systems, living organisms, or derivatives to make or modify products or processes for specific use (UNEP, 2011). Thus, both “biomorphology” and “biotechnology” were found unsuitable for the scope of the research.

After filtering the terms above, Table 3.1 consists of “bio” terms that might be suitable to describe innovations incorporated with living components in the framework of building design. The “bio” terms included in Table 3.1 cover as follows; concepts found in the explanations in the examples, concepts in the scholarly sources used to describe designing with living components into building design. Table 3.1 demonstrates the approach and scope of the concepts that could describe the incorporation of living organisms in the scope of building design.

Table 3.1 Terms in the Literature Exemplifying the Interrelation of Living and Manufactured Components with “bio” in Building Design (Kirbas Akyürek et al., 2020)

Terms	Approach	Scope
Bioarchitecture	It refers to architectural design with non-living and living elements of nature (Ripley & Bhuskan, 2016).	It is specified for architectural design, mainly used to determine the relationships between nature and the built environment (Eryildiz and Mezini, 2012; Pourjafar and Branch, 2011; Ripley and Bhushan, 2016).
Biocentric	It represents a moral attitude in terms of rethinking the human-nature relationship (Mathews, 2011).	Design thinking proposes to consider humans as a part of nature (Mathews, 2011).
Biodesign	Hybrid forms in architectural design as the intersection of biology and technology (Myers, 2018)	A general term is proposed for all design disciplines (Myers, 2018).
Biofabrication	It offers production with living organisms (Camere and Karana, 2017).	Commonly used in Material science and fabrication (Forgacs and Sun, 2013) and healthcare as such tissue engineering (Raman and Bashir, 2017).
Bioinspiration	Transfer of aesthetic and morphological aspects of nature (Gruber, 2013).	Stimulation of biological paradigms to non-biological science and technology (Deuerling et al., 2018).
Biomediated	Living organisms are mediated by the formation of hierarchical composite materials (Deuerling et al., 2018).	Indicated the guidance of living organisms in material science (Deuerling et al., 2018).
Biomimicry	A creative form of technology learning from the forms, processes, and strategies of nature (Benyus, 1997).	The comprehensive concept describes inspiration from nature for sustainable solutions in multiple disciplines (Aziz and El Sherif 2016).
Bionic	Application of biological function to provide engineering solutions (Wahl, 2006).	More specifically used to work on artificial intelligence (Vogel, 1998).
Bioutilization	Direct use of elements of nature for beneficial purposes (Kshirsager et al., 2017).	Leverages organisms or biological materials (Montana Hoyos and Fiorentino, 2016).
Biophilia	Aims to bond humans with the natural environment (Kellert and Winson, 1993; Tracada and Caperna, 2012).	To connect nature and other forms of life, aiming to create a balance between natural and building environments by supporting environmental sustainability (Tracada and Caperna, 2012).

In my view, the literature review once more underlines the lack of blanket term to determine the praxis despite the diversity of terms and definitions. The following part furtherly evaluates the findings by discusses the possible understandings of them.

3.3 Findings and Discussions

The terms in Table 3.1 presents a variety of concepts that could be used to explain the interrelation of living and manufactured components in building design. Within them, the related terms could be listed as “bioarchitecture,” “biocentric,” “biodesign,” biofabrication,” bioinspiration,” “biomediated,” “biomimicry,” bionic, “bioutilization,” and “biophilia.” “Biodesign,” “biofabrication,” “biomediated,” and “bioutilization” seem suitable to express the incorporation with the living organism in building design even though they are attached to multiple disciplines. Nevertheless, the terms of biomimicry, “biocentric,” “bionic,” “bioarchitecture,” “bioinspiration,” and “biophilia” indicate broader concepts. Therefore to specify them on the recent praxis can cause misunderstandings. In that sense, Table 3.3 also represents the missing transformed terminology in architectural discourse as such “biobuilding” or “biospace.” Bioarchitecture, on the other hand, encompasses emulation from both non-living and living elements of nature (Ripley&Bhuskan, 2016). The term embraces various relationships between nature and built environment while its scope might indicate bias in different sources (Eryildiz and Mezini, 2012; Pourjafar and Branch, 2011; Ripley and Bhushan, 2016). Hereby, “biodesign” might seem more relevant for building design, although the term indicates a more comprehensive approach suitable for all design disciplines (Myers, 2018).

On the other hand, “biofabrication,” “biomediated,” and “bioutilization” are related to material science and technology. Moreover, they explicitly indicate the incorporation of living and manufactured components. Thus, they might also tend to describe the praxis. Furthermore, the concepts of “biomimicry,” “biocentric,” “bioinspiration,” and “biophilia” represent design methods leading designers to

reconsider the relationships between nature, technology, and human. These terms were already used to determine the recent innovations in between living and manufactured worlds. However, they indicate broader concepts of which the recent innovations were misunderstood by encompassing any connection with nature, including both living and non-living components. Therefore, despite the popularity and critical importance, the term “biomimicry” cannot be considered as a blanket term since the primary goal of biomimicry is to translate biological processes into technologies not indicate using biological materials (Marshall and Lozeva, 2009). Likewise, “bioinspiration” includes simulation of the research in non-biological science and technology (Speck et al., 2017). While “biocentric” mainly focuses on the relationship between the natural environment and humans (Mathews, 2011), “biophilia” aims to satisfy the emotional and biological needs of humans by connecting with nature (Caperna, 2017). In other words, the scope of these concepts seems not accurate to define literal and phenomenological meanings of the used definitions.

Overall, the literature review clarifies the variety in the terminology by narrowing it down to specific terms to be used or disregard. Indeed, the number of bio-derived terms can be extended; nonetheless, the literature review could not provide a blanket term that is widely accepted in academic and popular literature.

3.4 Conclusions

In my opinion, without this part of the study, within this emerging field this thesis cannot provide knowledge on biobuilding components without specifying its used terminology. This Chapter offers solutions to the problem of missing accurate terms and definitions of biobuilding components despite the growing interest in multiple disciplines. The number of terms and definitions indeed causes misunderstandings. However, this once more underpins the critical importance of biobuilding components by being bonded with the concepts of nature and technology and multiple disciplines.

The literature review demonstrates the diversity in the terminology and the lack of blanket term with an accurate definition of designing with living organisms in

the building design domain. In that sense, to entitle the interrelation of living and manufactured components as “biobuilding” to lead us to emphasize designing with living organisms, specifically in the domain of building design.

The recent technologies interrelating living and manufactured components promote various advantages for daily lives and buildings. On the other hand, the number of studies gathering these examples together and exploring an overall understanding is limited. At this point, the ambiguity in the terminology might be seen as one of the critical problems. The extensive concept of nature, natural elements, mechanisms, process, and numerous solutions on one side, and different interpretations of the discipline and technique in multiple domains, on the other side, concluded with the appearance of various terms in academic and popular literature. Indeed, due to the literal, phenomenological, and historical meanings of the praxis, it seems there is a need for multiple terms with a variety of approaches. This led me to stress the growing interest in the praxis of the interrelation of living and manufactured components by means of being discussed in many studies with multiple terms and definitions within multiple disciplines. However, this also makes it difficult to perceive the praxis and carry out further studies and discussions. Therefore, the term of biobuilding leads us to specify the focus of the study in a straightforward way.

In conclusion, this Chapter gives an overview of terminology by demonstrating the other concepts which might be relevant to understand the broader aspects of the praxis. In that sense, it provides a better understanding of the ambiguity and complexity in the terminology by showing the reasons behind it, thereby underlining the critical importance of designing with living organisms and the diversity in the terminology by means of being related to several concepts. However, despite the crucial importance of the praxis, the lack of accurate terms and definitions could also be seen as a problem for causing misunderstandings. Therefore, the other step of the research of terminology continues in Chapter 6 by gathering expert opinions on their used terminology. In this sense, as the study unfolds, the thesis provides a better understanding of terminology by bridging theoretical and practical aspects of the praxis. In this way, the thesis presents an

overview of terminology on biobuilding components through multiple methods and answers to RQ2.1 from both theoretical and practical points of view (Figure 3.2).

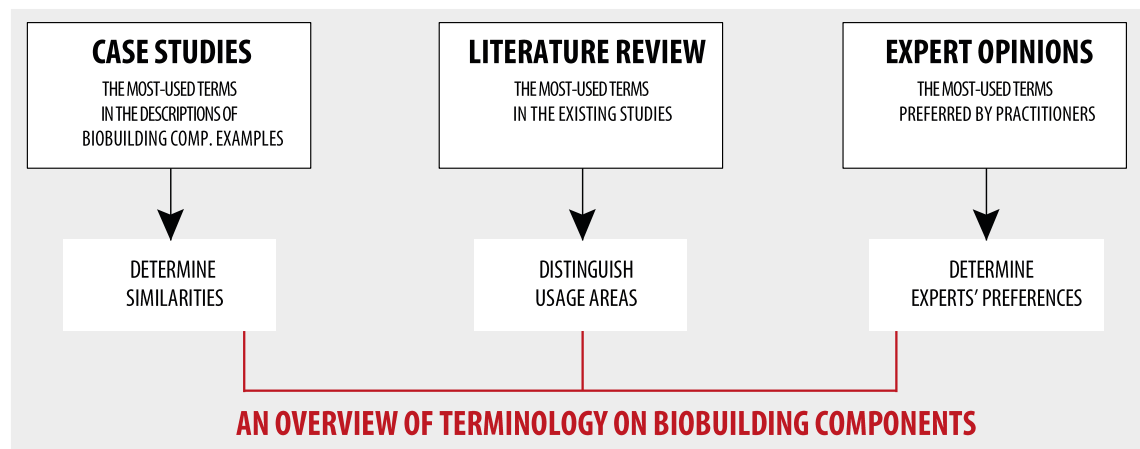


Figure 3.2 The Structure of the Overview of Terminology on Biobuilding Components

Before discussing the biobuilding examples in the following Chapters, this Chapter underpins the biobuilding term with a literature review. Thus, a better understanding provided on the following examples shall be discussed in detail.

DETERMINATION OF BIOBUILDING COMPONENTS IN BUILDING DESIGN

This Chapter presents a variety of biobuilding components that shall be highlighted in the scope of the study. In this way, this part of the study demonstrates the practical meanings of the interrelation of living and manufactured components. This Chapter seeks answers to RQ 2.2. The goals of this Chapter could be summarized as follows:

- To present a variety of biobuilding components, to further elaborate their main characteristics and their goals and objectives, and implementations into the buildings.
- To give a better understanding of the relationships between biobuilding components and building design.

In the framework of the Chapter, firstly, the *Methodology* part explains the limitations in determining the biobuilding components. Further on, in the *Examples of Biobuilding Components* section, Table 4.1 presents an overview of the determined examples. Thus, all the findings from Table 4.1 furtherly evaluated in the part of *Findings and Discussions*. The examples were discussed in that section, along with the highlights indicating certain similarities and differences regarding the gathered examples. What is remarkable here is that the gathered biobuilding components introduce a variety of goals, objectives, domains, actors, implementations, and impact multiple integration layers. At this point, this part of the study draws its conclusions by embracing Multi-level perspective approach (MLP) as a filter leading to comprehend relationships between different but related concepts (Geels, 2002). By applying this method, the study underlines the expected impact of biobuilding components through delivering knowledge of the connection between different scales, biobuilding components (micro), building

design (meso), and the advantages of biobuilding components on a larger scale (macro). Overall, this leads us to discuss the technological meanings of biobuilding components within more comprehensive concepts.

In my opinion, this part of the study provides an overview of the examples of biobuilding components. Moreover, a general comprehension of biobuilding components shall contribute to the architects' awareness of the possibilities to design at the intersection of living and manufactured worlds in building design. That's because, this part of the study highlights various biobuilding components and underpins their impacts by means of affecting buildings in multiple ways and within multiple scales.

4.1 Methodology

Two main selection criteria enlighten us to specify biobuilding components that shall be examined in the scope of the thesis. Firstly, the examples are limited to their particular integration level (Section 4.1.1) and help this study focus on certain prototypes of biobuilding components. Furthermore, the relevancy of biobuilding components with building design (Section 4.1.2) helps exclude certain examples and understand the possible roles of biobuilding components in building design. In this way, the overview presents seventy (70) examples of which found provocatively underlining the critical importance of biobuilding components for building design.

4.1.1 Level of Technological Integration

The level of technological integration based on the Pyramid of Technology by Koert van Mensvoort (2013a) is utilized as a tool to limit the examples in a certain level of technological integration. The examples are limited to their certain level of integration, which was limited to 'operational' and 'applied' level by relying on the Pyramid of Technology by Mensvoort (2013a) that any technology could become a vital part of our lives. The technologies in these two levels are the prototypes that are not part of our daily lives yet but could infiltrate into daily

lives soon (Figure 4.1). The study chooses to gather the examples of prototypes since they are the ‘experimental components act as a physical hypothesis that can be tested’ (Wensveen, 2018). This limitation helps to focus on the specific examples that there is enough information that could be found in the scholarly and non-scholarly sources. As aforementioned before (Section 2.4), innovations can also be placed in between levels, while through time, it is possible to rise up or fall down through steps in technological integration. What is important here is that a prototype is already explained to the public by their possible advantages, objectives, and clear goals, and they are included in this study. However, their societal impacts are not certain yet, since it is possible to reach ongoing plot studies on user experiences and academic discussions.

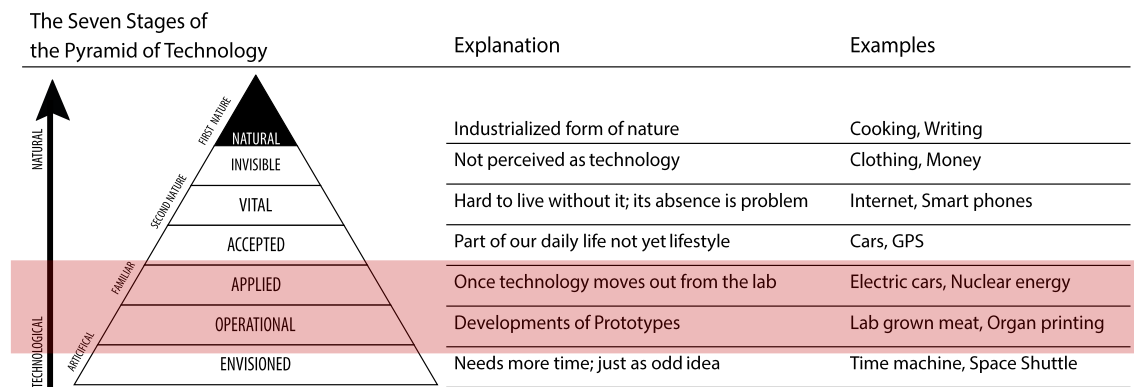


Figure 4.1 Level of Integration of Gathered Examples in Thesis

The examples are not limited to any domains, purposes, or industry. After limiting a certain technological level of integration, the following section introduces the relevance between the selected examples and building design.

4.1.2 Determination of the Relevance with Building Design

The theory of Brand (1994), suggesting different layers in a building, is utilized as an assistive tool to determine the possible roles and impacts of biobuilding components in a building, and also to exclude certain examples.

A building can be regarded as a composition with its internal and external parts assembled from hierarchical levels corresponding to different scales (Brand, 1994; Duffy, 1990; Leupen, 2004). This approach allows tracking the impact of technologies on the different components of a building, thereby determining the biobuilding components shall be evaluated in the scope of the thesis.

Through “shearing layers of change,” Brand (1994) emphasizes the heterogeneity in building design by embracing building and interior design as one unified entity. Brand (1994; 31-55) specifies six (6) timescales in a building; “site (external),” “structure (30-200 years),” “skin (20 years),” “service (7-15 years),” “space plan (3-20 years),” “stuff (1day – 1 month)” (Figure 4.2).

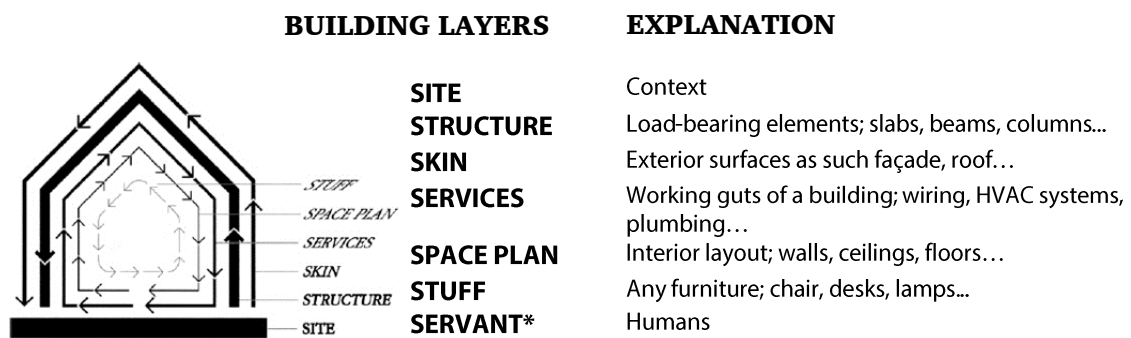


Figure 4.2 Building Layers Determined by Brand (1994)

He argues that “site” is external and permeant, so he places the site at the top of his hierarchy. After *site*, *structure* dominates the other building layers since it also rarely changes in a building. According to him, the hierarchy is followed from exterior to interior. “*Site* dominates the *Structure*, which dominates the *Skin*, which dominates the *Services*, which dominates the *Space Plan*, which dominates the *Stuff*” (Brand, 1994). Moreover, he also accepts humans as the “servant” of the stuff at the bottom of the hierarchy.¹² Additionally, the layers point out not only the differences in timescale but also both design and construction processes

¹² Interestingly, Brand (1994) accepts that human is part of a building as determining another layer. On the other hand, he does not place the human in his drawings, only mentions in the text (1994).

(Pushkar and Shaviv, 2016). In this way, the necessity and vitality of the technologies in a building can also be discussed individually through their integration level into a different process.

From my viewpoint, the categorization of the examples through the determination of Brand reveals the building parts that those innovations may take place. Since the focus of the study is initially limited to building design regardless of contextual factors, the site layer is eliminated from the scope of the determined examples. In this thesis, the examples are categorized through their suggested/demonstrated way of implementation into the buildings. Their potential to integrate into other building layers with other purposes and further implementations into different building layers are elaborated in the *Findings and Discussions* section.

4.2 Examples of Biobuilding Components

The scope of biobuilding components focused on within the thesis is demonstrated in Figure 4.3. All of the examples gathered here signify either a product or a specific way of material technology. Each of them might be considered a biobuilding component by being a part of one building layer.

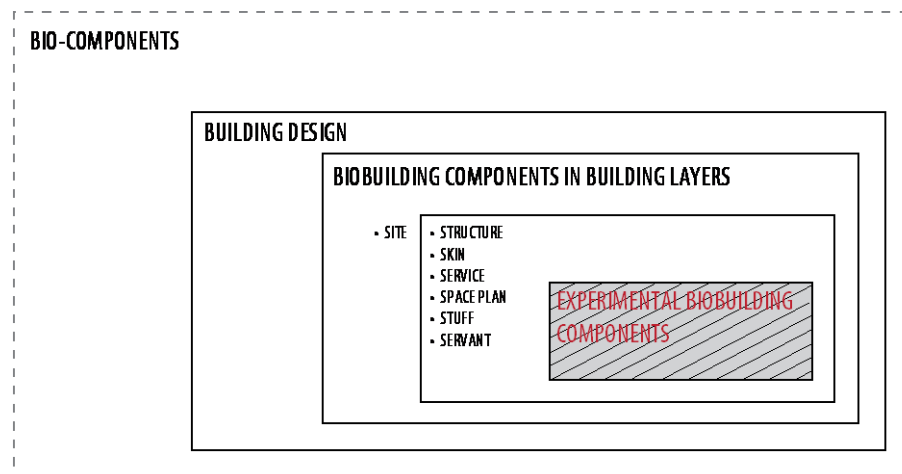


Figure 4.3 The Scope of Biobuilding Components Included in Thesis

The categorization of the examples through the layers of Brand (1994) exemplified, as shown in Figure 4.4. For example, self-healing concrete is placed into the Structure layer. This particular example is also related to the space plan

by affecting the interior walls of the building. But according to Brand's layer, it initially belongs to the Structure layer. The site layer is excluded as a limitation to the study. For instance, the aforementioned examples, root bridges in Meghalaya and Future Venice Project by Rachel Armstrong, belong to the Site layer.

Admittedly, more (similar and different) examples could be discussed. However, what is crucial here is to give architects insights on the potential of biobuilding components by providing an overlook. In my opinion, this overlook is fundamental to determine biobuilding components in the current industrial practice. Therefore, the study does not focus on specific examples and their technical attributes, area of use, or specific advantages. The determined examples explore the diversity in biobuilding components by means of integrating them into different building parts.

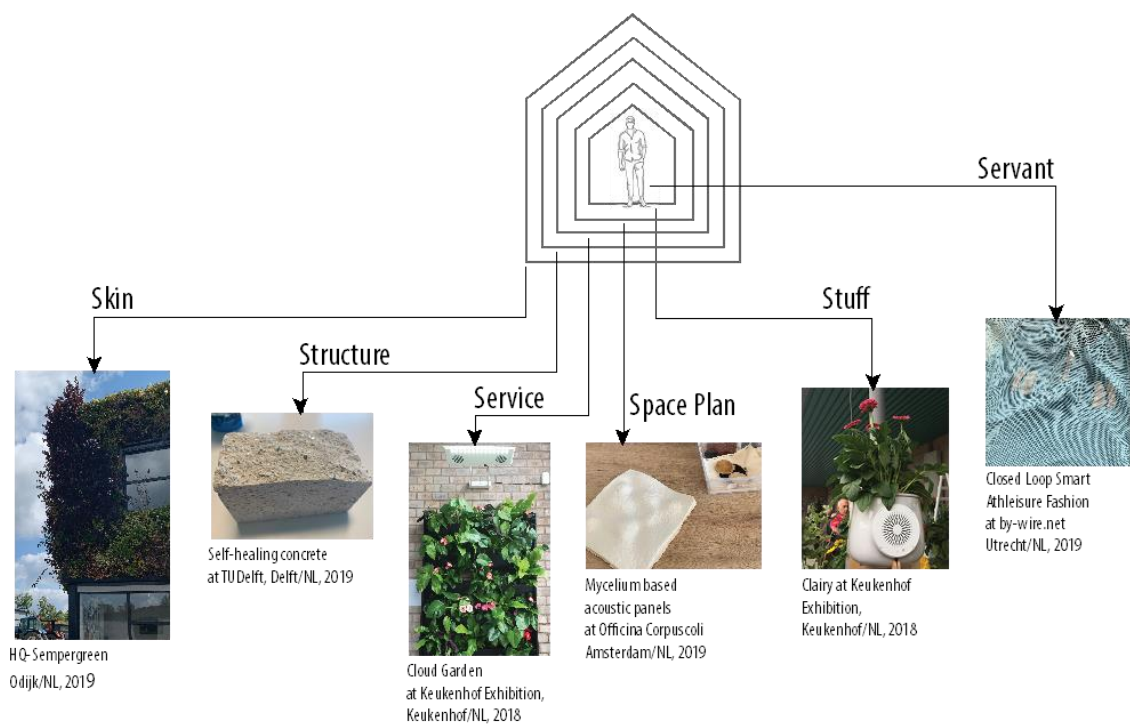


Figure 4.4 Example of Categorization of Biobuilding Components through Building Layers Determined by Brand (1994)

Table 4.1 offers brief information about biobuilding components by giving answers to the questions on related actors, domains, possible functions, objectives,

primary goals, incorporated living organisms, and the possible implementations for the buildings. The goals and objectives are discussed in different columns. In contrast, the goal represents the ultimate aim of the projects, mainly including visions of the developers towards the near future depending on the increase in the number of the projects. On the other hand, the objective explains the main advantage and promised function of the component could be observed in the short term. Implementation, as the outcomes of the goal and objective, suggests using the examples along with underlining the incorporated living organisms.¹³ Integration layer shows which building layer a biobuilding components are primarily and secondarily could be related. For example, Baubotanik, the project initiated by Ferdinand Ludwig (Ludwig et al., 2012), exemplifies an innovative proposal as trees becoming structural parts. In this sense, the integration layer is determined as 'structure,' but this innovation has a clear impact on the 'skin' of a building. Likewise, the example of Algae Curtain, the project by Eco Logic Studio London/UK (Ecologic Studio; 2014), could be placed both into the Skin and Service layer. The table and the integrated layers were only determined through the information declared with the innovators of the projects relying on their initial sources. Many other similar examples could be seen in Table 4.1.

Moreover, Table 4.1 presents an overview of the present; every day, the number of biobuilding components increase and they alter and are furtherly developed. These technologies are the prototypes; therefore, there is more to be discovered for their possible benefits and ways of use in different domains. What is significant here is to present the broad spectrum of their possible roles in building design, thereby leading architects to elaborate biobuilding components in their designs and theory.

¹³ Living organisms was not shown in separate column since what is important here in this study is to demonstrate the 'unity' not to put an extra emphasize on how to use mycelium, plants or any other living organisms in building design.

Table 4.1 Examples of Biobuilding Components

BIOBUILDING COMPONENTS		GOAL	OBJECTIVE	IMPLEMENTATION	INTEGRATION LAYER
1. Baubotanik 	2028 (Expected), Waldstetten/Germany. By Ferdinand Ludwig. Domain: Architecture design & construction. (F. Ludwig et al., 2012).	To "[r]edefine the relation between inside and outside, city and landscape, nature and culture."	To construct a "self-supporting" and "self-sufficient" structure by exploring vegetal technical compound structures.	Using living plants as load-bearing construction elements.	Structure Skin Service Space plan Stuff Servant
2. The Circular Garden installation 	2019, Milan Design Week, Milan/Italy. By Carlo Ratti. Domain: Architecture design & construction. ("The Circular Garden," n.d.).	To experiment with sustainable structures engaged to architectural scale that can grow organically and then return to nature in "a fully circular way."	To use mycelium (the fibrous root of mushrooms) in design.	Arches are grown through mycelium.	Structure Skin Service Space plan Stuff Servant
3. MycoTree 	2017, Seoul Biennale for Architecture and Urbanism, Seoul/S.Korea. By Sustainable Construction at Karlsruhe Institute of Technology and the Block Research Group at the Swiss Federal Institute of Technology Zurich. Domain: Architecture design & construction. (Heisel et al.).	To represent a provocative vision of a more sustainable building industry by exploring new material possibilities.	To explore structural geometry for "low strength" materials.	A spatial branching structure is grown through mycelium.	Structure Skin Service Space plan Stuff Servant
4. Common-action Gardens 	2017, International Architecture Biennial of Antalya, Antalya/Turkey. By Fulya Özsel Akipek and Tuğrul Yazar ([POT]plus) Design Research Group) Domain: Architecture design & construction. (Akipek, 2019).	To combine traditional techniques with digital technologies as well as people with nature.	To design a vertical planting-wall for growing and harvesting edible plants as well as a common action point for the users of the park.	A structural element in which edible plants can be cultivated.	Structure Skin Service Space plan Stuff Servant
5. Mushroom Based Sausage 	2017, Brunel University London, U.K. By Aleks Vesaluoma in collaboration with architecture firm Astudio. Domain: Architecture design & construction. (Jayatilake, 2008).	Zero-waste architecture in the near future where buildings are grown from the bottom-up instead of creating waste and consuming resources.	To provide an environmentally friendly alternative to more commonly used construction methods and materials.	A spatial structure grown from mycelium&cardboard mix molded into mushroom sausages.	Structure Skin Service Space plan Stuff Servant
6. The Hy-Fi 	2014, New York (MOMA, PS1 Space), U.S. By David Benjamin. Domain: Architecture design & construction. (Stott, 2014).	To design and build buildings with no energy and no waste.	To design a building made entirely from mushrooms. Bricks entirely from a fibrous fungus that grew from agricultural waste.	A spatial structure built with bricks made from farm waste and a fungus culture grown to fit a brick-shaped mold.	Structure Skin Service Space plan Stuff Servant
7. Zelfherstellend Paviljoen (Self-healing Building) 	2011, Prototypes developed at TU Delft, building at Breda, NL. By Henk Jonkers (Developer of self-healing concrete). Frank Marcus (Architect of the building). Domain: Architecture design & construction. (Jonkers, 2011).	To build economically viable, sustainable structures by reducing the necessity for regular maintenance and repair as well as CO ₂ emissions.	Building with self-healing concrete allows decreasing the necessity thickness of concrete beams and slabs since cracks on the surface heal themselves.	A building constructed with bacteria-based self-healing concrete.	Structure Skin Service Space plan Stuff Servant

Table 4.1 Examples of Biobuilding Components (Continued)

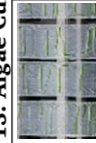
8. Growing Wall Sections (Prototype of Fab Tree Hab Project)  2010. By Mitchell Joachim, Javier Arbona, Lara Greden. Domain: Architecture design & construction. (Arbona et al., 2003).	To grow our own homes from native trees in the near future, thereby considering lifecycle for building industry.	To enable %100 natural and alive sustainable buildings grown through plants.	A wall grown through the "pleaching" of trees.	Structure Skin Service Space plan Stuff Servant
9. Sanfte Strukturen  Since 2000, Germany, Switzerland, Belgium, Spain, France, Denmark, Sweden. By Marcel Kalberer and his group "Sanfte Strukturen". Domain: Architecture design & construction. (Pohl, 2004).	To raise a question on the ecological footprint of our architecture along with boundaries of architecture, art, and landscape.	To explore possibilities to create "living architecture" through the ecological and botanical implications.	Structures from living and growing plants and trees (such as domes, arches, arbors, tunnels, fences, hedges, and even rooms and small buildings).	Structure Skin Service Space plan Stuff Servant
10. Living Willow Structures  Since 2004, the US By Bonnie Gale Domain: Architecture design & construction. (Gale, 2011, b).	To create an alive structure that is easy, sustainable, habitat itself, with carbon absorption, and no toxic preservatives are needed.	To spread living willow architecture, which changes through natural climatic cycles.	Structures from living and growing plants and trees (such as domes, arches, arbors, tunnels, fences, hedges, and even rooms and small buildings).	Structure Skin Service Space plan Stuff Servant
11. Growing Pavilion  2019, Dutch Design Week, Eindhoven, NL By Pascal Leboucq in collaboration with Krown.bio Domain: Architecture design & construction, Product design & development. (Klarenbeek, 2019).	To stimulate a new way of thinking on current environmental problems by showing the possibilities of a natural element.	To underline the potential of bio-based materials which most of them stayed as samples.	A round pavilion constructed with panels from mycelium supported on a timber frame.	Structure Skin Service Space plan Stuff Servant
12. Indus  2019, Bartlett School of Architecture, London/UK. By Shneel Malik. Domain: Architecture design & construction, Industrial design & development. (Hahn, 2019).	To introduce artificially designed natural processes within today's context by creating new forms of daily practice for the genuinely circular economy.	To provide a solution for water pollution (in India) through a modular bioreactor wall system that can filter toxic chemical dyes and heavy metals out of water.	An algae wall to cost-effectively purify polluted water.	Structure Skin Service Space plan Stuff Servant
13. Algae Curtain  2018, Climate Innovation Summit 2018, Dublin/Ireland. By EcoLogiStudio London/UK. Domain: Architecture design & construction. ("Ecologic Studio," 2019).	To make buildings more eco-friendly. "The message is one of spatial convergence and connectivity between the financial marketplace of cyberspace and the relative organic molecular transactions in the biosphere."	The serpentine tubes containing algae embedded into the panels promise to optimize the carbon sequestration process, thereby curbing air pollution.	Algae curtain of which micro-algae convert carbon dioxide in the air into oxygen through the process of photosynthesis.	Structure Skin Service Space plan Stuff Servant
14. Pavilion in Kerala  2016, 2017, Kochi Muziris Biennale 2016, India. By Asif Rahman (Indian studio Beetles 3.3), and Giombattista Arredia and Mohamad Yassin (Italian architecture studio). Domain: Architecture design & construction. (A. Frearson, 2017).	To criticize conventional demolition and disposal process of temporary structures by underlining the possibilities through "living buildings that arise from nature and return to nature".	To promote mycelium as an alternative construction material that is particularly suitable for building temporary structures due to its environmentally friendly properties.	The pavilion's roof formed with mycelium and leather.	Structure Skin Service Space plan Stuff Servant

Table 4.1 Examples of Biobuilding Components (Continued)

15. GrAB-Growing as Building 	2013-2015, Vienna, Austria. By Petra Gruber and Barbara Imhof. Domain: Architecture design & construction. (Imhof and Gruber, 2015).	To take dynamics and growth patterns from nature and apply them to architecture by aiming to develop architectural concepts for growing and living buildings.	To examine the ability of slime mold to grow three-dimensionally and explore the new pathways shall be brought by their biological growth to architecture.	Slime molds growing through the grid structure with the ability to transfer electricity.	Structure Skin Service Space plan Stuff Servant
	16. One Central Park 	2014, Sydney, Australia. By Ateliers Jean Nouvel. Domain: Architecture design & construction. (Myers, 2018).	To push the integration of landscape and tower architecture towards a new level for a sustainable future.	To apply sustainable design strategies suitable for the climatic conditions of Sydney.	Structure Skin Service Space plan Stuff Servant
17. Biofaçade 	2013, Barcelona, Spain. By The Structural Technology Group at Universitat Politècnica de Catalunya. Domain: Architecture design & construction. (Universitat Politècnica de Catalunya (UPC), 2012).	To underline possibilities to “blend buildings and constructions into the landscape.”	To improve thermal comfort and reduce atmospheric CO ₂ levels by creating a “patina” in the form of a biological covering.	A biological concrete for constructing “living” façades with lichens, mosses, and other microorganisms.	Structure Skin Service Space plan Stuff Servant
	18. Silk Pavilion 	2013, MIT, US. By Researchers at MIT Media Lab's Mediated Matter group. Domain: Architecture design & construction. (Oxman, 2015).	To explore the relationship between biological and digital fabrication on product and architectural scales.	3D space created together with silkworms.	Structure Skin Service Space plan Stuff Servant
19. Bio Intelligent Quotient (B.I.Q.) 	2014, Hamburg, Germany By Strategic Science Consult of Germany (SSC), Colt International, and Arup. Domain: Architecture design & construction. (Stelline, 2013).	To create synergies by linking different systems for building services, energy, heat distribution, diverse water systems, and combustion processes by generating energy through “bio intelligent” strategies.	To pioneer energy systems by harvesting fast-growing algae to create biofuel, produce heat, shade the building, abate street noise, and make history.	A building with a bioreactor façade powered by algae.	Structure Skin Service Space plan Stuff Servant
	20. Harmonia 57 	2008, Sao Paulo, Brazil. By Triptyque Architecture. Domain: Architecture design & construction. (Myers, 2018).	To present a new perspective on “live architecture.”	A building of which a vegetal layer covers walls, several plants could grow and live.	Structure Skin Service Space plan Stuff Servant
21. I am lost in Paris 	2008, Paris, France By R&Sle(n). Domain: Architecture design & construction, Lighting. (“I’m lost in Paris.” 2009).	To overcome the separation between nature and humans by sustainable and green design strategies.	To provide extra lighting with refraction through glass beakers filled with bacteria culture.	An external surface with glass breakers providing extra light through bacteria.	Structure Skin Service Space plan Stuff Servant

Table 4.1 Examples of Biobuilding Components (Continued)

22. Cloud Garden Green Wall  2016 By Cloud Garden Company found by Tom Koenderman, Domain: Interior design, HVAC Zwolle/NL ("Green Wall - Cloud Garden - Circular wall system," 2018).	To provide a better indoor environment with climate sensors.	To provide air-purification with a circular wall system with plants.	Modular construction with plants could be applied as interior elements.	Structure Skin Service Space plan Stuff Servant
23. Edible wall  2016, Dutch Design Week, Eindhoven, NL By Masi Mohammadi Domain: Architecture design&construction, healthcare (Loek Kusiak, n.d.).	To combine technology with human needs.	To provide an indoor garden that gives a signal to the older adults that she/he needs to eat.	A wall-mounted indoor garden was allowed to grow edible plants.	Structure Skin Service Space plan Stuff Servant
24. France's Expo Pavilion  2015, Milan Expo, Milan/Italy By Anouk Legendre and Nicolas Desmazières of XTU Architects Domain: Architecture design&construction, food (Bonenberg, 2015).	To explore a building to become a framework for climbing plants with edible produce.	"To show the world by inventing a 'built landscape' that all at once portrays the geographic diversity of France's regions, its unique agricultural offerings, and culinary traditions."	Wooden pavilion with edible plants ceiling for indoor farming.	Structure Skin Service Space plan Stuff Servant
25. Floor tiles from Snail Poo  2014, Exhibition Biodesign at The New Institute in Rotterdam By Lieske Schreuder Domain: Interior design (Cecchini, 2017).	To produce an alternative means of recycling materials.	To produce colored tiles by snail farm.	Colorful floor tiles made from snail poo.	Structure Skin Service Space plan Stuff Servant
26. Mogu Acoustic Panels  2014 By Maurizio Montalti, Milan/Italy Domain: Acoustics, Interior design (Appels et al., 2019).	To build a more virtuous relationship with the ecosystem by featuring remarkable technical properties and innovative aesthetics.	To develop sustainable solutions dedicated to acoustic comfort.	Acoustic panels are made of mycelium materials and upcycled textile residues.	Structure Skin Service Space plan Stuff Servant
27. Bio Detecting Floor  2013, Design Futures Lab at Drexel University in Philadelphia/US By Tashia Tucker Domain: Interior design (Yelavich, 2019).	To explore how synthetic biology could be used in architecture to create smart surfaces impregnated with bacteria.	Bio-surfaces containing "hacked" bacteria could clean your feet as you walk on them.	The floor covering is embedded with bacteria.	Structure Skin Service Space plan Stuff Servant
28. Head Office Sempergreen  2013, Odijk, NL By Sempergreen Domain: Architecture design&construction, interior design ("HQ Sempergreen," n.d.).	To design a building like a living body through living plants and water treatment systems like veins and arteries of a body.	To provide a smart solution to face climate change by positively affecting people's health and indoor comfort.	A wall with living, growing plants.	Structure Skin Service Space plan Stuff Servant

Table 4.1 Examples of Biobuilding Components (Continued)

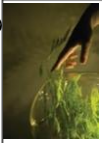
29. Between Air Installation  2012, Spain Pavilion at Venice Biennale, Venice/Italy By Selgascano Architects Domain: Architecture design&construction, interior design, HVAC ("Between Air installation explores the relation between nature and technology," n.d.).	To discover the relationship between nature and technology.	The installation considers the ways to grow plants by ensuring environmentally friendly solutions.	An interior element With a collection of suspended "airports" filled with edible <u>plants</u> .	Structure Slide Service Space plan Stuff Servant
30. Living Light  2017, Dutch Design Week, Eindhoven/NL By Ermi van Oers Domain: Lighting ("Plant microbial energy & the cycle of conversion," n.d.).	Plants could power future cities, and the electric grid could be replaced with a more sustainable microbial energy system.	To design a lamp to be fully self-sufficient and off-grid.	An off-grid lamp powered by the photosynthesis of <u>plants</u> .	Structure Slide Service Space plan Stuff Servant
31. Exhale (Bionic Chandelier)  2017, London Design Festival, London/UK By Julian Melchiorri Domain: Lighting ("Bionic Chandelier," 2017).	To explore ways to apply for advances in biotechnology and engineering in the form of everyday objects and architecture, thereby increasing the quality of our lives.	To purify the air through photosynthesis performed by living microalgae within leaf modules of the chandelier.	A chandelier with algae-filled leaves naturally purifies the air	Structure Slide Service Space plan Stuff Servant
32. Drop by drop  2017, Royal College of Art Graduate Show, London/UK By Pratik Ghosh Domain: HVAC (Tucker, 2017).	To bring changes the way we procure and consume water at a larger level.	This filtration system is a "considerably slow process"; but can be upscaled in the near future.	A home filtration system that purifies (grey) wastewater via <u>plants</u> .	Structure Slide Service Space plan Stuff Servant
33. Clairity  2016, By Clairty Company Group, Italy Domain: HVAC (Masi et al., 2015).	To achieve perfect synergy between nature, technology, and design.	To amplify the natural properties of the plants by directing toxic agents through the roots of the plant, thus enhancing a healthy indoor environment.	A flowerpot reducing pollution levels and monitor environmental parameters via <u>plants</u> .	Structure Slide Service Space plan Stuff Servant
34. Grove Ecosystem - Grow Fresh Food In Your Home  2016, By Grove Company, US Domain: Food (L. Stewart, 2016).	To lead a way to grow food towards sustainable and diversified agriculture by empowering people to grow fresh and local food.	To design a web-connected intelligent indoor garden simulating self-sustainability of nature.	An indoor self-sustainable garden (About the size of a bookshelf), including fish and <u>plants</u> .	Structure Slide Service Space plan Stuff Servant
35. Livesglass  2015, By Jonathan Che, founder of CHE Design in Sydney Domain: HVAC (Ong, 2017).	To show the potential of small-scale products to reduce fatigue, stress, dry throat, headache, cough, and dry skin.	To bring clean air to small spaces by providing a stress-free healthy environment.	A small-scale object can clean air by watering <u>plants</u> .	Structure Slide Service Space plan Stuff Servant

Table 4.1 Examples of Biobuilding Components (Continued)

36. Ambio lamp  2015, Dutch Design Week, Eindhoven/NL By Teresa van Dongen Domain: Lighting (Amy Frearson, 2014).	To explore new ways to create light with zero energy.	To show the potential of harnessing bioluminescent organisms for creating light more sustainably.	A lamp obtaining energy through <u>octopus bacteria</u> .	Structure Skin Service Space plan Stuff Servant
37. BioGlow  2014, By Alexander Krichevsky, BioGlow Bioluminescence, NL Domain: Lighting (Grose, 2014).	To create a world where, rather than electric-based energies, plants might illuminate our surroundings.	The use of the genetically modified plant as a light source since it glows a soft blue-green in the dark.	Lamp with genetically modified <u>plants</u> .	Structure Skin Service Space plan Stuff Servant
38. Mushroom Chairs  2013, Dutch Design Week in Eindhoven, NL By Eric Klarenbeek Domain: Interior design Source: (Bernabei and Power, 2016).	To “bring together the machine and nature” by developing a new way of printing with living organisms as any product.	To promote new material might be used for anything soon.	Furniture in which <u>mycelium</u> grew within the structure, while mushrooms began sprouting on the surface.	Structure Skin Service Space plan Stuff Servant
39. Moss Table  2012, Milan Furniture Fair, Milan/Italy By Itai Lahat Domain: Interior Design (Myers, 2018).	This table converts chemical energy into electrical energy using biological material, which might be the future of furniture.	To demonstrate the potential of “Biophotovoltaic technology.”	A table can produce energy with the photosynthesis process of living organisms such as cyanobacteria, moss, algae, and vascular plants.	Structure Skin Service Space plan Stuff Servant
40. Bacterioptica Chandelier  2010, By Matlab Architecture Firm, New York/US Domain: Lighting (Derringer, 2018).	To create an adaptive design, not only in its form and mechanics but in the way it evolves.	To symbolize the life of the family by designing an “alive” chandelier.	A living&growing chandelier made from fiber optics and petri dishes of <u>bacteria</u> .	Structure Skin Service Space plan Stuff Servant
41. Latro Lamp  2010 By Mike Thompson, UK Domain: Lighting (Sepehri, 2016).	To demonstrate “idealist” alternative power sources.	To utilize living algae as its power source.	A lamp powered through <u>algae</u> .	Structure Skin Service Space plan Stuff Servant
42. Controllable Third Thumb  2017 By Dani Clode, UK Domain: Healthcare (Aouf, 2017a).	To challenge common understanding towards prosthetics – usually thought of as devices only for people with disabilities. On the other hand, prosthetics can be developed for human body enhancement.	To let wearers extend their natural abilities.	An apparatus for a <u>human</u> to have an additional thumb	Structure Skin Service Space plan Stuff Servant

Table 4.1 Examples of Biobuilding Components (Continued)

43. Petit Pli Clothing  2017 By Ryan Mario Yasin Domain: Fashion&textile (Yasin, 2018).	To reduce the huge amount of waste generated by the fashion and textile industry.	To develop clothing that expands to fit children as they grow	Garment that expands in parallel to the growth of children's bodies.	Structure Skin Service Space plan Stuff Servant
44. Closed Loop Smart Athleisure Fashion  2017 By Marina Toeters, NL Domain: Fashion&textile (Veske et al., 2019).	To develop a sustainable economic model increasing functionality and multiple usages of sensors.	To increase the reusability of electronic garments and potential recyclability.	A smart shirt for humans measuring wearer's key vital signals	Structure Skin Service Space plan Stuff Servant
45. UA Athlete Recovery Sleepwear  2017 By Underarmour Company, US Domain: Fashion&textile (Maslakovic, 2018).	To transfer existing technology already used for therapeutic purposes in lamps and saunas.	To reduce inflammation and help sleep athletes better.	A smart shirt for humans improves sleep quality.	Structure Skin Service Space plan Stuff Servant
46. Polar Team Pro Shirt  2017 By Polar Electro Oy (globally known as Polar), US Domain: Fashion&textile (Fox et al., 2019).	To create the "ultimate solution" for player tracking in team sports.	To monitor the heart rate, track fitness activity of the players/athletes.	A smart shirt for humans monitoring heart rate and tracking fitness activity.	Structure Skin Service Space plan Stuff Servant
47. Levi's Commuter Trucker Jacket  2017 By Levi's® Commuter™ x Jacquard Levi Strauss and Google ATAP (Advanced Technology and Projects) Domain: Fashion&textile (Metcalf et al., 2018).	An alternative for a smartwatch for bikers.	To develop a safe way to connect without having to stop and reach for your phone	A smart jacket for humans allowing them to connect their phones while biking.	Structure Skin Service Space plan Stuff Servant
48. Token, The Ring  2017 By Team of Token Company, US and UK Domain: ICT (Information and Communication Technologies) ("The Ring," n.d.).	To provide security through enhancing usability.	Let people access all personal information (password, house key, credit card, car key, access badge, and transit card) via one ring.	A smart ring for humans allowing to access your data.	Structure Skin Service Space plan Stuff Servant
49. Scroll ring (spatialize)  2017 By Nat Martin, UK Domain: ICT (Information and Communication Technologies) (Aouf, 2017, b).	To provide alternative access to augmented reality experiences rather than smartphones of separate handheld controllers.	Let users easily interact with augmented reality	A ring for humans to easily access augmented reality experience.	Structure Skin Service Space plan Stuff Servant

Table 4.1 Examples of Biobuilding Components (Continued)

50. Thin Ice Clothing  2016 By Adam Paulin Domain: Fashion&textile (Paulin, n.d.).	To drive people to eat and consume more without thinking and caring.	To make it possible to lose weight only by wearing the product.	Clothing easing <u>humans</u> to lose weight.	Structure Skin Service Space plan Stuff Servant
51. Neopenda smart baby hat  2016 By Ciklum R&D Team Domain: Fashion&textile (Charara, 2016).	To provide assistive solutions for the lack of caring facilities for babies in low-resource areas.	To monitor the baby's health. It can measure temperature, heart rate, respiratory rate, and blood oxygen saturation.	A smart hat for <u>babies</u> .	Structure Skin Service Space plan Stuff Servant
52. Bikini connecté  2015 By Spinali Design Group Domain: Fashion&textile (Sharma et al., 2017).	To protect human body from the sun with smart features.	To alert you when you've had too much sun via a waterproof UV sensor and your smartphone.	A smart bikini for <u>humans</u> giving protection from the sun.	Structure Skin Service Space plan Stuff Servant
53. Samsung NFC Suit  2015 By Samsung C&T Domain: Fashion&textile (Falke et al., 2007).	To differentiate forms of wearables.	To let users to connect with their smartphones in an easy and fast way.	A suit for <u>humans</u> allowing to connect their phones.	Structure Skin Service Space plan Stuff Servant
54. Electric Clothes  2015 By Sang-Woo KIM, S. Korea Domain: Fashion&textile (Seung et al., 2015).	To provide alternative forms of energy harvesting.	To transform friction energy into electrical energy.	Clothing for <u>humans</u> harvests energy from its wearers.	Structure Skin Service Space plan Stuff Servant
55. Smart Earbuds  2014 By Indira Negi, US Domain: ICT (Information and Communication Technologies) (Dysart, 2017).	To provide alternative design solutions to monitor the heart rate more accurately.	To monitor and measure real-time heart rate.	Earbuds for monitoring the health activity of <u>humans</u> .	Structure Skin Service Space plan Stuff Servant
56. Wearable Senses  2014, Department of Industrial Design, TU Eindhoven/NL By Oscar Tomico, Stephan Wensveen, Kristi Kuusk, Martijn ten Bhömer, René Ahn, Marina Toeters, and Maarten Versteeg Domain: Fashion&textile (Tomico et al., 2014).	To create smart textiles by integrating research, education, and innovation.	To design "close-to-the-body interactions, specifically designs that incorporate wearable computing or smart textiles."	A variety of smart clothing for <u>humans</u> and textiles.	Structure Skin Service Space plan Stuff Servant

Table 4.1 Examples of Biobuilding Components (Continued)

57. Mi.Mu Gloves 	2014 By Imogen Heap Domain: ICT (Information and Communication Technologies) (Freire et al., 2017).	“To create something where I could manipulate my computer on the move wirelessly so that music becomes more like a dance rather than a robotic act like pressing a button or moving a fader.” To reach abilities which shall be enabled through identifying smells. This could be locating foods or guessing perfumes, but you can also use it to find persons.	To allow musicians to create music through movement and gesture. To visualize scent in a Google glass style.	Gloves for humans to create music through their movements wirelessly. An apparatus for humans can be placed on your face like glasses.	Structure Skin Service Space plan Stuff Servant
	58. Siniffer, google nose 2013 By Lloyd Alberts, coached by Arne Hendriks, NL Domain: ICT (Information and Communication Technologies) (Mensvoort, 2013b).				Structure Skin Service Space plan Stuff Servant
59. Nadi X, Smart yoga pants 	2013 By Wearable X (Sydney-based startup company) Domain: Fashion&textile (Muhammad Sayem et al., 2020).	To provide self-training to everyone by providing their own personal trainer at anytime and anywhere.	To provide an alternative personal digital yoga coach with the feeling of touch.	Yoga pants for humans	Structure Skin Service Space plan Stuff Servant
	60. Wearable Solar 2013 By Pauline van Dongen, NL Domain: Fashion&textile (Pan et al., 2014).	To provide alternative forms of energy production and harnessing	To transform sunlight energy into electrical energy via a yarn into all sorts of fabrics.	Clothing for humans providing electricity through wearable solar systems.	Structure Skin Service Space plan Stuff Servant
61. Owllet Smart Sock 2 	2013 By Owllet Baby Care Domain: Fashion&textile (Dalsgaard and Sterrett, 2014).	To provide easy and real-time healthcare for babies.	To monitor baby's health at night.	An accessory monitoring health of babies.	Structure Skin Service Space plan Stuff Servant
	62. The Navigate Jacket 2013 By Ben Moir, (Wearable Experiments Company founder) Domain: Fashion&textile (Clegg et al., 2017).	An alternative way to enhance the capabilities of humans through smart technologies.	To create the jacket, wearers can program their destination using a custom-made mapping app that connects wirelessly to the jacket.	A jacket could navigate humans.	Structure Skin Service Space plan Stuff Servant
63. Athos 	2012 By Athos Domain: Fashion&textile (Sawh, 2018).	To offer an alternative to the lack of a needed tool to monitor progress, optimize technique, and quantify the impact of training volume.	To track and guide fitness activity.	Training clothes for humans.	Structure Skin Service Space plan Stuff Servant

Table 4.1 Examples of Biobuilding Components (Continued)

64. Google Glass (Smart Glasses) 	2011 By Google, US Domain: ICT (Information and Communication Technologies) (Lv et al., 2014).	To give the ability to do their jobs faster, smarter, and safer.	To create a smart and safe work environment for the users who need to be focused on their hands while working.	Glasses for <u>humans</u> , a hands-free device, for hands-on workers.	Structure Skin
					Service Space plan Stuff Servant
65. USB Finger 	2009 By Jerry Jalava Domain: ICT (Information and Communication Technologies) ("Computer programmer from Finland has lost finger replaced with USB drive," 2009).	To have a prosthesis would enhance daily lives.	To use a prosthesis, which is a USB memory stick.	An apparatus for <u>humans</u> .	Structure Skin
					Service Space plan Stuff Servant
66. France Telecom – Create Wear 	2004 By Elisabeth de Senneville Domain: Fashion&textile (Hurford, 2009).	To make clothing a critical interface for giving graphic expression and form to your moods.	To design clothes with an integrated, flexible screen to display animated graphics.	Clothing for <u>humans</u> .	Structure Skin
					Service Space plan Stuff Servant
67. Biocouture 	2004 By Suzanne Lee, Modern Meadow Inc. US. Domain: Fashion&textile (Wang et al., 2012).	To provide alternative environment friendly ways of production and materials with living organisms.	To grow clothing by using a recipe of green tea, sugar, bacteria, and yeast bacteria.	Clothing for <u>humans</u> grown vegetable leather from green tea, sugar, <u>bacteria</u> , and yeast.	Structure Skin
					Service Space plan Stuff Servant
68. Cicret bracelet (E-Skin project) 	2004 By Pascal Pommier Domain: ICT (Information and Communication Technologies), Healthcare (Singh and Kumar, 2018).	"Incoming years, we are likely to see Operational e-skin devices gaining momentum in the form of wearable bodily sensors, and potentially as a way to harvest energy from the body's movement."	To create a touch screen from your arm with the advantages of flexibility, water resistance. It works like a tablet but on your arm.	A touch screen is an expansion of the <u>human</u> body.	Structure Skin
					Service Space plan Stuff Servant
69. The Hug T-shirt 	2002 By Francesca Rosella and Ryan Genz, CureCircuit Company Domain: ICT (Information and Communication Technologies) (Angelini et al., 2014).	To create an alternative way to connect with humans.	To design a shirt that makes people send hugs over distance.	A t-shirt for allowing long-distance <u>human</u> contact.	Structure Skin
					Service Space plan Stuff Servant
70. Tongue placed tactile output device 	2004 By Google Domain: ICT (Information and Communication Technologies), Healthcare (Bach-y-Rita and W. Kercel, 2003).	To provide other ways for blind people to see.	To create a tactile vision for blind people, allow seeing via skin receptors.	Glasses providing tangible vision for <u>humans</u> .	Structure Skin
					Service Space plan Stuff Servant

4.3 Findings and Discussions

This section of the study discusses the findings drawn from Table 4.1. First of all, the gathered examples of biobuilding components in the scope of the thesis underline ‘multiplicity.’ This multiplicity means diversity to be found out in multiple domains with multiple goals, objectives, integration layers, and lead us to stress this diversity instead of generating patterns or definite categories. This diversity could be noticed initially in the necessary information on biobuilding components by means of being developed by *multiple actors in multiple countries* with the involvement of *multiple initiators, multiple ways of presentations* (e.g., a showcase in design exhibitions, temporary structures, buildings, etc.) *to the society*. Meanwhile, the goals and objectives of the examples also present *multiple promises* by means of different expected achievements concerning *multiple domains, multiple scales*, and the incorporation of *multiple living organisms*. At the same time, biobuilding components could be categorized under *multiple integration layers*. Moreover, based on this research, this thesis also reveals that this diversity might increase when more examples are gathered instead of revealing specific findings. The summary of the findings could be seen in Table 4.2 at the end of the section and explained as follows.

Terminology

Regarding the findings of Table 4.1, the 34% of examples are described through the customized terms with ‘bio’ prefix as such ‘bioconcrete,’ ‘biobrick’ and ‘bioglow’ and many more. Secondly, 20% of the samples are explained with their ‘smart’ features. In 18% of the samples, the terms related to ‘living’ is detected, while in 17%, terms related to ‘growing’ is used. The terms ‘bio,’ ‘living’ and ‘growing’ are mainly used to emphasize the use of natural components, whereas the term ‘smart’ is used to stress the role of technology.

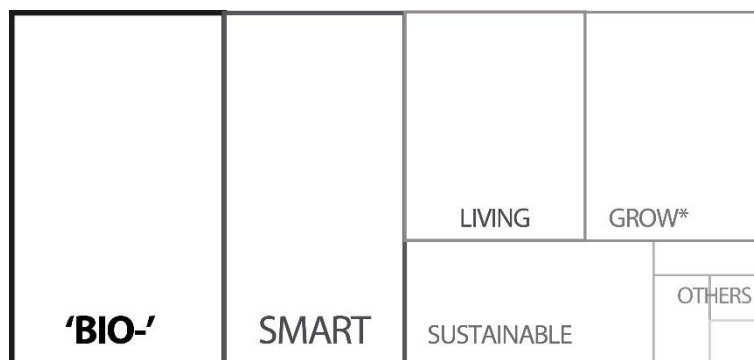


Figure 4.5 The Mostly Used Terms in the Determined Biobuilding Components

Actors

The designers of the biobuilding examples in Table 4.1 show the involvement of multiple actors such as 'architects,' 'interior designers,' 'product designers/developers,' 'biologists,' 'academicians,' 'engineers,' 'fashion designers.' The projects could start up by companies, universities, or independent organizations. At this point, the projects range from clothing to structural columns.

Ways of presentations

Regarding the findings of Table 4.1, the examples include multiple ways to be presented into society. The examples cover 'showcases' presented in design organizations and events such as Venice Biennale, Dutch Design Week, London Design Festival, Royal College of Art Graduate Show, and many more. Moreover, the projects might also directly introduce to society by different companies as prototypes and simulations and commercials explaining their features.

Living Components

More examples could present more living organisms, yet prevailing living organisms could be listed as mycelium, algae, plants, bacteria, and humans. There is no apparent relationship between the use of specific living organism utilization into a particular building layer. But it is possible to discuss clustering towards specific use of particular living organisms. The examples incorporated with plants, bacteria, algae, and fungus exemplify ways to enhance the advantages of living

organisms for buildings. Living organisms could be utilized as the primary material or the product, like in the examples of *Mushroom chairs*, *Growing Wall Sections (Prototype of Fab Tree Hab Project)*, *Sanfte Strukturen*, *Living Willow Structures Growing Pavilion*. Moreover, they could act as a supporter or catalyzer of the conventional systems, such as in the example of *Cloud Garden Green Wall*. In the examples, as the human body embraced as a living component such as *Sniffer nose*, *Google Glass*, *Token*, humans can gain an active role in building design by providing additional features to ‘servant.’ For example, with the *Sniffer nose* project with enhanced senses of smell, a human can act like a smell detector as such noticing smoke, and harmful gases.

Moreover, living and manufactured components can be interrelated in different ways. For example, wearable technologies like *Token* and *Google Glass* represent the articulation of manufactured components to a living component; the human body. On the one side, the examples like *Cloud Garden Green Wall*, *Bioconcrete*, *Living Light*, *Common Action walls* represent more likely a ‘jointed’ relationship in which living and the manufactured component cannot be easily separated. Furthermore, as in the examples of *mushroom chairs*, *Arching Pavilion in Kerala*, *Self-healing concrete building*, it is possible to claim that they represent a ‘hybrid’ relationship between the living and manufactured worlds.

Goals

The goals of the projects in Table 4.1 emphasize the critical meanings of the biobuilding components aiming to provide so many achievements in different ways instead of resulting in mutual goals. But in general, many examples indicate ‘ambitious’ goals by providing alternative ways to change the current production system to create a balance between nature and technology. For example, innovations, especially in the fashion industry, such as *Closed Loop Smart Athleisure Fashion*, aims to develop a sustainable economic model’ (Toeters et al., 2017). Likewise, *Google Glass* envisions to enhance a safe and smarter work environment (Lv et al., 2014). The examples like *The Circular Garden Installation* (“The Circular Garden | Carlo Ratti Associati,” 2020), *Cloud Garden Green Wall*

(“Green Wall - Cloud Garden - Circular wall system,” 2018), *Grove Ecosystem - Grow Fresh Food In Your Home* (Stewart, L, 2018) goals to be the initiators of circular system thinking by showing the possibilities. Furthermore, many projects like Clairry (Masi et al., 2000), Between Air Installation (Between Air installation explores the relationship between nature and technology, 2018), and I am lost in Paris (Arbona, 2010.), might be seen as ‘ambitious’ to declare their ultimate aim to harmonize nature and technology.

Despite the diversity of goals, many similarities could be detected in the goals of examples that might generate recognizable ‘patterns’ and ‘categories.’ To present mutual categories might help understand the goal roles of biobuilding components intersection of living and manufactured worlds. Hereby, these categories could be explained as follows.

The examples as *USB Finger*, *Controllable Third Thumb*, *Cicret Bracelet (E-Skin project)*, *Scroll Ring (Spatialize)*, *Token*, *The Ring*, *Google Glass (Smart Glasses)*, *Levi’s Commuter Trucker Jacket*, *Samsung NFC Suit*, *France Telecom – CreateWear*, *The Navigate Jacket*, *Tongue placed tactile output device TDU (Tongue Display Unit)*, *Sniffer*, *google nose*, *Mi.Mu Gloves* and *The Hug T-shirt* could be categorized under the main goal as ‘human (body) enhancement via expansion of natural capabilities.’ These technologies exemplify any attempt to temporarily or permanently overcome the current limitations of the human body through natural or artificial extensions. The examples in these categories are all in human scale as apparatus or garment since their fundamental purpose is to expand the limits of the human body.

The examples as *Smart Earbuds*, *Wearable Senses*, *Owlet Smart Sock 2*, *Neopenda Smart Baby Hat*, *Polar Team Pro Shirt*, *Nadi X*, *Smart yoga pants*, *Athos*, *Sensoria running socks 2.0*, and *shoe*, *Thin Ice Clothing*, *Bikini connecté*, *UA Athlete Recovery Sleepwear*, *Ministry of Supply Mercury Heated Jacket* could be categorized under the title of ‘productive daily life via real-time healthcare and/or wellness assistant technologies.’ These innovations encourage people to build up a productive daily routine through monitoring and scheduling, thus controlling their daily activities

and getting professional help. A real-time medical data measurement may assist the human body to be healthy and keep it controlled. Furthermore, innovations offering easy fitness coaching services may prompt effectiveness and efficiency in sports performance. The examples in this category are all in the human scale as apparatus and garment since they assist the human body by attaching to it.

The examples like *Wearable Solar*, *Electric Clothes*, *The Zegna Ecotech Solar Jacket*, *Latro Lamp*, *Ambio Lamp (Bioluminescent lamp)*, *Living Light*, *Bioglow*, *starlight avatar*, *Moss Table*, *Latro Lamp*, *Closed Loop Smart Athleisure Fashion*, *Bio Intelligent Quotient (B.I.Q.)*, *Indus*, *Algae Curtain*, and *Petit Pli Clothing* can be clustered as alternative forms of energy harvesting via new sustainable energy production techniques. Energy harvesting is the process in which energy is derived from external sources (e.g., solar power). What is proposed in the thesis with these examples that the suggestions of new methods on energy harvesting, which is now rarely existing, uncommon, or less known in fact, sounds possible. The examples in these categories can be found on different scales.

Biocouture, *Bacterioptica Chandelier*, *Mushroom Chairs*, *Floor tiles from snail poo*, *Arching Pavilion in Kerala*, *MycoTree*, *The Hy-Fi*, *Mushroom Based Sausage*, and *Silk Pavilion* are the examples in multiple scales, functions, and multiple objects which makes them similar is that instead of the end product, these examples aims to explore and demonstrate the potential benefits and uses of new environmentally-friendly (bio)materials. Moreover, developing environmentally friendly biomaterials indicates chemical products that can replace conventionally non-degradable (generally petroleum-based materials) with biodegradable and preferably compostable solutions.

Clairy, *Livesglass*, *Drop by Drop*, *Exhale*, *Cloud Garden Green Wall*, and *Bio Detecting Floor* focuses on indoor health and comfort. Most people spend more than 80% of their time indoors, and for that reason, experts accept as true that more health issues occur due to indoor air pollution than to outdoor. Consequently, the products in this category offer a healthy indoor environment by bringing solutions

to air quality, water recycles, and many more. The examples in this category can be found in product scale, furniture, and interior elements.

Baubotanik, The Circular Garden installation, Common-action walls, Zelfherstellend Paviljoen (Self-healing Building), Growing Wall Sections (Prototype of Fab Tree Hab Project), Sanfte Strukturen, Living Willow Structures Growing Pavilion, Pavilion in Kerala, GrAB-Growing as Building, One Central Park, Biofaçade compose visionary perspective on architectural design. The examples here can be determined as a search for an ultimate way of creating a balance between nature and technology in the framework of building design through smart and sustainable solutions provided by biobuilding components. Indeed, they can also be discussed similar to the examples of Living root bridges in India by means of accepting them as attempts to imitate regenerative aspects of living organisms in nature.

At this point, it is essential to say that these categories help to discuss biobuilding components through their similarities and differences. More studies might add new categories as well. What is important here, these goals might inspire architects to include biobuilding components into their designs.

All in all, biobuilding examples encompass ‘long-term’ and ‘broader’ goals independently from their scales and integration layers. In this sense, it is possible to discuss two different scales; ‘micro’ and ‘macro.’ The scale of a product could be very small, even hidden, while the possible impact of the product could be macro to estimate. For example, wearable technologies might initially take place in a building as a servant or stuff. At this point, the examples show that their integration with the human body might indicate more significant impacts on buildings and lead the way to a smart and sustainable built environment.

Objectives

While the goals of the projects generally indicate broader aspects of biobuilding components, the multiple objectives of the examples show their possibility to be utilized into multiple functions. In this regard, the examples could be seen in relation to multiple domains.

Table 4.1 includes various examples related to multiple domains that could take place in several domains such as ‘building design and construction,’ ‘healthcare,’ ‘sport,’ ‘interior design,’ and many more. However, in Table 4.1, it was not preferred to make an emphasis on the domains. One project could be designed in one specific domain, yet its application might indicate a great potential for another domain. For example, the Edible wall, designed by Masi Mohammadi (De woonomgeving die ‘meevoelt’ - Empathische Woning., 2018), is related to healthcare and architecture domains design and construction. Since these projects are on the experimental level, their impact domain could not be determined yet. As another example, Wearable Solar designed by a fashion designer Pauline van Dongen (Pan et al., 2014), indicates a great potential of use for other domains. The project produces solar energy, which could be combined with any other domains in the near future. For example, the produced energy could be integrated with smart devices such as smartphones or smart home technologies, thereby linking other functions and other domains.

Implementations

Table 4.1 shows the implementations of the examples that show the outcomes of the projects that could be placed into the buildings. Biobuilding components vary from clothes to building bricks. Thus, multiple ways of incorporation with living organisms could also be seen. For example, in *Petit Pli Clothing*, the project simultaneously alters together with the human body. In the example of *Controllable Third Thumb*, the project acts as another part of humans. In examples like *Mushroom Chairs*, *The Hi-fi*, and *Growing Pavilion*, fungal become living, growing building component. These different implementations lead us to see the adaptation of the interrelation of living and manufactured components in different ways.

Integration Layers

But most importantly, the findings after the categorization of the innovations regarding the layers of Brand are shown in Table 4.1 points out the changing dynamics at the interrelations between the different parts of a building. Whereas,

the hierarchy from site to the servant is now altering as different layers of a building may have a 'nonhierarchical' impact on the others.

Hereby, Brand's theory acts as an assistive tool, therefore helps this study as a starting point. But it seems that his theory is sufficient to evaluate biobuilding components through their potentials to be integrated into multiple layers and altering relationships between different building layers. The Brand theory allows us to point out the potential integrations of the innovations into a building. Nevertheless, it becomes unclear to distinguish the segments in a building as the innovations remark new and quasi layers by diffusing into the multiple parts. At this juncture, the innovations can be categorized into renewed layers by composing a new classification system. However, instead of introducing further distinction, the thesis concerns examining the domination and relation inside the different parts of a building. Therefore, Brand determination was utilized as a tool to comprehend the different 'paths' that innovations followed to affect the other layers and building design in general.

What is evident in the examples, the service layer is about to be replaced by other layers either on a bigger scale such as structure or skin, or space plan, stuff, or even servant. In this way, a human can have an active role in building design, thereby interacts with different building parts. By this means, a human can participate in building design, having an active role as a servant. For example, wearable technologies allow humans to connect service layers of buildings. Along with the aforementioned impacts of various studies showing the impacts of small-scale examples on building design, the gathered examples of biobuilding components here once more underline the expected impacts of products on small-scales.

The categorization of the gathered examples in the distinct layers reveals that the innovations do not always dominate the other parts within the hierarchical determination of Brand from "structure" to "stuff." Even the small-scale products might indicate critical importance in building design by influencing the larger

scale, while the products in the larger scales might also affect both the larger and the smaller scales.

At the layers of structure and skin, the innovations remark the possibility to dominate the building parts in smaller scales as such stuff, and space plan similar to the determination of Brand, so they can be easily associated with the design of a building and architecture. However, the innovations at the product level imply a quasi-position by affecting both larger and smaller scales. Besides, the innovations at the human level may reverse the determination of Brand from "servant" to "structure" by empowering the impact of the human. The pilot design experiment and survey study also point out that innovations can play critical roles in influencing the building design by spreading into different parts of a building. The theory of Brand, domination from exterior to interior, leads us to disregard the potential of the innovations at the human and product level for being 'temporary' in a building; besides, the innovations at the human and building-level might seem less connected to the building.

As the innovations in smaller scales as such apparatus and garments at the human level are described with the term of "smart" along with favoring their technical attributes and major advancements, the innovative projects as such construction elements and façade modules are presented with their newly established connections with the living components of nature. In this sense, the desire among humans to be more 'technological' is corresponded with the demands on the building to be 'natural.'

The innovations entitled to smart mainly indicate products aiming to empower daily life by focusing on health and well-being and directly means related purposes. While the products monitor health and blood pressure, various products purify the air, maintain freshwater, and many more. By this means, they can be easily associated with the studies on human health, well-being, and comfort in building design. On the other hand, the innovations with environmental concerns aiming to provide clear and healthy air also concern people's health and develop solutions, but indirectly and on an expanded scale.

Human-centered design approaches favor smart products supporting the quality of life. Depending on this, architects have driven with the idea to design smart environments, homes, and buildings that centered around the perception of a human; experience, emotions, and feelings. On the other side, sustainable, 'natural,' environmentally friendly, energy-efficient applications in building level take an important place in the existing literature as well as in practice by determining an environmental-design approach.

It is essential to underline that the differentiations above underline the knowledge gap prevalingly restrain the integration of the innovations into building design. Undoubtedly, the 'gap' hampering the integration of the innovations into building design has been empowered with the different concerns and scopes inside the disciplines; architectural design and industrial design. But more importantly, the knowledge gap ensures through the hierarchy between the different levels of a building and the differentiation mentioned above. Thus, this led architects to include only the specific innovations into their design by disregarding the others, in fact, finding them irrelevant or out of the scope. The different approaches to building design, human-centered and environmental-oriented, must be mediated to lead architects to utilize the potential of the variety of innovations in their designs.

Therefore, the study suggests a qualitative analysis including interviews of professionals (architects) and the architecture students (as young professionals and the early adopters of the innovations) to fill the omission between different approaches to providing ideas on how to create 'balance' that assist architects in having both human-centered and environmentally oriented approaches. Surely, architects are free to integrate innovations into their designs or not. At this point, this part of the study aims to assist architects in this decision by empowering their level of consciousness. In addition to all, two countries (the Netherlands and the US) were came forward as the most places that biobuilding components are currently developed and presented. This also encourages this study to conducted interviews in the Netherlands in the following qualitative analysis.

Table 4.2 Findings from the Determination of Biobuilding Components

TIME	DOMAINS	GOALS	OBJECTIVES	IMPLEMENTATIONS	INT. LAYERS
2000-2019	- Building design & construction - Interior design - Healthcare - Food - Acoustics - HVAC (Heating ventilation air conditioning systems) - Lighting - Fashion&textile - ICT (Information and computer technology) - Material Technology	- Smart & Sustainable built environment - To create a balance between nature, technology, and design. - To combine digital and traditional techniques. - To present alternative solutions as methods, materials, forms of energy harvesting, and techniques to current environmental problems. - Healthy Indoor Environment - To present solutions by exploring the relationship between nature, products, and buildings. - Productive Daily Life - To empower user's health and wellness via real-time healthcare and/or wellness assistant technologies. - Human (body) Enhancement - To empower needs and abilities.	- To experience and spread new material possibilities as an alternative to current construction methods and materials. - To apply sustainable design strategies as solutions to; - Water pollution - Waste management - Air pollution - Heat and thermal comfort - Sound and noise control - Light and energy - Food production - Indoor comfort - Acoustic comfort - Reusability - User's healthcare problems - User's daily life comfort (cleaning, etc.) - To adopt the aesthetic of nature. - To provide automated solutions that might ease the user's daily life, such as cleaning, tidying, or contacting any part of the buildings.	- Biobuilding components are detected to be implemented in three scales; building, product, human. - Building scale exemplifies the use of biobuilding components in the building environment, such as: - Load-bearing structural elements; beams, columns, etc. - Construction material as in Structural elements, walls, ceiling, flooring, façade, roof - Product scale exemplifies the use of biobuilding component as a product unattached to the building like: - Light (chandelier, table lamp, etc.) - Furniture (sofa, table, flower pot, indoor garden, etc.) - Human scale exemplifies the use of biobuilding components as personal products like: - Clothing - Personal items (apparatus, earpods, prosthesis, etc.)	- Structure-Skin - Structure-Skin-Space Plan - Structure-Space Plan - Skin-Service-Space Plan - Skin-Service - Skin-Space Plan - Space Plan - Space Plan-Stuff - Space Plan-Service - Stuff-Service - Stuff - Servant
DEMONSTRATION (as and in) design exhibitions. - Showcases in research and ongoing building constructions - Projects experimenting in the labs - Simulations - Products in the market	LIVING COMPONENT - Plants (including trees) - Bacteria - Protists (moss, lichen) - Mycelium - Fungus - Slime molds - Algae - Human - Animals (silkworms, snails, fish)	TERMINOLOGY - Bio-.. (as such) - Sustainable - Growing - biomaterial, Living - biomimetic, Eco - and bio-augmented reality [product name]) - Movement - Smart	ACTORS - Architects - Fashion designers - Constructors - Engineers - Interior designers - Researchers - Product designers - Biologists - Product developers - Gardener		

4.4 Conclusions

This Chapter presents various biobuilding components by revealing their characteristics and how they can play a role in a building. The information demonstrated in Table 4.1 and summarized in Table 4.2 allows us to examine prevailing goals, objectives, implementations, incorporated living organisms, related domains, and possible integration layers. In this way, this overview leads us to draw conclusions on the multiplicity regarding the potential of biobuilding components by targeting to affect multiple domains, provide multiple goals and objectives, be implemented in multiple ways, and be integrated into multiple building layers. From my perspective, the overview underlines the multiplicity in the importance of biobuilding components in building design instead of resulting in specific purpose or advantages. In this sense, the information regarding biobuilding components underpins the ultimate goal to be achieved with biobuilding components to carry biobuilding design as a biophilic built environment through multiple advantages in multiple ways. By this means, it seems possible to mention the possible role of biobuilding components in technological transition. Technological transition often shows itself with tangible and visible materials and components and materials (Kemp et al., 1998) as here with biobuilding components. Meanwhile, a global change could be implicated through multiple both as ‘problem’ or ‘solution,’ ‘instrument,’ or ‘measurement’ (Kemp et al., 1998). Hereby, biobuilding components shall be elaborated through as a part of this technological transition towards a biophilic built environment.

At this juncture, the Multi-level perspective (MLP) approach could help to understand this technological change and draw conclusions accordingly. The multi-level perspective assists us to combine findings related to different disciplines (Geels, 2002). Adopting the MLP approach as a filter provides a broader perspective (Geels and Schot, 2007). Thus, in this Chapter, MLP can help us analyze the relationships between biobuilding components, building design, and the ultimate goal of a smart and sustainable built environment.

Geels (2002) emphasizes the social aspects of technological transition by addressing a gap between different elements and between short and long terms, although they affect each other. The MLP introduces three levels 'niche-innovations', 'socio-technical regimes,' and 'socio-technical landscape' that determines micro, meso, and macro levels (Geels, 2002; Kemp et al., 1998). These three levels shall firstly be elucidated to comprehend the MLP approach. The micro-level represents the alternative, niche-innovations, which describes where underlying technologies emerge. These niches could be seen as 'insulated' from the regular market by action started in the 'incubation rooms' (Schot et al., 1994). Most of the time, they have low technical performance and expensive (Geels, 2002). The meso-level indicates the socio-technical regime that specifies the system. The regime is a constellation of rules that stabilize the system. Therefore, it encompasses different dimensions and ongoing processes (Geels, 2002). Geels & Schot (2007) determines the sociotechnical regime as the 'extended version' of the determination of Nelson and Winter, 1982.¹⁴ Multiple actors such as scientists, policymakers, users, and special-interest groups can contribute to the patterning of technological development since it is a social change as well as technological change (Geels and Schot, 2007). The macro-level is entitled to socio-technical landscape as the 'literal connotation of relative hardness and the material context of society' (Geels, 2002). The socio-technical landscape covers external, long-term, heterogeneous, and contextual factors that stabilize the regime or put pressure on it, therefore changing landscape is more difficult than changing the regime.

The relation between these multiple levels is demonstrated as a nested hierarchy (Geels, 2002). Their integration into building layers promises a 'bio layer' linking biobuilding design and a 'biophilic' built environment in which natural and technological are in balance. In this way, the MLP approach clarifies the possible

¹⁴ In the book, *An Evolutionary Theory of Economic Change*, Nelson and Winter determines technological regimes with the shared cognitive routines in an engineering community (Nelson and Winter, 1982).

role of biobuilding components in the transition in the technologies, thereby could be demonstrated in Figure 4.6.

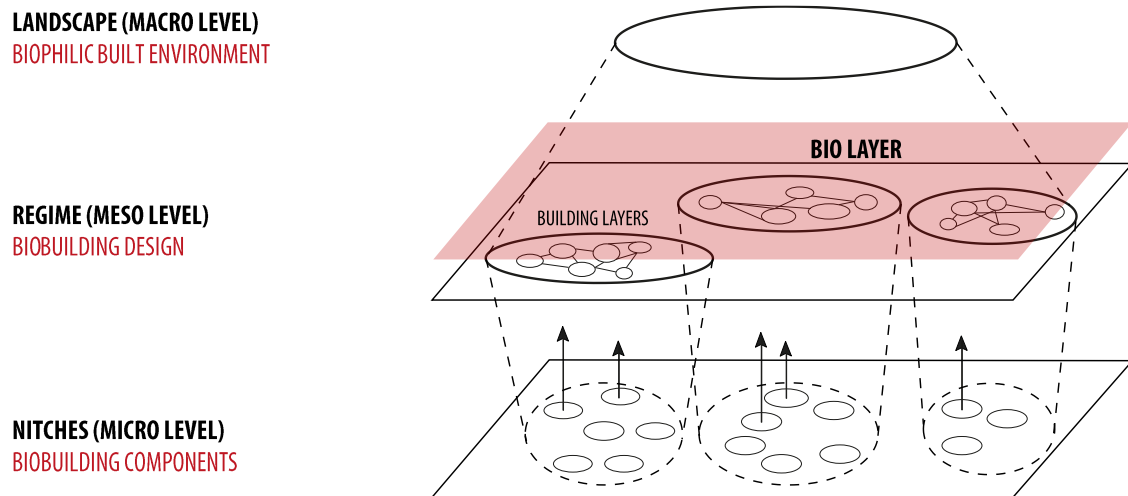


Figure 4.6 Biobuilding Components in the Nested Hierarchy (Based on Geels, 2002).

The classification of Geels leads us to underpins the critical importance of biobuilding components and the necessity to evaluate them in building design by understanding their potential impacts in building design. Biobuilding components refer to a niche alternative since they indicate various alternative innovations, still new, sometimes expensive, and comparably hard to obtain. The increasing number of biobuilding components; in other words, the pressure of niches affects meso level; socio-technological regime. Biobuilding design refers to incumbents here addresses the heterogenous system, including ongoing processes, multiple dimensions, and multiple actors as well. Biobuilding components affect building layers in this system by bringing several advantages to buildings and create linkages with the landscape as a 'biophilic' built environment.

Biobuilding components might have an impact on reaching targets in the landscape by creating a 'bio' layer with the incorporation of living organisms. The bio layer creates a link between a 'biophilic' built environment with biobuilding design. At this point, like the *Fab Three Hab* project, or *The Hi-fi* promises more radical changes in building design, which could change the conventional way how the building is built. However, the building design process remains the same

within the majority of the examples, like facades made from mushrooms, plants providing electricity, and many more. Geels & Schot explains this adaptation of novelties that might be seen as adjustments to the socio-technological regime with a ‘reconfiguration pathway’ (Geels and Schot, 2007). Sequences of component innovations can thus, over time and under the influence of landscape pressures, add up to major reconfigurations and regime changes. In these distributed systems, transitions are not caused by the breakthrough of one technology but by sequences of multiple component-innovations. While regime actors survive in the reconfiguration path, competition and tensions occur among component suppliers (Geels and Schot, 2007). This could be applied to the relations between biobuilding components, biobuilding design, and biophilic built environment, as shown in Figure 4.7.

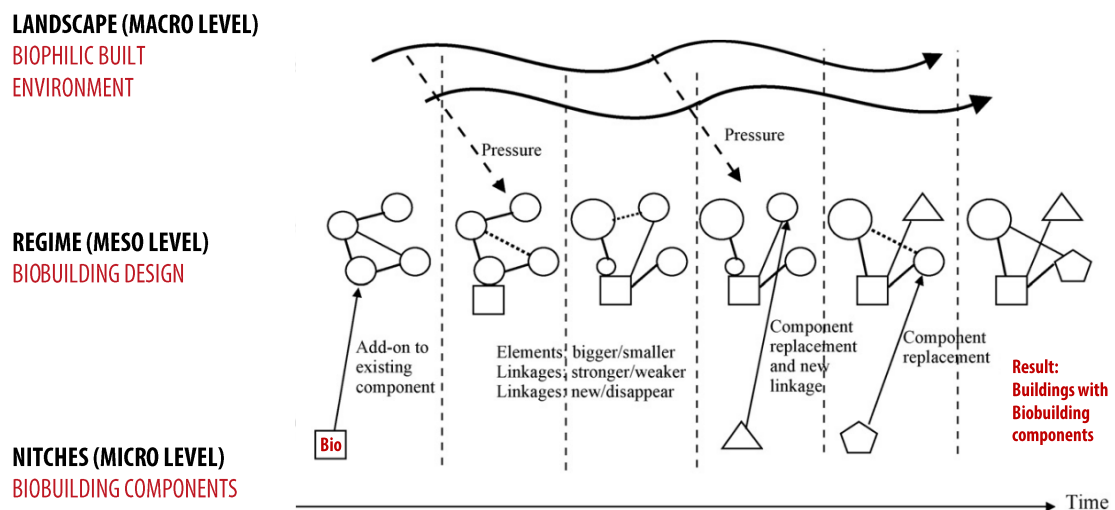


Figure 4.7 Biobuilding Components in the Reconfiguration Pathway (Based on Geels, & Schot, 2007).

In summary, Figure 4.7 shows the relation between biobuilding components, biobuilding design, and biophilic built environment; thus, it reveals the critical role of biobuilding components in the ongoing technological transition by creating a bio layer as a response to the reach ultimate goal. At this point, the increasing number of biobuilding components refers to the multiplication of the components and leads us to prospect changes in the building design as the regime.

In conclusion, this chapter provides answers to the question of what biobuilding components are by revealing their technological meanings with their critical role in the technological transition at the intersection of living and manufactured words. Further on, the study continues with the following research question on how biobuilding components could be integrated into the buildings.

EXPLORING BIOBUILDING COMPONENTS FROM FUTURE ARCHITECTS' VIEWPOINTS

This Chapter presents a building design experiment by observing the impacts of biobuilding components on building design in an architectural design studio. Thus, this part of the study seeks answers to RQ 3.1 and RQ 3.2. The goals of this Chapter could be summarized as follows:

- To experience the expected impacts of biobuilding components on building design in an architectural design studio.
- To determine opportunities and barriers regarding the integration of biobuilding components into building design.

In this way, this part of the study gives insights into the expected impacts of the integrations of biobuilding components into building design through future architects who will have more experience of biobuilding components into daily lives soon.

In the framework of the Chapter, a building design experiment in the architectural design studio at the Department of Architecture in Yildiz Technical University is explained. The design experiment encompasses several different studies with first-year architecture students. Therefore, firstly the scope of the design experiment is explained, then the methodology section introduces the applied methods and design approaches. Different phases of the experiment; *Phase 01, Warm-up, and Phase 02, The Experiment* introduced with students' illustrations. Moreover, *Final presentations & key results* were explained along with the final works of the students after six (6) months long experiment. Overall, the experiment leads us to draw conclusions regarding the translation of biobuilding components into building design. Further studies drive this thesis to continue and make suggestions for future studies.

All in all, this part of the study leads us to experience the translation of biobuilding components in an architectural design studio, thereby observing the process. This allows us to evaluate the opportunities and barriers to the integration of biobuilding components into building design.

5.1 A Building Design Experiment in Building Design Studio

The design experiment was conducted in the architectural design studio, of which architecture students were assigned to develop single-house designs. The applied methodology sets the organization of the experiment, the role of the actors and place, assigned technologies, and data gathering is elucidated. The experiment is further explained with the results found in two phases; Phase 01 (warm-up) and Phase 02 (research).

The goal of the design experiment is to examine the influences of biobuilding components on building design by their integrations into the different building parts. The experiment enables us to observe the design process of the integration of biobuilding components on the different parts of the building, and its objectives are as follows:

- To analyze the relationship between the introduction of biobuilding components in the design process and their integration.
- To observe the approach of the architecture students towards upcoming products within architectural design.

At the beginning of the experiment, the students were divided into two groups: 'test' and 'control' based on the given time of biobuilding components in a different period of the same design process of a single-housing project. During the experiment, the student assignments: diagrams, sketches, graphs, hand-written memos, and models were collected and photographed, along with the notes of the author during the design process. To determine the affected building parts from the integration of biobuilding components into building design, the theory of Brand (1994), specifying on building layers ('site,' 'structure,' 'skin,' 'service,'

‘space plan’ and ‘stuff,’ and ‘servant’) were utilized as an ‘assistive tool.’ The qualitative data gathered as the transcriptions of the verbal data of the student presentations were analyzed with Protocol Analysis (PA) method as the retrospective reports.

As a result, the experiment presented four (4) key results in line with the objectives of the experiment; ‘different design approaches,’ ‘associated and affected building parts,’ ‘advances,’ and ‘concerns’ that either motivate or demote the integration of biobuilding components. The experiment also showed that the students in both groups choose either to integrate or exclude the given innovations. However, test group students were consciously aware of the reflections of the innovations on different parts of a building. Control group students, on the other hand, ignored the impacts of the innovations on their designs even though they integrated the given innovations into their designs. Overall, for both groups, the individual works of the students underlined the significance of the design approach towards the relationships among user, product, and the building on the integration of biobuilding components. To compare the findings from each group is revealed that the links between their introductions into the design process and the possible outcomes of biobuilding components on different building parts.

5.1.1 Methodology

The experiment was held between September 2018 to January 2019 with a gender-equal group of sixteen (16) first-year architecture undergraduate students as a part of the first-year design studio project. The experiment coordinated with the project course weekly schedule (Figure 02). The experiment started with ‘Phase 01’ (warm-up) to introduce the background of the research to the students. Then, ‘Phase 02’ (research) was planned with two interferences in the design process by introducing the biobuilding components in the different periods.

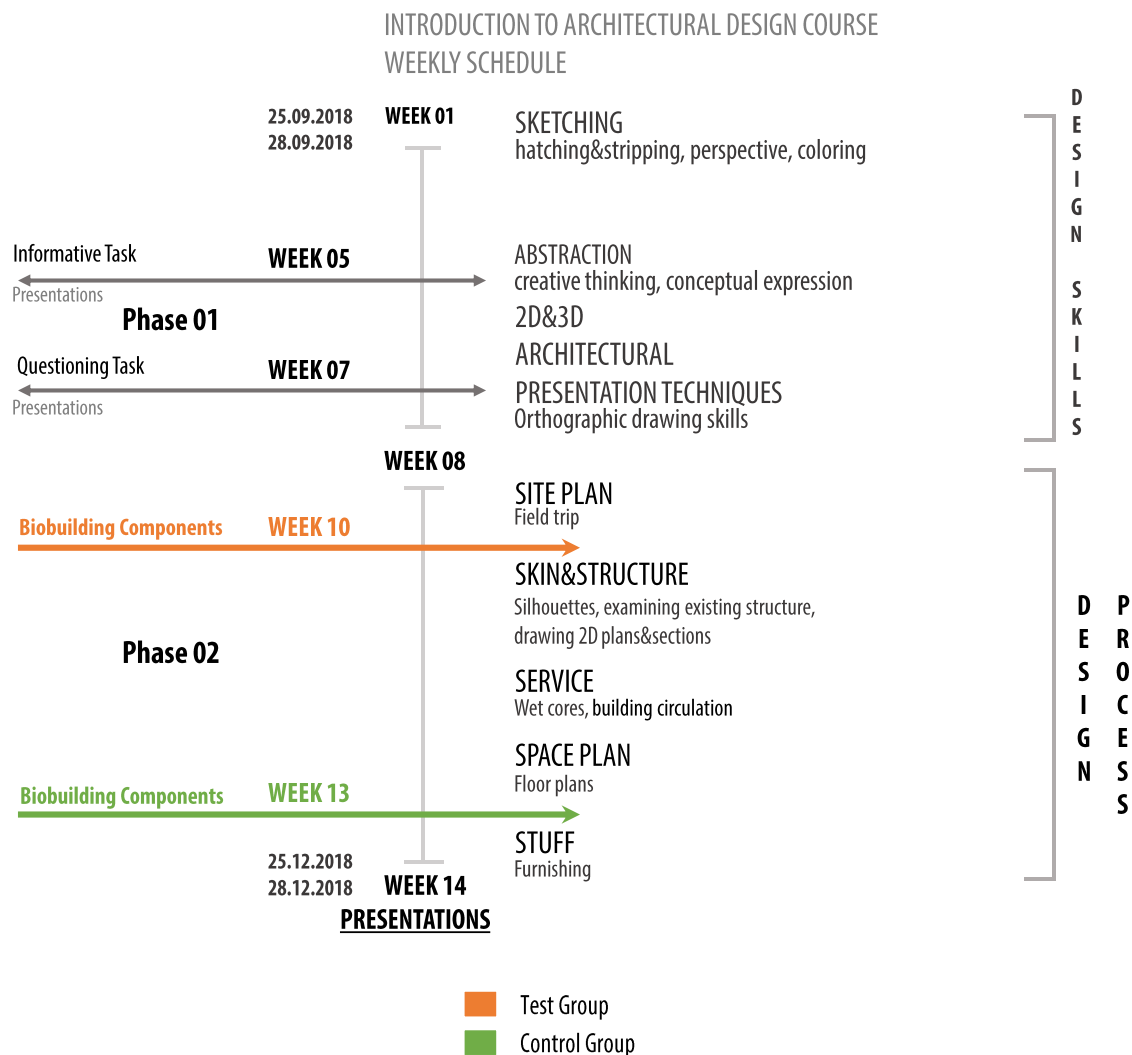


Figure 5.1 The Weekly Schedule of the Project Course

The experiment hypothesizes that the introduction of biobuilding components at the early stage of the design process shall result in integrations into building design. Since the students have higher awareness and understanding of technological advancement, they are expected to integrate innovations into different building parts. Therefore, firstly, biobuilding components were given to half of the students at the beginning of the design process. This group of students (test group) developed their final single-housing designs with the given biobuilding components through the entire design process. Secondly, biobuilding components were also given to the other half of the students (control group) at the end of the design process. Each student was tasked to present their final designs in relation to the given innovations. Control group students expected to

exclude or partly integrate biobuilding components, while test group students expected to integrate biobuilding components into different building parts.

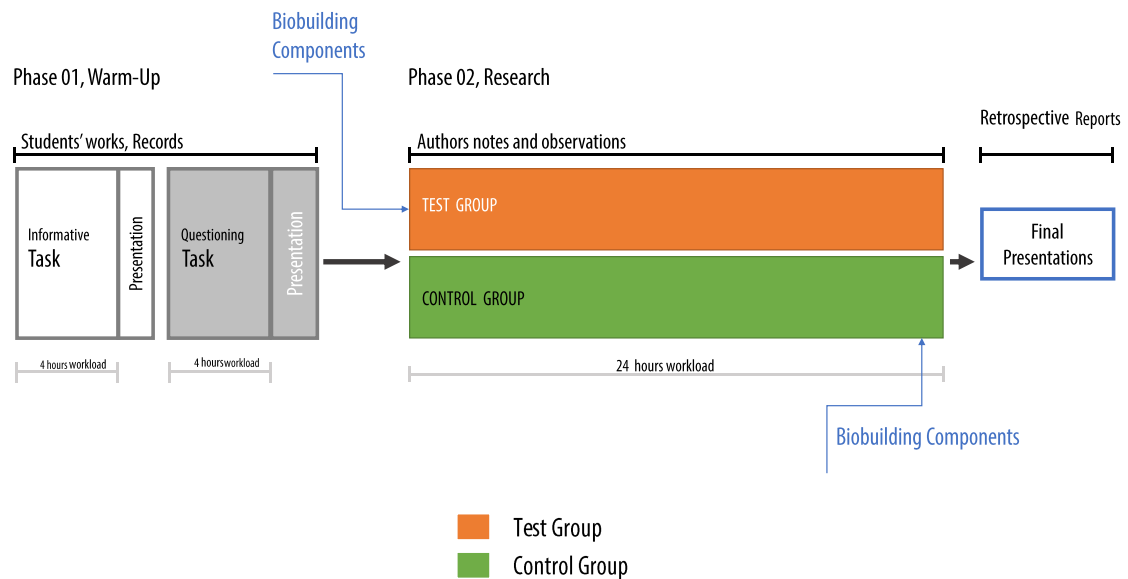


Figure 5.2 The Organization of the Experiment

The role of the actors and place

The primary motivation behind the selection of first-year students for this experiment is to draw attention to the changing roles of the architects soon with the increasing number of biobuilding components. Moreover, to carry out the design experiment in the architectural design studio as a part of the first-year project course has brought four (4) significant advantages to the research.

- First of all, the architectural design studios represent the core of architectural education in which students try to bring solutions to several architectural design problems; contextual, climatic, and programmatic (Caglar and Uludag, 2006).
- Secondly, the architectural design studios embrace the learning by doing approach by asking students to design even though they do not know what design indicates.
- Thirdly, the project course starts with developing basic design skills and later introduces the fundamental steps of the building design process,

particularly to housing design, mainly focusing on the interior dynamics at home environment with limited attention to the urban context.

- Lastly, the course lasts fourteen (14) weeks that provide to observe the entire building design process instead of conducting a workshop in a limited time or evaluating only the end product.

Validation of the abilities of the Students: An Auxiliary Survey

An auxiliary survey study was conducted with thirty (30) architecture bachelor students at the Department of Architecture at Yildiz Technical University, Istanbul-Turkey. The survey inquired the comprehension of the building layers determined by Brand and examined the general ability of the students to interpret the innovations into different parts of a building. This survey was found necessary to validate the performance of first-year architecture students to understand and interpret biobuilding components, thereby to be able to choose to integrate or them.

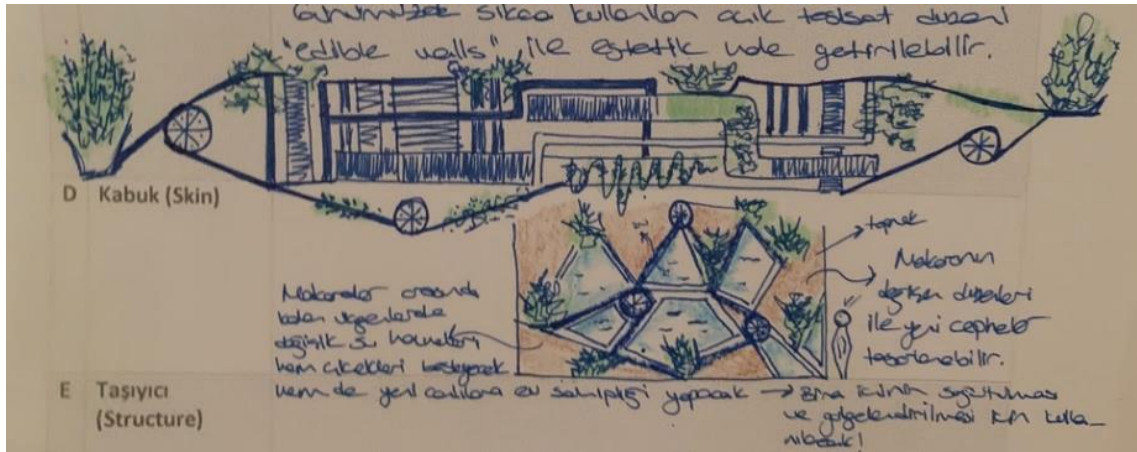


Figure 5.3 Translation of Drop by Drop Project into Different Building Layers: An Example of a Student Answer

In the survey, each student was randomly given one random biobuilding example. The students were given brief information about the given an example and biobuilding layers. Further on, they are asked to adapt them into one or multiple building layers. As a result of the survey, all of the students could able to translate the given an example into at least one building layer. Twenty-six of the students were able to translate the given an example into multiple building layers.

Determination of the affected building parts

To determine the affected building parts with the integration of biobuilding components, the theory of Brand (1994) was embraced as an assistive tool. The building layers of Brand allow us to trace the established relationships between biobuilding components and the buildings by showing the related building parts in the designs of the students. As shown in Figure 5.1, in the Introduction to Architectural Design course, students also follow the same process starts from ‘site’ and ends with ‘stuff&servant.’

Assigned Biobuilding Components

Within the aforementioned (80) biobuilding components, each student was given randomly selected biobuilding components that can originally be placed in the ‘stuff’ layer determined by Brand (1994) (Table 5.1). Some of the examples could also be divided into ‘stuff’ and ‘servant.’ Hereby, concerning the organization of the design course (Figure 5.1), Brand’s (1994) determination to servant layer as a ‘hidden layer,’ the examples were accepted as in ‘stuff’ layer.

Table 5.1 Assigned Biobuilding Components to the Students

	#	The Projects	Function	Students
Test Group	1	Google Glass	Hands-free safety guidance device for hands-on workers.	Student 01
	2	Living Light	An off-grid lamp powered by photosynthesis.	Student 02
	3	Mercury Heated Jacket	To heat the body by receiving voice commands and adjusting body habits.	Student 03
	4	Mushroom Chairs	3D printed mushrooms which grow inside the structure to give it strength.	Student 04
	5	Grove Ecosystem	The indoor self-sustainable garden suggests to ‘Grow Fresh Food In Your Home.’	Student 05
	6	Bacterioptica Chandelier	A living&growing chandelier made from fiber optics and petri dishes.	Student 06
	7	Cicret Bracelet	E-Skin project creates a touch screen from your arm.	Student 07
	8	Mi.Mu Gloves	Gloves allow composing music through movement and gesture.	Student 08
Control Group	9	Scroll Ring (Spatialize)	A ring lets users easily interact with augmented reality.	Student 09
	10	Livesglass	To bring clean air to small spaces by providing a stress-free healthy environment.	Student 10
	11	Drop by Drop	A plant base home filtration system that purifies (grey) wastewater.	Student 11

12	Polar Team Pro Shirt	To monitor the heart rate, track fitness activity of the players/athletes.	Student 12
13	Clairy	Plants reducing pollution levels and monitor environmental parameters.	Student 13
14	Levi's Commuter Trucker Jacket	A safe way to connect without having to stop and reach for your phone.	Student 14
15	Nadi X, Smart yoga pants	An alternative personal digital yoga coach	Student 15
16	Ambio Lamp (Bioluminescent lamp)	Living zero energy lamp using octopus bacteria.	Student 16

Data gathering

During the experiment, the works of the students, diagrams, sketches, graphs, hand-written memos, and models were collected and photographed. The author observed the whole process as a project tutor. In the entire project course, the author took notes systematically and continuously. Additionally, presentations of the students at the end of the assignments were recorded in audio and video.

The Protocol Analysis (PA) method was selected to analyze collected verbal data in the experiment. PA is an observational research method of analyzing the behaviors of designers in empirical studies (Önal, 2015) by allowing to encode cognitive approaches and problem-solving abilities of designers (Cross, 2001; Dorst and Dijkhuis, 1995). In this respect, the design disciplines such as industrial design, architectural design, engineering design, and interior design have adopted the method as a valid research tool (Jiang and Ching-Chiuan, 2009).

Initially, PA is conducted through verbal data with the single-subject talk known as the “thinking-aloud” technique, which is also revised as conversational protocols to employ in group design activities (Ericsson, 1980; Jiang and Ching-Chiuan, 2009). However, using verbal data of a single subject or conversational protocols of a group has been criticized because of neglecting the complexity of design that includes “interlocking and overlapping” process and any other design activities (Lloyd et al. 1995). Indeed, the architectural design process includes several complex layers and different design activities except for verbal data such as: visual, verbal, tactile, written, and is therefore rich in communication potential

(Çıkış and Çil, 2009). The use of verbal data alone in PA to evaluate the architectural design process has been discussed as insufficient (Jiang and Ching-Chiuan, 2009; Lawson, 2005; Suwa and Tversky, 1997). Tversky and Suwa (1997) argue that verbal data is limited regardless of its relevance and necessity in terms of the architectural design process. This is because architects express their ideas on paper through sketches, schemes, and any further drawings that trigger their creativity and lead them to think more and design more (Tversky and Suwa, 1997).

Moreover, talking aloud concurrently in the design process may interfere and manipulate the perception of the subjects during their sketching activities (Ericsson, 1987; Lloyd et al., 1995; Suwa and Tversky, 1997). Therefore, PA is divided into two approaches; concurrent (the report is collected during the task) and retrospective (the report is collected after the task) protocols (Ericsson, K. A., Simon, 1980). In this thesis, retrospective protocols were found appropriate in the framework of this experiment.

Design always indicates a process, and the evaluation of this activity can only be observed simultaneously, yet retrospective reports might give additional information through the designer's perspectives (Önal, 2015). Likewise, retrospective protocols were found appropriate in the framework of this experiment.

5.1.2 Phase 01, Warm-Up

The warm-up phase was found necessary concerning the complexity and wider aspects of the issue. The objectives of the warm-up assignments were:

- To provide a discussion platform to the students on recent advancements of technology at the intersection of living and manufactured.
- To observe ideas and prejudices that hampers the creativity of the students on biobuilding components.

This phase conducted in two tasks; informative (briefing) and questioning. Firstly, the students were divided into four random groups, and one keyword was given

for each. The keywords, ‘nature,’ ‘technology,’ ‘integration,’ and ‘innovation’ led us to open a discussion of the awareness of the students on the increasing number of biobuilding components and their integration into everyday life. Each group was tasked to conceptualize their keywords into 2D-3D sketches and a 3D model. Secondly, the students were tasked to redesign their design studio considering the recent technological advancements in building design. In both tasks, the students were encouraged to ask questions, discuss with each other, and express their opinions and curiosities shall be prepared for the actual experiment.

Informative Task

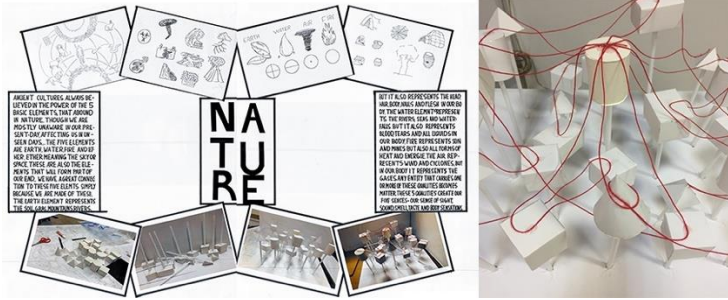
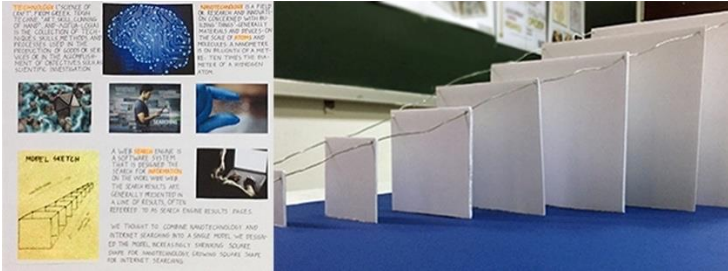
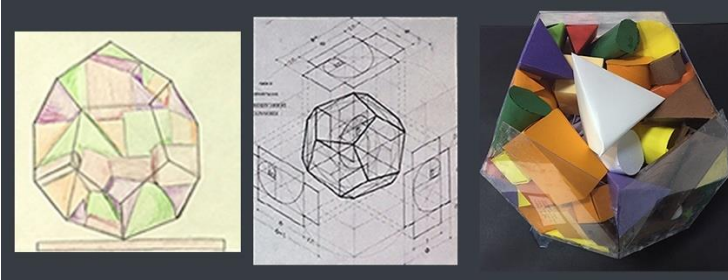
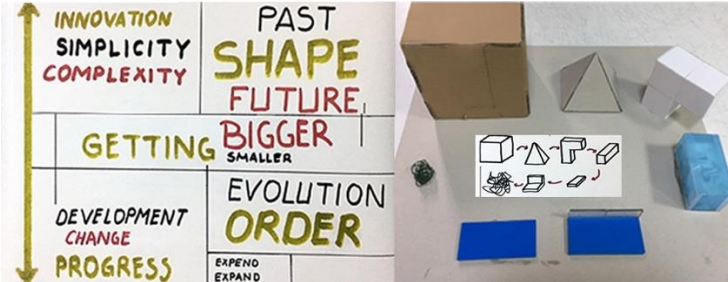
Firstly, the students were divided into four random groups and given one keyword each. The objectives of the assignment were as follows:

- To warm up the students by thinking, exploring, discussing the basic terminology.
- To provide an ability to materialize the abstract concepts.

Outputs & Results

Table 5.2 below shows the drawings and the models created by students with the associated keywords and explanations encoded from their verbal expressions in the presentations.

Table 5.2 Students Works on the Abstraction of the Keywords

Keywords	Students' Works	Verbal Expressions
Nature		“Everything in Nature is related. Human is a part of nature.” Infinity Harmony Human
Technology		“Technology getting smaller every day.” Search&Finding Internet Information
Integration		“Different and independent pieces may determine one unity.” Adaptation Heterogeneity Unity
Innovation		“Innovation can be identified with development and new.” Evaluation Change Time

Questioning Task

Before the second part of the experiment, it is necessary to discuss evolving relationships between nature and technology by giving examples of biobuilding components. Thus, the students were tasked to redesign their architectural design studio considering the changing dynamics in technology and nature. The students

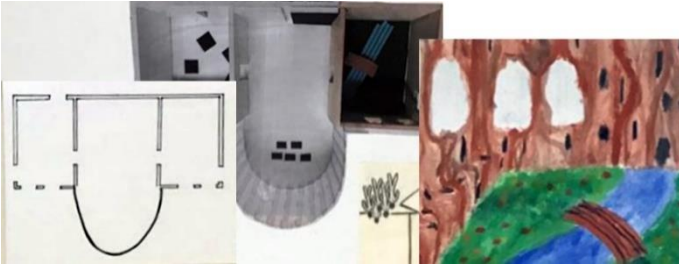
were asked to keep the borders of the existing space. The objectives of the assignment were as follows:

- To lead students to re-question their understandings of nature and technology.
- To introduce recent advancements in technology and discuss their possible reflections on architectural design.

During the discussion session, the students were encouraged to ask questions and express their opinions and curiosities within an hour. Then, students were divided into four groups, and each group was tasked to develop their designs, find a name for their designs, and specify their approach.

Outputs&Results

Table 5.3 shows the given name, approach, and design of each group.

Table 5.3 Students works on Redesigning their Design Studio		
Growing green	 	Approach: To connect with nature. Vision: 'In the future, we will be more connected with nature.'
		Approach: 'Envision a life not attached to anywhere; anyone can be at any place by using hologram technology.' Vision: 'In the future, the boundaries between indoor and outdoor will disappear.'

Imagine by
hologram



Approach:

'Dividing the classroom into three different spaces, one of which connects with nature and helps students to get relax.'

Vision:

'Architectural spaces will be 'high-tech' in the future. Thus there is a need for separate space to connect with nature.'

Let's move



Approach:

'Movable modules bring flexible design.'

Vision:

'Furniture will become dynamics just like natural elements.'

Growing Green group mainly focused on the escalating power of nature that assumedly is more integrated with the architectural environment. Likewise, Imagine by Hologram group suggested that the boundaries between interior and exterior will fade away soon. Plus, Let's Move group recommended moveable, flexible, and dynamic design in architecture with inspiration from nature. The proposals of these three groups favored the incorporation of natural elements into the built environment. On the other hand, Separating Space group declared that anything natural, organic, or green would become endangered soon. Therefore, they proposed a 'separated,' shielded, individual space to reach nature.

5.1.3 Phase 02, The Experiment

After the warm-up phase, all students were tasked to design a two-story single-house in a given parcel as the final assignment of the course (Figure 02, 03). Test group students developed their designs in parallel with the integration of biobuilding components since the 10th week. Control group students also followed the same building design process, but biobuilding components were given at the 13th week while they were at the 'stuff&servant' level of the design process.

In the design studio, the author informed the students regarding the technical attributes of given biobuilding components. Moreover, both test and control group students discussed their ideas of each other as in the natural atmosphere of the design studio. All the students were neither given information nor guided on how the products can be integrated into the buildings. Indeed, they were freed to choose not to integrate them at all.

Design Process of Test Group

The given design problem at the beginning of the design process to the Test group was:

- To develop a design considering the role of the given biobuilding components.

During the design process, particular integration stages experienced by the students were detected and categorized (Table 5.4). Six (6) stages of integration are determined; ‘figuring out,’ ‘negligence’ and ‘rejection,’ ‘association,’ and finally ‘implementation.’ The stages are constituted by the systematic notes taken by the author in every class. The notes included both the verbal expressions and explanations regarding the draft drawings of the students.

Table 5.4 Integration Stages of Test Group Students

Stages	Explanation
Figuring out	The subjects needed more time to discover the technical attributes of the given product.
Rejection	The students had trouble associating the given product with their design. Unlikely negligence, the subjects argued that biobuilding components were not related to architectural design.
Negligence	The subjects did not verbally or visually include biobuilding components in his/her design.
Exploring	The students are still searching for the possible benefits of innovations in building design and construction.
Association	The subjects first created pre-mature thoughts on the new connections between the product and the other building layers.
Implementation	Biobuilding components started to play a role in architectural design.

The students did not pursue these stages in order; each student followed a specific integration pattern by following and/or skipping particular stages (Table 5.5). Almost all of the students except st02 needed time to figure out the technical attributes of the given product at the beginning of the experiment. Later on, students pursued different paths.

Table 5.5 Followed Stages of Test Group Students in the Design Process

	Week 10-T	Week 10-F	Week 11-T	Week 11-F	Week 12-T	Week 12-F	Week 13-T	Week 13-F	Final Design
st01	Figuring out	Rejection	Exploring			Rejection			<u>Segregated</u>
st02	Exploring	Association	Rejection	Implementation					Integrated
st03	Figuring out		Rejection	Negligence			Exploring	Implementation	Integrated
st04	Figuring out	Rejection	Negligence			Exploring		Implementation	Integrated
st05	Figuring out	Exploring	Association	Negligence					Integrated
st06	Figuring out	Exploring			Rejection		Exploring		Integrated
st07	Figuring out				Exploring		Association	Implementation	Integrated
st08	Figuring out	Rejection	Negligence	Exploring		Association	Implementation		Integrated

The expected result was that all students would reach the implementation stage in the design process; therefore, biobuilding components would be integrated into the final designs. However, the students st01, st05, st06 failed to integrate innovations into their designs during the process. St01 purposely rejected to design together with biobuilding components after exploring the given innovation's technical attributes and benefits. St05 had trouble associating the given biobuilding components with building design, therefore neglected the design problem, yet at the final design explained the impacts of biobuilding components on 'space plan.' Likewise, st06 remained at the exploring stage while the given period was not sufficient for him, even though he claimed that the given biobuilding components were integrated into the building. Overall, all students except st01 reached the integration level in their final designs. Only st01 purposely rejected to integrate the given biobuilding components.

Design Process of Control Group

Control group students followed the course design process until the end of the 13th week without taking into account any example of biobuilding components in their designs. Therefore they did not follow the integration stages, unlike Test group students. No difference between the two groups observed between the learning process and efforts regarding the issues related to architectural design.

In the 13th week, biobuilding components were distributed to the students. To accelerate the figuring out stage, the students were helped by giving additional information; photos, websites, articles on the technical attributes of the given innovations. Moreover, as a natural advantage of the design studio, the students, like Test group students, did in the process, discussed the given examples with each other and tried to link them with their designs. In two (2) hours of workload, the students were assigned to develop their designs with the given biobuilding components.

5.1.4 Final presentations & Key Results

In the final presentation, the students expressed their ideas verbally by explaining their drawings and/or models. The author also asked questions regarding the visual data, which helped students to structuralize their approach and even encouraged them to narrate more (Figure 5.4).

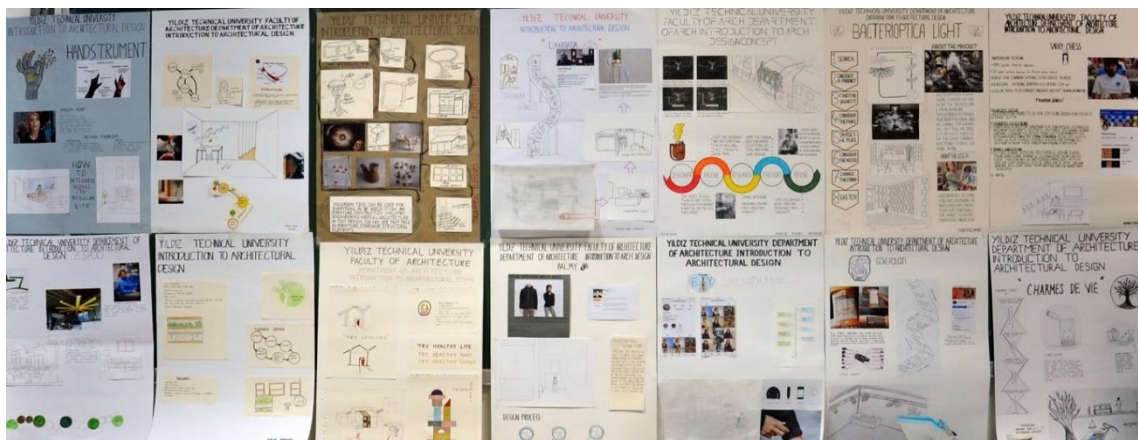


Figure 5.4 Final Presentations of the Students

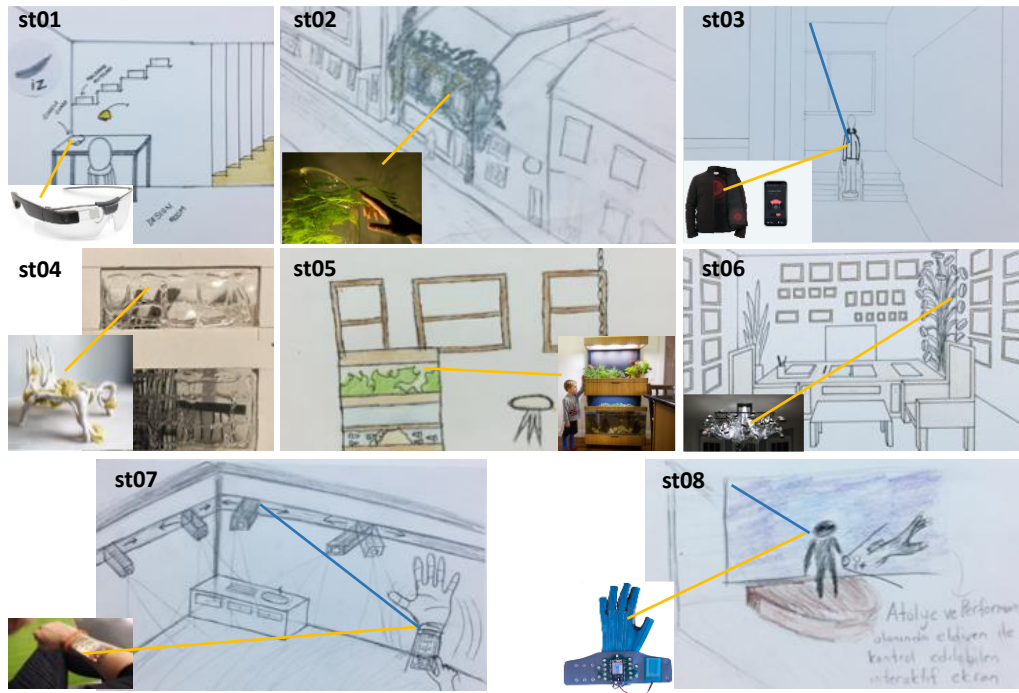


Figure 5.5 Examples from the Works of Test Group (the biobuilding components shown by the author).

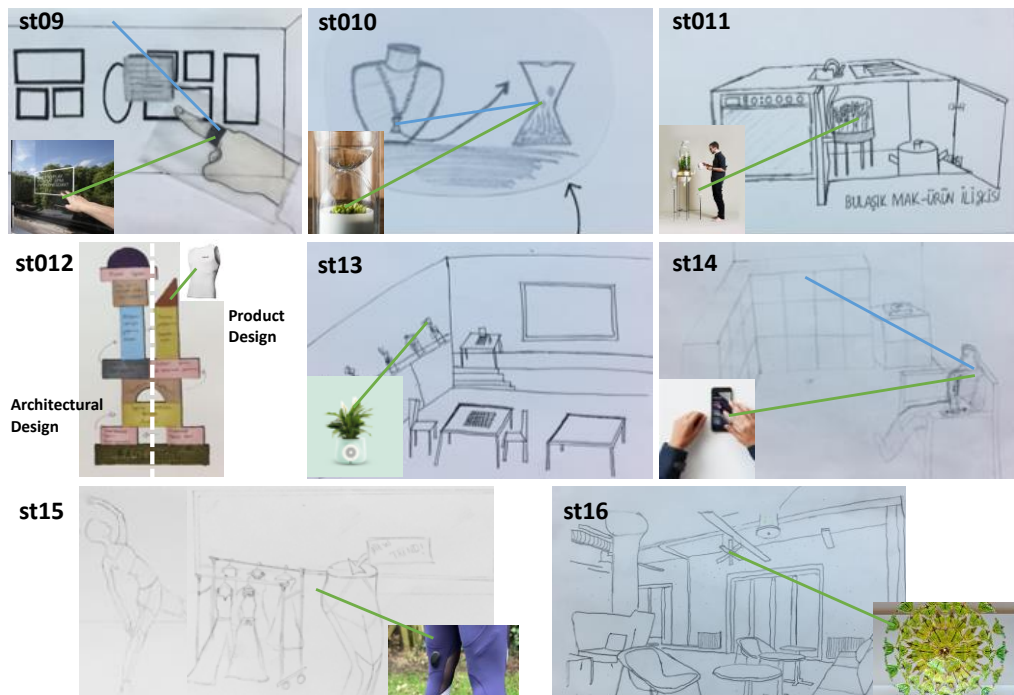


Figure 5.6 Examples from the Works of Test Group (the biobuilding components shown by the author).

By following the steps of the PA method, the verbal expressions of the student presentations were encoded into information categories (Table 5.6). The main categories were identified as; ‘(affected) building layers,’ ‘approach,’ ‘opportunities,’ and ‘barriers.’

‘Building Layers’ led us to categorize the information on the affected building parts as a result of the integration of biobuilding components. The ‘approach’ of the students was divided into four categories. Subclasses ‘segregated’ and ‘integrated’ implied the attitudes of the students towards product and architectural design in terms of accepting the impacts of biobuilding components on building design. Subclasses ‘human-centered’ and ‘top-down’ appeared after the transcription of the data indicating the main concerns in the designs either centered around human or building parts hierarchically affecting the human. Moreover, the ‘opportunities’ category indicated the benefits of the biobuilding components stated by the students, whereas the ‘barriers’ verified the prevailing concerns along with the prejudices.

Table 5.6 Information Categories and Their Subclasses

Main Category	Subclasses	Examples of phrases in the protocols as evidence
Building Layers	Stuff	‘belonging,’ ‘personal,’ ‘furniture,’ ‘portable,’ ‘fitting.’
	Space plan	‘spatial,’ ‘walls.’
	Service	‘HVAC systems,’ ‘electricity.’
	Skin	‘façade,’ ‘openings.’
	Structure	‘columns,’ ‘beams,’ ‘foundation.’
Approach	Segregated	‘architectural and product design cannot be united...’
	Integrated	‘not a part of architectural design...’
	Human-centered	‘considering human,’ ‘depending on human...’
	Top-down	‘started from the site,’ ‘space led people...’
Opportunities	Daily Activities	‘everyday use,’ ‘control’ (the home environment)...
	Well-being of Users	‘psychological support,’ ‘comfort.’
	Sustainability	‘organic,’ ‘energy efficiency.’
	Leisure	‘hobby,’ ‘fun.’
	Endurance	‘estimated obsolescence rate,’ ‘structural reliability.’
Barriers	Economic	‘affordability,’ ‘expensive.’
	Functional	‘not required,’ ‘insufficient’ (features)...
	Technical details	‘lack of security,’ ‘maintenance requirement.’
	Contextual	‘depends on site.’

While the presentations of the students were encoded into information categories, the tension between the conflicting answers became more apparent. The verbal expressions of the students and their sketches, as shown in Figure 04 that was inconsistent for both groups, but especially in the Control group. Moreover, the differences between test and control groups became visible (Table 5.7).

Table 5.7 Encoded Protocols of All Students into Information Categories

Information Categories Subclasses		Test Group								Control Group							
		st1	st2	st3	st4	st5	st6	st7	st8	st9	st10	st11	st12	st13	st14	st15	st16
Building Layers	Stuff																
	Space plan																
	Service																
	Skin																
	Structure																
Approach	Segregated																
	Integrated																
	Human-centered																
Opportunities	Daily Activities																
	Well-being of Users																
	Sustainability																
	Leisure																
Barriers	Endurance																
	Economic																
	Functional																
	Technical details																
	Contextual																

Building Layers

Students in the test group integrated biobuilding components into multiple building layers (Fig. 05). However, all students were associated with biobuilding components with different building layers in their sketches; verbally, they only mention one specific building layer. For instance, st3 had a vision regarding buildings without mechanical systems, and the sketches tried to reveal the idea. Nevertheless, she only told the impacts on the service layer, not on the entire building layers. In the Control Group, students (st9, st10, st12, st13, st14, st15) could only relate the given innovations with the stuff layer. St11 and st16 integrated the given examples into the service layer, but only st16 mentioned the integration of biobuilding components affecting other building layers.

Approach

The results on the approach of the students on the integration underline the conflict between visual and verbal data (Figure 5.7). While five students (st2, st3, st4, st7, st8) in the Test group advocated an ‘integrated’ approach among product and building scale, only one student (st16) shared the same approach in the Control group. The students (st1, st5, st6, st9, st10, st11, st12, st13, st14, st15) declared that biobuilding components are related to product design, and architectural design was segregated, and they did not even affect each other. Nevertheless, in the drawings of (st9, st14, st16), the impact of biobuilding components was apparent. The students (st1, st2, st4, st5, st6, st11, st12, st13, st14, st15, st16) argued that they proceed with a top-down approach. However, the subjects (st5, st6, st11, st12) also mentioned the impact of innovations on the well-being of humans might advance the integration of technologies into the buildings. Likewise, the students (st9, st11, st12) underlined the benefits of the products on daily activities, but only st9 assumed their approach as human-centered.

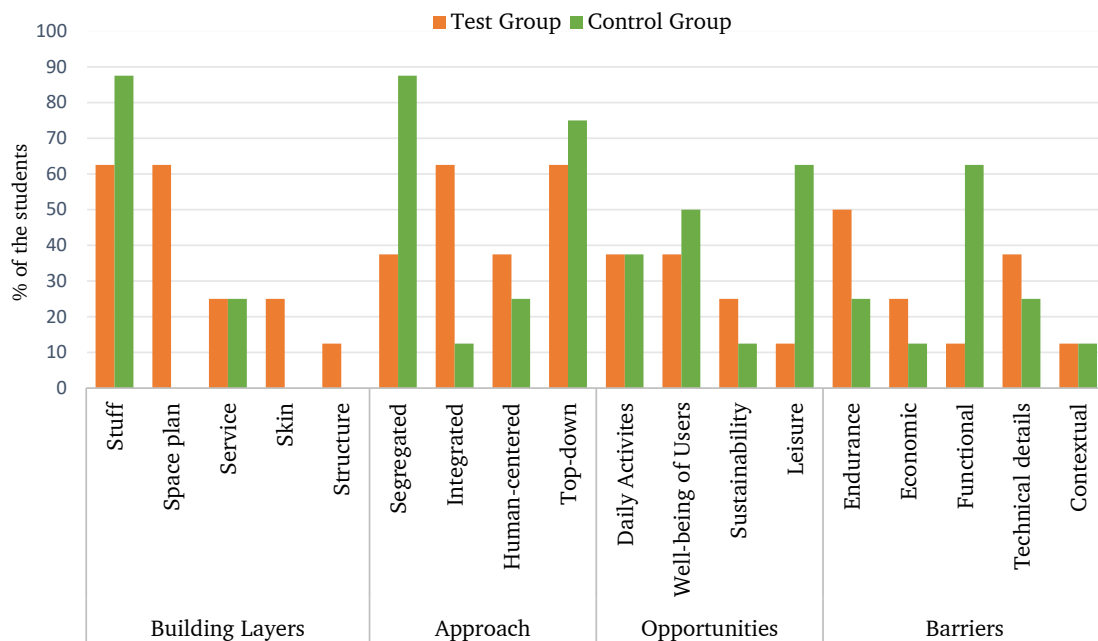


Figure 5.7 Comparison of the Percentage of the Students from the Encoded Protocols of Test and Control Group Students

Opportunities

All of the students in both groups were aware of the advances of biobuilding components. Test group students expressed these advances as one of their motivations for the integration of the innovations. On the contrary, Control group students (st9, st10, st13, st15) mentioned the benefits of biobuilding components by being related to daily activities, the well-being of users, and leisure, but they foresaw these advances to unrelated to architectural design.

Barriers

The prominent concern of Test group students was the ‘endurance’ of the products. Test Group students (st2, st4, st5, st6) highlighted the lack of knowledge on durability hampered the integration process. On the other hand, the major concern of Control group students was ‘functional’ by claiming that biobuilding components were unnecessary and unrequired to be included in the buildings.

Finally, the design experiment underlined the infiltration of biobuilding components into the building layers by observing the design process and analyzing both verbal and visual data. Moreover, designing with biobuilding components from the beginning of the design process allowed Test group students to discover the expected impacts of the innovations on the entire building design process. Thus, biobuilding components became an integral part of building design towards to attitude of the designer. On the other hand, the reports revealed that the introduction of innovations at the end of the design process intensified the concerns of the students on the functions and technical attributes of biobuilding components. Control group students criticized innovations as being unnecessary and hard to use. They were also aware of the interaction between biobuilding components and the other layers of the buildings, as clearly seen in their sketches.

More importantly, the introduction of biobuilding components at the beginning of the design process led all students to develop their designs centered on humans, considering the interactions between user, product, and the building. The introduction of biobuilding components led Test group students to develop their designs by creating bonds between humans, product (biobuilding components),

and building in the entire building process. In contrast, control group students did not consider the relationships between user, product, and architectural design. Unlike Test group students, their approaches are mainly shaped around the followed top-down design process in which humans are affected by building design. Proceeding a top-down design approach and including biobuilding components at the stage of stuff cause this conflict to consider them only as products.

5.2 Conclusions

This Chapter contributes to the literature on biobuilding components by observing their possible integrations into building design in an architectural design studio, thus evaluating the impact of biobuilding components on the building design process.

The experiment indicates that biobuilding components can be integrated into building design, while their introductions at the early stages of the design process increase their integrability. Biobuilding components were given as toolsets that could be integrated into different building parts if they embraced as ‘non-hierarchically.’ The hierarchy lies in the theory of Brand (1994) as such structure to be accepted as more important than space plan on building design, and also the organization of the project course (Figure 5.1). Hereby, the experiment indicates the necessity to destroy the hierarchy between different building layers in the mindset of future architects for the integration of biobuilding components into building design.

Therefore, biobuilding components should be considered in the discipline of architecture at the earliest stages of design education. Even though material scientists and product designers develop these innovations, and engineers and programmers write the code, architects are responsible for integrating them into building design. Therefore, their approach to these technologies majorly influences our surroundings as well as our daily lives. The changes in the daily activities and everyday life through biobuilding components and their increasing

integration into the home environment will assumedly affect building design; thereby, the roles of the architects will also be altered. Thus, the mindset of the architects needs to be revised with the growing number of innovations empowering the interactions between the user and the building. Conducting a design experiment that describes a multi-disciplinary area of rapid growth, such as introducing biobuilding components in the discipline of architecture, is challenging yet promising. To deliberate this issue, further design experiments require different actors, such as urban designers and professional architects. Linking the experiments with an urban scale may also bring different results. Giving the same innovations to each actor may also lead us to find results on the relationship between the technical attributes of the innovations and different ways of integrating the technologies into the buildings through their specific advantages on building design.

Architecture students indeed can integrate biobuilding components into their design by evaluating conceptual, social, and phenomenal aspects of the biobuilding components. Further studies could be developed and conclude by giving additional information on how biobuilding components could be integrated into the buildings. What matters here, the embracement of biobuilding components in building design regardless of their scale and building layer.

As Chapter 4 explained the critical role of biobuilding components on the ongoing technological transition, this Chapter concludes with the critical importance of the approach towards the integration of biobuilding components. The design process of the translation of biobuilding components into building design still stays as a 'black box' by means of not revealing any information. Nevertheless, it leads us to underline the importance of the design approach. Moreover, this part of the study gives insights into the necessity and vitality to discuss biobuilding components in architectural education. Thus, the awareness of future architects on the growing number of innovations could be empowered. In that sense, the awareness and approach of architects could be admitted as both opportunities and barriers regarding the translation of biobuilding components into building design.

This Chapter leads us to discuss the integration of biobuilding components into building design through the perspectives of future architects. To provide further insights on the translation of biobuilding components, the following Chapter continues with exploring the transition of biobuilding components into building design by gathering the views of practitioners.

EXPLORING BIOBUILDING COMPONENTS FROM PRACTITIONERS' VIEWPOINTS

This Chapter presents a qualitative analysis of the interviews with practitioners determined in the scope of the thesis, i.e., experts such as initiators, developers, designers, implementors working with biobuilding components. This part of the study provides answers to the aforementioned RQ3 and the sub-questions RQ3.1, 3.2. The goals of the Chapter could be summarized with the following remarks:

- To validate information on the found meanings of the biobuilding components in the *Background and Overview*.
- To give an understanding of practitioners' mindset regarding the development of biobuilding components.
- To explore if there is a common design thinking pattern(s) on the integration of biobuilding components into buildings.

The *Overview* part of the thesis, Chapter 3 and 4, presents information in the academic and popular literature regarding the terminology, characteristics of biobuilding components, and their relevancy with building design. At this point, the interviews here lead us to summarize and elucidate the information on biobuilding components with practitioners in current practice. In this way, it also provides answers to RQ1.2 and RQ2 and its sub-questions.

The design experiment with the future architects in Chapter 5 reveals the critical role of the design approach on the integration of biobuilding components into building design, especially by underlining the importance of non-hierarchical thinking. Although the design experiment seems insufficient to provide information on the design process of the integration of biobuilding components into building design, it underlines the need for further understanding of the mindset behind the translation of biobuilding components from industrial design

to building design. Hereby, the interviews provide insights from practitioners' perspectives through discussions on the developments of biobuilding components and their integrations into the building design.

All in all, discussing biobuilding components with practitioners leads us to understand the practical implications of the incorporation of living and manufactured components in building design.

6.1 Interviews with the Practitioners

This part of the study introduces twenty (20) interviews conducted between July 2019 – September 2019 with twenty-one (21) professionals who are the 'practitioners' working with biobuilding components. The interviews seek to gain a detailed knowledge of practitioners' professional experiences on the development of biobuilding components with the following issues:

- focus,
- beliefs, motivations, and underlying reasons,
- terminology,
- advantages,
- challenges,
- expected results,
- expected impacts and visions,
- relationship with building design.
- expectations for the future.

Accordingly, the interviews play a critical role in this thesis by bridging information on biobuilding components in existing academic and popular literature with information in current practice.

The analysis of the interviews is, firstly, introduced with the *Methodology* section describing the applied methods and approaches on *Selection of the Actors*, *Preparation of the Questions*, *Conduction of the Interviews*, *Data Analysis*, and *Expected Results*. Further on, the practitioners' answers to the questions are

discussed and presented in the section of *Summary of the Interviews*. This section provides additional information for the aforementioned RQ2 and the sub-questions; RQ2.1, 2.2 through practitioners' perspectives. Moreover, the section, *Development of Biobuilding Components and their Integration into Building Design*, elaborates on the analysis of the interviews. By the significant contribution of this section to understand the design process of biobuilding components among their developments and integrations into buildings, the Chapter concludes with understanding the dialogue between industrial and building design.

6.1.1 Methodology

The multiple qualitative analysis methods are applied in the interviews' scope, including the preparation and conduction of the interviews and the analysis part. First of all, chain referral sampling was chosen to determine interviewees. Chain referral sampling, also called snowball or chain sampling, is a widely used qualitative sociological research method, especially on a sensitive topic, which requires specific knowledge within a hidden population (Biernacki and Waldorf, 1981). The chain referral sampling allows researchers to reach populations that are difficult to sample while there is no reliable data to specify the sampling unit or apply other sampling methods like random sampling (Faugier and Sargeant, 1997). Simply, it is a strategy to find research subjects, and it proceeds with the suggestions of initial subjects to connect other research subjects, and so on (Atkinson R and J, 2001). In this study, the initial interviewees are determined by the developers and initiators (in the Netherlands) in the biobuilding examples in Table 4.1. Then those initial interviewees became the first chain and were asked to suggest other experts with similar specialties (Table 6.1).

Regarding the conduction of the interviews, the oral history method is adapted. Oral history method is a common method to access information, is not accessible in other kinds of research like literature and societal research, through individual narratives and memories by creating a 'social relationship' between interviewers and the interviewees (Federer, 2015; Hesse-Biber and Leavy, 2005; Miller-Rosser et al., 2009; Thomson, 2015). Oral history is based on individual narratives and

memories; however, the analysis of individual narratives can provide disciplinary, collective, or social patterns and specific kinds of individual habits that don't fit in any classification (Portelli, 2009). In this sense, the oral history method allows fulfilling the research aims by giving a better understanding of a subject through collecting, interpreting, and filtering relevant evidence (Beard, 2017). In this study, this method helps to reach information on biobuilding components from different perspectives based on the individual narratives and memories of the practitioners, thus adapted in the preparation of questions and the conduction of the interviews.

In the analysis of the verbal data transcription, thematic analysis (TA) is adapted. Thematic analysis is a flexible method helping to identify patterns or themes within qualitative data in the transcript the verbal data of the interviews (Alhojailan and Ibrahim, 2012; Braun and Clarke, 2006; Clarke and Braun, 2013; Fereday and Muir-Cochrane, 2006; Herzog et al., 2019; Nowell et al., 2017). The thematic analysis helps to identify, analyze, and report patterns (themes) within the data (Boyatzis, 1998). In that sense, it helps this study to analyze and discover if there is a shared knowledge of biobuilding components and their integration within the individual narratives of the practitioners.

In the below sections, how these multiple methods applied to the study shall be furtherly explained.

Selection of the Actors

The data-gathering phase (Chapter 5) has already shown that biobuilding components indicate the cooperation of multiple actors, affecting multiple domains. For this matter, the background of the interviewee took into account, and the interviewees are determined to cover 'multiple actors' found out in the data gathering, as shown in Table 4.2. The selected actors all together represent the 'multiple domains' of the research. The actors and domains included in the study are as follows:

- Actors: architects, interior designers, product designers/developers, biologists, academicians, engineers, fashion designers.

- Domains: building design & construction, product design, material technology, interior design, light, food, healthcare, entertainment, fashion, sport.

Within many biobuilding components, thereby, many practitioners, the chain referral sampling strategy leads us to reach key experts. Firstly, eight (8) practitioners determined in Table 4.1 were reached out for the interviews. Secondly, these experts help to reach seven more experts in the second chain, while later on, six (6) more experts were reached. After conducting twenty (20) interviews, it is decided that the saturation point has been reached out. Table 6.2 below shows the list of the interviewees.

Preparation of the Questions

What is crucial for this exploratory study is to have research on the recent advancements of technology while the technological transition is taking place right now. In that sense, this part of the research is ambitious to create knowledge for future studies by providing information on the distinguished ways of thinking of the experts. In this regard, oral history method was adopted for the preparation of the questions and the conduction of the interviews. Oral history method allows recording the experience of people who have been ‘hidden from history’ (Perks and Thomson, 2003). By this means, this research composes information on the experiences and knowledge of biobuilding components that cannot be accessible in the existing literature yet. Moreover, the combination of individual narratives provides knowledge on biobuilding components by evaluating different perspectives, in fact, contradictory ideas and approaches.

The preparation of the questions could be seen as the key elements of the interviews. Biobuilding components indicate and emerging praxis comes with ambiguity and complexity in the terminology. To draw a neutral tone by leading them to express their own ideas with their individual terminology was crucial. The questions were prepared without using or referring to any terms, concepts, or specifications (Table 6.2); only after the interviewees use specific terms, the interviewer uses them (Appendix A Interview transcripts). This helps experts to

express their own terminology, thereby encourages them to explain more about their ideas without being limited by specific concepts and approaches. In the end, this also helped to create a more neutral and friendly atmosphere during the interview by leading the feeling to the practitioners that they can control the information and knowledge they are sharing instead of misinterpretations within unrelated terms and definitions.

The first two questions aimed to create a friendly environment by making room for practitioners to introduce themselves. Regarding the flow of the conversation, in some interviews, the first questions were asked together as one question. Or the experts already started to speak by answering them. Further on, the order of the questions was changed according to the flow of the conversation. Moreover, by showing her knowledge of the practitioner's projects and their working domains, the interviewer asked additional questions. These additional questions were encouraged the interviewees to explain more about their projects, experiences, and ideas. Furthermore, probe questions specific to the building design domain (Probe 6a, 6b, 8a, 8b) were excluded if the interviewee is not working in the building design domain or if s/he does not want to express opinions about the subject.

Table 6.1 Interviewee List

#	Name	Background (Education)	Focus Issue/Project In The Interview	Related Domains
1	Christiaan Bakker ¹	Sale and Management	Green wall systems	Building design&construction
2	Ermi van Oers ¹	Product Design	Living Light	Interior design, Lighting
3	Henk Jonkers ¹	Biology	Self-healing concrete	Building design&construction
4	Lloyd Alberts ¹	Industrial Design	Sniffer nose	Food, Education, Healthcare
5	Maurizio Montalti ¹	Industrial Engineering and Mycelium based products Management		Fashion&textile, Interior design
6	Tom Koenderman ¹	Biology	Smart Climate Solutions	Healthcare, HVAC systems
7	Stephan Wensveen ¹	Fashion Design	Textales	Fashion&textile, Healthcare
8	Teresa van Dongen ¹	Biology	Ambio lamp	Lighting, Interior design
9	William Myers ¹	Art&History	Biodesign Book	Building design&construction
10	Boris Zeisser ²	Architecture	Biomaterials in architecture	Building design&construction
11	Frank Marcus ²	Architecture	Self-healing concrete	Building design&construction
12	Marina Toeters ²	Fashion design	Closed Loop Smart Athleisure	Fashion&textile. Healthcare
13	Natalia Romero Herrera ²	Computer Engineering	E-health systems	Food, Healthcare. ICT
14	Tjeerd Veenhoven ²	Product Design	Algae Fabrics	Fashion&textile
15	Wanda Kruijt ²	Chemistry	Implementation of technologies	Healthcare, Lighting
16	Elvin Karana ³	Industrial Design	Material driven approach	Fashion&textile, Product design
17	Melle Janssen ³ Jordy Senssen ³	Business and Finance Programming	Fear therapy Fear therapy	Healthcare Healthcare
18	Michael J. Dawkins ³	Physical Therapy	Exponential Mindset	Building design&construction, Healthcare
19	Nadia Jellouli-Guachar ³	Architecture	BioAmi	Building design&construction
20	Raymond Cuipers ³	Physics	Social Robots	Healthcare, ICT

¹First chain ²Second chain ³Third chain

Table 6.2 Questions of the Interviews

1.	Can you tell me about your background? How do you describe your profession?
2.	Can you tell me about your current projects as such aim / your role of/ in your company, mission, and goals?
3	What is the main intention and motivation behind the development of your project(s)?
4.	Could you describe the ‘novelty’ of your project?
5.	Nowadays, these innovations are described with a variety of terms: ‘sustainability,’ ‘natural,’ ‘organic,’ ‘smart,’ ‘bio,’ etc.: Which terminology do you prefer to refer to your designs? Probe: What do you mean about smart/ sustainable / bio ? could you tell me more?
6	What would you like to achieve with the application/spread of these products? Probe a: Do you foresee any consequences of the integration of these products into the buildings? Probe b: In which part of the building design process do you think this project could be applied?
7.	Is there any study that has been done to evaluate the user’s experience? Probe: Could you tell me about your studies/observations/ideas on user feedback?
8.	Could you tell me the potential impact(s) of these products (from a wider perspective)? Probe a: Do you think it is possible to see any impacts on building design? Probe b: Which parts of a building will be assumedly affected?
9.	Could you tell me the challenges that you faced in the design of the project?
10a.	Regarding what we discussed here, Could you tell me about your expectations for the future?
	10b. Do you have any recommendations for future designers and architects in particular?

Conduction of the Interviews and Data Collection

The research was conducted as in-depth, semi-structured interviews with multiple actors with open-ended questions by motivating interviewees to tell their story by probing questions. The semi-structured interview is a method widely used data collection method by offering a focused structure for the conversation during the interviews but should not be followed strictly (Kallio et al., 2016). Meanwhile, it gives researchers to explore subjective viewpoints by allowing enough autonomy to the respondent to discuss issues and topics significant to them (Flick, 2009).

In this study, the semi-structured interview method is eased to create a friendly atmosphere by encouraging interviewees to share their knowledge with the interviewer. According to the conversation flow, the order of the questions is changed, additional questions are asked, and also some questions are omitted. For example, if the interviewees have a related background in building design and construction, they are inspired to express their visions on building design. If the interviewees have a background in other domains than building design, they were also asked about the possible relationships between their domain and building design. Moreover, the additional questions lead interviewees to explain his/her other studies to express their visions through recent technological developments and the novelty of the incorporation with living organisms in comparison to their other studies and projects.

All of the interviews were completed between July 2019 – September 2019 with twenty-one (21) professionals in the Netherlands. However, as seen in the Table 6.1 practitioners are not limited to Dutch innovators, experts are from different nationalities (e.g., William Myers, Maurizio Montalti, Elvin Karana). The interviews were preferably conducted face-to-face except for only two exceptions that one is on the phone the other via skype due to the experts' busy schedule. Each interview approximately took one (1) hour. For the conduction of the interviews, the author also tried to reach experts in other countries such as Belgium, Germany, and Luxemburg. However, the applied oral history methods provided better results in face-to-face interviews instead of skype and phone

meetings. With the lack of physical connection, experts preferred to answer only the given questions instead of providing additional information and studies. By this means, face-to-face interviews provided more opportunities to ask probe questions comparing to skype or phone interviews. Therefore, the study is decided to be limited to the current number of interviews.

Data Analysis

The verbal data is summarized, organized, and then analyzed. Firstly, the verbal data of each interview was transcribed into text. The practitioners' answers to the questions were summarized by highlighting similar and different answers. Categories were only given to ease to discuss similar or close answers, while the categories were determined by highlighting the general idea within these similar answers. Oral narratives are the neutral expressions of the interviewees, including traits and idiosyncrasies, that scholars aim to reach (Beard, 2017). Thus the summary of the interviews helps us to underline the information on biobuilding components already discussed in the Overview part from the professional's point of view in a more brief, precise, and transparent manner.

Secondly, theoretical thematic approach analysis (TA) was applied to find answers to the aforementioned research questions. Thematic analysis is a flexible method helping to identify patterns or themes within qualitative data widely used to analyze semi-structured interviews (Braun & Clarke 2006; Clarke & Braun, 2013). In oral history research, applying thematic analysis can lead us to reach the 'extracts' of the conversation by means of finding the 'collective meaning of the participants' (Miller-Rosser et al., 2009).

TA is suited to a wide range of research interests and theoretical perspectives, and it is beneficial as a 'basic' method in many ways:

- It works with a wide range of research questions, from those about people's experiences or understandings to those about the representation and construction of particular phenomena in particular contexts;
- It can be used to analyze different types of data, from secondary sources such as media to transcripts of focus groups or interviews;

- It works with large or small data-sets; and
- It can be applied to produce data-driven or theory-driven analyses (Braun and Clarke, 2006; Clarke and Braun, 2018).

Thematic analyses seek to unearth the themes salient in a text at different levels, and thematic networks aim to facilitate the structuring and depiction of these themes (Berkhout et al., 2004). Thematic analysis is the process of identifying patterns or themes within qualitative data in a 'hermeneutic' way. Since first being named as an approach in the 1970s (Merton, 1975), a number of different versions of thematic analysis have been proposed within psychology (Attride-Stirling, 2001; Boyatzis, 1998; Braun and Clarke, 2006; Jodi, 1994; Joffe, H., & Yardley, 2004; Tuckett, 2005). Some authors manifest TA as a phenomenological method (Guest et al., 2006; Joffe, 2011). Braun and Clarke (2006) emphasize the theoretical flexibility of TA and identify it as just an analytic method, rather than a methodology, which most other qualitative approaches are.

Thematic analysis is a search for themes that emerge as necessary to describe the phenomenon (Daly, Kellehear, & Gliksman, 1997). The process involves identifying themes through "careful reading and re-reading of the data" (Rice & Ezzy, 1999; 258). It is a form of pattern recognition within the data, where emerging themes become the categories for analysis. Boyatzis described the thematic analysis as a method to identify, analyze, and report patterns (themes) within the data (Boyatzis, 1998).

In this study, the thematic analysis method helped us to determine certain themes and patterns, providing answers to RQ 3.1 and 3.2. This method is applied to understand the process of the development of biobuilding components and their translation into building design.

Expected Results

The expected result of the interviews was to generate an overall understanding of the development of biobuilding components and their use in building design. Moreover, to see if the actors apply any common design thinking patterns.

6.1.2 Summary of the Interviews

In this section, interview data is summarized by discussing the practitioners' responses to each question in the following sub-sections. This part of the study provides information on biobuilding components by gathering and transparently presenting the statements of the practitioners. The answers are briefly presented in tables in which the similar statements were divided into categories. Based on similarities in practitioners' statements to highlight and explain their answers, these categories help to notice and interpret different, in fact, contradictory ideas.¹⁵ Thus, this part of the study presents an elaborative discussion conducted through the answers of the practitioners concerning the findings and the discussions in the aforementioned parts of the thesis.

Multi-disciplinary Background of the Interviewees

What is interesting in the answers that even the first two questions to start a conversation underlined the novelty of the topic. The experts prefer to describe their professionals with an emphasis on the interdisciplinarity of their expertise either by a 'hybrid practice' or with an additional layer to their existing studies (Table 6.3). Hybrid practice indicates the involvement of different disciplines as well as domains in their professional practice. Therefore, they do not define their profession by limiting it to a single domain or discipline.

Twelve (12) of twenty-one (21) experts choose to introduce themselves using conventional professions as product designers, biologists, etc. However, five (5) of twelve (12) with their professions as an additional layer to their discipline (e.g., P04 architect experienced in material technology). Nine (9) of the interviewees chose to emphasize the novelty of their expertise as a new profession, either as hybrid practice or bridging multiple disciplines.

¹⁵ In the Tables on below, practitioners are randomly given numbers as such P1, P2,P3 in order to respect some of the interviewees' confidentiality request.

Interestingly, the answers show the excitement towards biobuilding components practice that cannot be categorized under conventional occupations. This also points out the necessity to approach any classifications with similar skepticism, even in this thesis, like Mensvoort's Technology Pyramid (2013a). His approach explains the integration of currently known technologies in daily life, but biobuilding components' novelty may require another way of thinking.

In this sense, even by introducing themselves, the interviewees point out the novelty of their practices in their disciplines.

Table 6.3 Practitioners' Descriptions of their Professional Practice

Q01-2 How do you describe your profession? Can you tell me about your current projects as such aim / your role of/ in your company, mission, and goals?

CONVENTIONAL PROFESSION	WITH COMMON DESCRIPTIONS	P07	"I still consider myself a biologist."
		P09	"I am still a product designer, in essence. It has not changed and will not change in the future. I do think that any designer these days cannot only design a product anymore."
		P12b	"...my role in the company is in the business and finance of the company."
		P14	"A curator, author, and teacher."
		P15	"...a researcher."
		P17	"Too little" changed in the description of my profession after the use of self-healing concrete.
		P19	"I am an associate professor, so part research, part teaching, part management."
	WITH ADDITIONAL SPECIALTY	P01	"On paper, I call myself an industrial designer... I also see myself as a general engineer with a bit of mechanical expertise, a bit of practice, and invent field."
		P04	"...I learned a lot about the 'next level' in architecture from Erick van Egeraat. He was interested in shapes and spaces as well, but he adds another chapter to what I regard as an architect."
		P05	"I profile myself who is interested in the development of innovations in technologies but with a user-centered focus."
		P10	"I am a design researcher with interest in emerging technologies and materials."
		P12a	"I work at the Mind mansion as a developer like programming, and also a designer."
NEW PROFESSION	HYBRID PRACTICE	P02	"I am an entrepreneur, innovator. I like to define myself as a creative explorer in some ways. Still, it is difficult to find one formula that could be easily accepted and understood from everybody what this practice is about."
		P08	"...they call me 'innovations scout.' I am the person who scouts for new technologies that could be potentially interesting for mental healthcare."
		P18	"I studied biology and business economics. So I am number's guy."
		P16	"We knew our interest in textiles and materials. We call ourselves material fetishists."
	BRIDGING MULTIPLE DISCIPLINES	P03	"Fashion technology is an umbrella for both the three fields that I just expressed new materials, wearable technology, and the production process. That is the way I think it describes myself. Sometimes, it should be shorter, so it is a fashion technologist. I have a few terminologies there."
		P06	"I am creating a bridge between a laboratory and daily life."
		P11	"I am a green wall specialist...I know technique and construction. I know in green itself, everything about green."
		P13	"I started with studying biology... And I wanted to create things... At some point, I began to integrate these two."
		P20	"I started really learning after school a lot of emerging technologies around us. Social media, and how social media could impact society and organizations to become decentralized and non-hierarchical. How can we work together?"

Motivation behind the development of biobuilding components

The motivation behind the development of biobuilding components mainly shaped around the vision of the experts on creating a balance with nature and technology by promoting the advantages of circular system thinking. With circular system thinking, practitioners underline the need to adapt the logic of nature by creating circles in everything connected in harmony. For example, in nature, one species of waste becomes another one's nutrition; thus, the cycle continues in balance.

The answers to the question on the motivation behind biobuilding components' development could be categorized under two main titles: environment-centered design and human-centered design approaches, except for other motivations (Table 6.4).

Six (6) of the experts claimed that their main motivation was to empower human lives in different ways; human enhancement, healthcare system improvement, and human-material relationship. This could be specifically related to health and wellness, the extension of humans' abilities, or to explore and strengthen the relationship between humans and materials by means of their advantages to the users. Twelve (12) of the practitioners focus on environmental benefits that could be provided through biobuilding components. These environment-centered solutions could be grouped under the titles of; "creating awareness," "providing sustainable solutions," and "circular system thinking."

The interviewees' answers on the motivations lead us to underline the impact scale of biobuilding components despite their self-scales. For example, biobuilding components could be in the form of small-scale objects such as a lamp, furniture, clothing, etc. Yet, a broader, even a solution for a global problem (e.g., climate change) might nourish practitioners to develop, design, and implement them. In this way, interviewees' answers on the motivations lead us to see the 'ambition' behind the interest in the design, development, implementation, and translation of biobuilding components.

Table 6.4 Motivations behind Practitioners' Practice

Q3 What is the main intention and motivation behind the development of your project(s)?			
HUMAN-CENTERED APPROACH	HUMAN ENHANCEMENT	P01	"...improve our scent...we could use smells and add color code in terms of categorizing the smells."
		P05	"...empower people to have more time-agency on their decisions and what they do."
	HUMAN-MATERIAL RELATIONSHIP	P10	"To brand material and understand how it could be received and recognized by people."
		P15	"If we were able to design it, then I am curious about what does with the uses... What other people are going to do with my technology instead of I only design this technology..."
	HEALTHCARE SYSTEM IMPROVEMENT	P08	"...the most important thing in healthcare is the huge shortage of people at health; carers and curers. People provide treatments but also need to take care of the others, and this is going to be a huge shortage of that. Also, going to be an increase in the number of people that will need some form of care."
		P12	"...fear could be treated" with the combination of technologies; biofeedback, VR, gamification.
ENVIRONMENT-CENTERED APPROACH	CIRCULAR SYSTEM THINKING	P02	"It is about removing from this entirely anthropocentric perspective that human is always in central. It is not always about humans, and it is about the relationship. It is about the dialogue between the systems."
		P03	"...garments become less and less quality, less and less value, and we have to change that kind of thinking."
		P04	"...we have to find a balance with nature. It is really about saving human kinds instead of saving the earth."
		P06	"...we are the only organisms in this whole World that using linear systems instead of circular systems... Actually, it is so crazy, and I really wanted to change that habit."
		P20	"...questioning the system where the problem resides... We need a new system in order to solve the problem."
	SUSTAINABLE SOLUTIONS	P07	"...improving functional performance and lowering environmental impacts."
		P11	"The motivation is absolutely making the World better... We see the biodiversity is getting better at that place where it is installed."
		P17	"...it has a significant impact on the CO ₂ footprint of concrete, it is specified in this project and also for the whole building industry."
		P18	"...saving energy for better climate conditions indoors."
	CREATING AWARENESS	P14	"To put them into the exhibition would speed the innovation and advance the field."
		P13	"...what I consider very important that if you want to tell people a story, everybody perceives it differently... I think it is also good people take away something in it and do their own thing afterward."
		P16	"It is about creating awareness, inspiring, exaggerating innovation, and educating because we think different kinds of people are acquainted with biomimicry through the properties of biological nanostructures."
OTHER	i.e., coincidences, etc.	P19	"When I come here, I was appointed as an assistant professor. My main task was to take care education task. I had to take cover a course on visual perception, and I had a good background for it."
		P10	"A lot of coincidences...I completed my research Ph.D. on the meanings of materials. I look into the materials around us and how people really give meaning to them."

Novelty of Biobuilding Components

Chapter 4 presents an overview of biobuilding components, thereby validates the information regarding their novelties as well. However, due to the number of examined biobuilding components, it seems difficult to follow their novelties. Therefore, in the interviews' scope, the practitioners were asked to determine the novelty of their projects (Table 6.5).

The novelties mentioned by interviews are mainly centered around three subjects: living organisms, performability in the projects, and system thinking. System thinking means that innovations can provide alternative and collective ways of thinking on bigger scales such as marketing, production, and waste management.

The majority of the experts underlined the novelty of the innovations with their 'performability' of the biobuilding components by providing adequate performance that made them preferable compared to the products meeting the same function. Moreover, seven (7) practitioners determine their projects' novelty with 'system thinking' by implying circular system models (e.g., waste management, production cycle, etc.). This shows the estimated potential of small-scale products on broader, even global scales.

Interestingly, only three (3) of twenty-one practitioners described the products' novelty with the use of living organisms. This can be interpreted as the embracement of living organisms as another component or material. This is interesting and shows the benefit of interviews. In the literature studies on the concept of nature (Section 2.2) and the discussion on contemporary examples (Section 2.4), the key hypothesis lies in the novelty in incorporating living organisms. Therefore, in the *Overview*, the study elaborates on using different living components (Table 4.2). However, the interviews lead us to underline that with practical experience, living organisms' use seems not novel anymore. What is highlighted here is the crucial benefits adapted into the innovations through the interrelation of living and manufactured components.

Table 6.5 The Novelty of Practitioners' Practice

Q4 Could you describe the 'novelty' of your project?		
THE ROLE OF LIVING ORGANISMS	P04	"...the concrete industry is big in the Netherlands. My ambition is to move that towards bio-based materials."
	P07	"...biological systems to enhance and improve the materials."
	P10	"...to understand and analyze the design process when living organisms are there when the material is the starting point."
PERFORMABILITY OF THE PRODUCTS	P02	"Is it perfect? No. Is it preferable? Yes"
	P03	"...aiming for everyday use, advances but you do not necessarily see."
	P09	"For me, it is about mapping opportunity. Nature is, for sure, an 'inspiration' and also the 'ignorance.' We, as humans, have these approaches in our system. Outside nature provides, so few of our things work despite the opportunities. Within this current time, with so many innovations started to move, temporary connections, and the systems taking apart and rebuilding again, we are on the brain part of that change."
	P15	"One is demonstrating the opportunities of these new materials, smart textiles, in the sense of demonstrating a new class of products, more embodied wearable service systems."
	P18	"In brief, it is performability, and working in quantitatively. You are presenting a new system and also infiltrating into the existing system."
	P01	"...the improvement of the human scent by using technology."
	P05	"I generate contextual knowledge. One is expert knowledge. This is what we mostly do when we want to understand how energy works and behavior work. But we do not understand in many of these projects talking about data is the 'why.' Why are these things happening?"
	P11	"Our pre-cultivation is our novelty."
	P12	"The combination of all aspects makes us unique, comparing the other virtual reality exposed therapies in the Netherlands."
SYSTEM THINKING	P06	"I think humans to be in touch with nature again is the novelty.... I think you can only change behavior by experience, not like telling you should do differently."
	P08	"Novelty is using as technology, not necessarily apply as a replacement, but as an additional something that you can add to your care system to bring them your personnel and cost."
	P14	"We have an outside environment; we have lots of stuff like plants, biology, the biosphere is happening. Let's work together and create a friendship not to be odd to each other."
	P15	"That is my interest how can we move product design to service design and system design. That was one of the knowledge contributions."
	P16	"I think for me, the most important thing is how we can reach sustainability as much as we can."
	P19	"I think a different approach than most. One of the main things that I do differently, I am biologically inspired."
	P20	"I believe that if you want to change the system, the system should be better and easier."
ECONOMIC BENEFITS	P17	"For a very low budget, you can make a shell construction."

Terminology of Biobuilding Components

The interviews underlined the complexity and confusion in the terminology once more. Despite a few suggestions of the interviewees, no blanket term was determined (Table 6.6). None of the experts could suggest one specific term or disagree with this question. In this sense, the experts with an academic background (P05, P11, P19) have been struggling with this problem from a theoretical point of view. and potential in a diversity of terms and definitions. Meanwhile, experts like P17 and P20 are more focused on practice, do not see a problem in terminology, and feel freer to use their own terms and definitions without restricting themselves.

The eight (8) experts declared that they do not have any preferences in the use of terminology (P03, P05, P06, P10, P12, P13, P18, P19). They claimed that even though technologies indeed in transition, there is no certain term to express the potential of the interrelation of living and manufactured components. Therefore, the priority was to resonate with their audience and make people understand.

The nine (9) experts answered the question by stating their preferred terms. P01, P07, P08, P15 underlined the importance of the concept of smart; thus, smart terms can provide people a better understanding. Experts P04 and P20 stated that the term biophilia is useful in terms of emphasizing the relationship between people and nature. P11 stated that the term of living is the one we should emphasize. P14 emphasized that he came up with the term “biodesign” since it covers to design with biological organisms. P17 suggested combining bio and smart as bio-smart to emphasize the technologies become smart with the use of living organisms even though the term bio-smart mainly use to describe wearable technologies as such smartwatches and bracelets.

Table 6.6 Practitioner's Preferences in the Terminology of Biobuilding Components

Q5 Nowadays, these innovations are described with various terms such as; 'sustainability,' 'natural,' 'organic,' 'smart,' 'bio,' etc. Which terminology do you prefer to refer to your designs as such this specific building?

Probe: What do you mean about smart/ sustainable / bio ? could you tell me more?		
PREFERRED TERMS	SMART	P01 “For me, the important thing is the customer to understand it.”
		P07 “I would say smart. Smart means something is clever.”
		P08 “For me, smart and e-heath. I also use many different terminologies. It does not matter so much. Usually, I use smart if it is more connected to some kind of remote and digital part.”
		P15 “At that point, it was about smart textiles. We know that smartness is not integrated into the textile anymore because it has huge sustainability issues. But actually, smartness is in production...”
	BIOPHILIA	P04 “I use biophilic architecture as a starting point, which helps to clear out the main goal of making balance with nature.”
		P20 “Biophilia is a word that I came across just so soon...for me, and it is all about life.”
	LIVING	P11 “It must be living.”
DISREGARDED TERMS	BIODESIGN	P14 “Language-wise biodesign is a very useful term because it is like an umbrella under which all these ways of design making.”
	BIO-SMART	P17 “I think ‘biosmart’ is the general word.”
	SUSTAINABILITY (AVOID TO USE)	P02 “It is a word that almost lost its meaning despite the critical value that it owns. Sustainability is so easily misinterpreted besides using it as a greenwashing flag.”
		P04 “Sustainability does not mean anything anymore.”
		P07 “Sustainability still has a political meaning.”
	BIO-BASED	P09 “...you will not hear me saying ‘bio-based.’ Because bio-based is a basic concept to find something from nature and to organize it, and propose in such a way to fit existing synthetic technology.”
		P16 “Bio-based is not always something very well to nature. It can have a part that is biologically done. It is not degradable as fast as everybody thinks.”
MULTIPLE TERMS	CONTEXTUAL TERMINOLOGY	P05 “...using these words, depending on my audience, who I communicate with. I often chose the one there is making more impact on the context.”
		P10 “...depending on the context, I really changed the terminology.”
	NO PREFERENCE	P06 “I do not always use just one terminology.”
		P03 “...terminology is kidnapped into different fields.”
		P12 -
		P13 “I like to use the word innovation and nature.”
		P18 “...it is semantics, is not it? The word does not carry meaning.”
P19 “...there are a lot of terms out there if you are in the field, could mean a number of different things.”		

Furthermore, five (5) experts answered the question with the terms they avoid to use. P02, P04, and P05 implied that sustainability is a broad term that lost its meaning due to its attachment to politics. As a result of this, the term sustainability to describe recent innovations can cause misunderstandings. Indeed,

sustainability is a problematic concept that entailed several dilemmas, including different approaches to the relationships between nature and technology (Ciravoglu, 2004). P09 and P16 expressed that bio-based is also a term that should be avoided. Anything can be bio-based as being adopted from the future, which does not mean the interrelation of living and manufactured components.

Hereby, practitioners use contextual terminology to use various terms and definitions to make their points, which underlines how their perspectives approach the subject and interpret it. This makes it possible to understand the interviewees' additional value to this thesis by evaluating a counter thinking through all kind of terminological classification. The perspectivist approach leads us to discuss the value of different terms and definitions by means of bridging contradictory approaches on biobuilding components instead of generating definite categories and classifications.

Goal of Biobuilding Components' Development

The goal, the main achievement, under the development of the biobuilding components, was to develop best practice examples and the transference of the knowledge. In this way, practitioners underlined the importance of showing the value of in-betweenness of living and manufactured in multiple design fields. The second most common goal was to empower the abilities of humans. The answers were centered around to improve the current healthcare system in the Netherlands.

Moreover, the probe questions were also encouraged experts to express their ideas on building design. However, any specific goal related to building design was not mentioned. Therefore, probe questions lead to finding answers to the design stages of biobuilding components' development in relation to building design. Even though the practitioners have different expertise in different disciplines, they were encouraged to mention if they cooperate with the building design industry.

Table 6.7 The Expected Results from Practitioners' Practice

Q6 What would you like to achieve with the application/spread of these products?

- a. Probe: Do you foresee any consequences of the integration of these products into the buildings?
- b. Probe: In which part of the building design process, do you think this project could be applied?

SOLUTIONS FOR	BRODER SENSE	P01	"Human enhancement."
		P05	"...to activate us; people, I mean humans."
	HEALTHCARE SYSTEM	P12	"...faster and targeted treatments."
		P08	"...to make healthcare still possible, but shorter and faster...to make this transition into our home environment."
TO DEVELOP BEST PRACTICE EXAMPLES	SHOWING THE VALUE AND POSSIBILITY OF IN 'BETWEENNESS' of LIVING AND MANUFACTURED	P04	"...making balance with nature."
		P02	"...once something is tangible, and you could talk about... That allows for communicating about it and changing the perception of the public, audience, and the outside world."
		P07	"To show that it is possible to apply this to the existing buildings in the form of repair products."
		P09	"...developing best practice examples. They will contribute to the transition, like many other designs."
		P17	"Most of the design improvement can be learned from it.."
		P13	"...sparkle a conversation between people, and they could start to talk about the planet, sustainability, and smart becoming natural."
		P20	"We see nature as a cost instead of value, that is an issue...It is about a new story, a new narrative, a new system."
		P16	"...to introduce various stakeholders, through the technical/functional properties of biological nanostructures, to biomimicry so that they understand that nature is the source of inspiration for the development of sustainable materials."
		P19	"to say what socio-robots be like in the future."
		P18	"Efficiency is my greatest driver... I do care more about the impact and progress efficiency."
OTHERS	ENERGY EFFICIENCY	P11	"...we need more nature, less air-conditioning, and less electricity."
	GUIDANCE	P10	"...to make this method (material driven design) in general in design."
	BUSINESS MODELS	P03	"...to look more circular business models.."

P14* N/A

Studies on User's Experience

In the interviews, the practitioners were asked if they have any studies on the user's expertise. The answer to this question leads to validate why this study cannot gather information from the end-user. Indeed, there are not yet end-users of the biobuilding components. Practitioners have been conducting studies on user's experiences, whereas they still have insufficient information.

In the eight (8) of twenty interviews, the practitioners mentioned that there is no study conducted yet on the user's experiences. Meanwhile, in four of them, practitioners stated that the studies are minimal.

For the other practitioners who could conduct studies on user experiences, the practitioners found that they were surprised about the positive feedback gathered from pilot studies. The reactions of end-users towards adapting technology into their daily lives were generally found more positive than expected. The practitioners (e.g., P03, P05) shared their worries on people's pre-judgments on human-technology interaction as such, wearing a technological product. However, in the end, they found out that users are OK with the attachment of any technology if they accept and understand something is for their benefit. At the same time, practitioners are still dealing with much negative feedback.

This question and the answers also lead us to understand that these innovations are still developing. There is a lot more to research, and especially with their impacts on users.

Table 6.8 Practitioner's Existing and Ongoing Studies on User's Experience

Q7 Is there any study that has been done to evaluate the user's experience?

Probe: Could you tell me about your studies/observations/ideas on user feedback?

NOT APPLICABLE	P01	(Project is in envisioned level)
	P06	"We only have user feedbacks from the exhibition, and people seem very inspired and excited."
	P13	"Not yet."
	P14	-
	P16	-
	P18	-
	P20	-
	P04	"We do not interact with the end-user much."
POSITIVE FEEDBACKS	RAISING ACCEPTANCE	P02 "The acceptance was less than today, due to also the controversial role of media. There are a rising sensitivity and ever-growing acceptance for these kinds of technologies today."
		P03 "...people want to take better care of themselves. That was the specific request they expressed over and over."
	RAISING AWARENESS	P07 "...the owners prescribe self-healing concrete. Moreover, the architects become more convinced to use it in different design options."
		P08 "They told us that as long as the data is used to give personal feedback that they can do something, they do not mind."
NEGATIVE FEEDBACKS	P03	"2/3 of the users told me that they could see the benefits, but it is not for them; it is for people in need as such disabilities, health problems, elderly, etc."
	P05	"The constant feeling of the user as being judged by using these technologies."
	P09	"...we need focus groups because people appreciate the innovations, but they are too critical. ."
	P12	"...we had a more significant impact on clients at the moment than therapists... therapists do not believe that VR works even though many studies in the literature proving it is working."
LIMITED INFORMATION	P10	"...scholarly feedbacks are also positive."
	P11	"...it is all about how people feel. You want to access physiological information, but you cannot do that directly."
	P17	"A big war is going on in concrete technology. Concrete technologists are divided, refusers, and believers."
	P19	"You want to access physiological information, but you cannot do that directly. You need to measure something else like the distance, time, or roof of a questionnaire. Sometimes physiological variables do not give expected results, but it is typical for physiological research."

Impacts of Biobuilding Components

The impacts underline the three levels of sustainability; societal, environmental, and economic. The answers to this question prove the relationship between biobuilding components and sustainability as they can be seen as a part of the discussions. On the other hand, as it could be seen from the experts' other answers and the debates on sustainability, sustainability could be seen as a 'troubled'

concept with various interpretations over the years, similar to the concept of nature.

The answers of the practitioners lead us to underline embrace biobuilding components under the umbrella of sustainability. In a broad sense, practitioners target bringing sustainable solutions at each level; environmental, societal, and economic. Environmental society is explained centered around living organisms become energy source with less waste. Societal sustainability implies creating a balance between humans and nature by means of symbiotic interrelation instead of the utilization of living organisms for specific purposes.

Despite all, at least for now, as practitioners underlined that, biobuilding components do not fit into regulations such as Leeds, Breeam, and any other standards. This also creates a big problem for practitioners for advertising, validating, and selling their projects. Biobuilding components aim ‘radical,’ but high-performance new ways of thinking towards producing any technology and the sustainable built environment. In this way, biobuilding components could be seen as a part of sustainability, but not by following the current regulations, etc., by presenting another perspective to sustainability.

Table 6.9 The Impacts of Biobuilding Components from the Practitioner's Perspectives

Q8 Could you tell me the potential impact(s) of these products?

Probe: Do you think it is possible to see any impacts on building design?

Probe: Which parts of a building will be assumedly affected?

SUSTAINABILITY	SOCIETAL	P01	... "it would have an impact on social behavior."
		P02	"...disruptive change...That is one and only way to really change society."
		P03	"Every project has it is own application area. I think garments can support your life a little bit better in your daily activities, in your physical behavior, getting you out of your phone."
		P05	"...we are looking at awareness, healthcare, active involvement that may affect building design and bring societal changes."
		P08	"I think the impact is on the healthcare system in terms of society being provided by a high level of care."
		P10	"...transitions to more sustainable behaviors."
		P11	"That all helps people to feel better and then work better. It is psychological."
		P15	"...it made a lot of additional changes that probably have more impact over time than the actual thing itself like the way we work, the way we behave, and the way we communicate to each other, which we found valuable."
		P12	"... more people that can be treated...we are not only improving the current system but also adding a new customer group."
		P13	"Maybe there is a point to it will become normal to use nature and biology. Maybe it is also a part, education or something. Perhaps it is helping others also to find a way to do it."
	ENVIRONMENTAL	P16	"Context with social matters is very important, that's why I think architects are also responsible for these kinds of things. You do not want to be aware of the decisions you made that are having an impact on society is non-sense."
		P19	"..robots will actively collaborate with people rather than independently doing things, and where the robot is, people should not go."
		P20	"It is important to realize where technology is at, what is the potentiality of it. But also what is human, society thinking of it."
		P03	"...the other one is a huge problem with garment production. We made so far away from polluting materials, not sustainable, linear process on throwing away when they are ruined... You can also approach the fashion industry a little more holistic compared to working on small superficial changes like color, style, marketing, etc."
		P04	"...all the choices that we do, we have to choose to create in-balance with nature."
	ECONOMIC	P05	"Green around us can be an energy source. Technology is applicable to plants and the other streams that are full of organic compacts like organic waste, domestic wastewater, and many more. All these waste sources can turn into energy sources."
		P09	"...it is all about LCA, life cycle assessment."
		P17	"The reduction of fossil maintenance products, the reduction of volume needed to make a proper concrete construction, furthermore, the nice skin that we discussed."
		P18	"...creating efficient systems where you use a system that creates a system rather than product dynamics."
OTHER		P07	"Now, we are trying to save money by adding the self -healing agent. At the same time, this also lowers the environmental impact of steel again. So, now two ways of benefits are available, 'economic' and 'environmental.'"
		P14	"Designing with knowledge of what's happening around us is important. I hope that some of the technologies that we have now might be replaced by utilizing biology better."
		P15	"It's interesting that it blurs the boundaries of disciplines, creating new disciplines, and these new disciplines start working together with other disciplines."

Challenges in the Practice of Biobuilding Components

The practitioners were asked to tell their main challenges in working with biobuilding components. These challenges seemed to be grouped into four main categories; practical challenges, users' prejudgments, stakeholders, working across disciplines, and others (e.g., physiological) (Table 6.10).

The majority of the practitioners, thirteen (13), mentioned the practical challenges through the innovations' design and development. These challenges indicate practical problems such as the 'uncertainty' in working with living organisms, challenges related to the market (e.g., problems in funding, lack of regulations, etc.), and technical challenges related to technological speed achievements.

Moreover, convincing people is one of the experts' prevailing challenges, along with practical challenges, market requirements, and working across disciplines. In this sense, the practitioners mentioned their complaints about the production system, current regulations, and stakeholders' prejudices, not the end-users. Furthermore, working across disciplines is one of the challenges expressed by the practitioners. To design, develop, and implement a biobuilding component requires the involvement of multiple actors in multiple disciplines. And this brings many problems, as such the knowledge gap between the design disciplines.

Table 6.10 Challenges Experienced by the Practitioners

Q9 Could you tell me the challenges that you faced in the design of the project?		
PRACTICAL CHALLENGES	P01	"The challenges are more about design... More how I presented it back then."
	P02	"...it takes time for traditional practitioners to get acquainted with the fact that it a different rhythm in fact, entirely different practice the one you were conducting."
	P04	"...there are no regulations...municipalities do not have rules to check it."
	P05	" My technology should be stable enough to survive daily life context."
	P06	"...working with nature is not constant. It is too broad, and everybody expects a consistent product with high quality."
	P10	"There are lots of uncertainties in the process. They are living, and they have their agencies... I think challenges depend on the speed of technology, speed of design, and learning how we can balance, and how we will adopt them."
	P11	"I think the challenge is the height of the building. How high is the building? How high can we install? How can we do that?... The challenges are also related to the technical parts of water pipes that we need for a building."
	P12	"...there are a lot of problems with the insurances. We do not have specific data that they provide faster treatments. So they do not see in a way to earn extra money back."
	P13	"...working with living organisms brings so many challenges because you are doing something that probably has not been done that you are probably doing it."
	P14	"...challenges like finding the platform, funding, etc."
PREJUDGMENTS OF USERS & STAKEHOLDERS	P17	"...a technical question into applying this technique and getting insulated as well."
	P19	"...robots cannot really do what we want them to do yet. So they do not move fast, are not accurate enough; they have limitations."
	P03	"The biggest challenge is to bring it forward within fashion labels, garment manufacturers to convince them they have to innovate."
	P04	"Convincing clients."
	P05	"That I am fighting against other pressing needs and issues people have."
	P07	"The difficulty in the building sector is that there are so many players."
	P08	"Prejudgments are everywhere all around the care system. People are refusing to work with technology, saying that they want to work with people, not technology."
	P09	"...how to get the consumer on board with accepting mediating with the accepting of the function of the products."
	P12	"...therapists do not really believe that VR works even though the many works of literature proving it is working."
	P18	"People and companies are always thinking about the short-term benefits for a single product, not the long-term."
WORKING ACROSS DISCIPLINES	P20	"We created systems that are so large. Anyone does not feel involved anymore. People do not feel responsible anymore, or do not think they have any influence."
	P15	"...working across disciplines is hard. It is difficult; it takes a lot of time.... confronting yourself with your limited knowledge, limited scales, and limited attitudes."
	P16	"There is also a lot to find sustainable materials. Technology itself is needed to be developed when it comes to biology. These kinds of developments do not come from architecture. They come from product design and material design."

Future Expectations

At the end of the interview sessions, practitioners were asked to share their expectations for the future (Table 6.11). The practitioners' expectations were divided into two questions: one is to get an idea of their expected ideas in the near future and recommendations for future architects.

In summary, the practitioners stated on the future expectation that “change is coming.” Relying on the increasing number of biobuilding components and the advances towards their performability, all the experts believe that biobuilding technologies will become our ‘new normal.’ According to them, the current industrial production system will eventually change, while these technologies exponentially will get better and become routine for people. The practitioners' statements underpin the argument that a large part of the society shall accept biobuilding components, and in that sense, they shall become ordinary for everyday life.

Table 6.11 Future Expectations of the Practitioners

Q10a Regarding what we discussed here, Could you tell me about your expectations for the future?

Acceptation	P01	"I think sensor technology will be developed further."
	P02	"I have no doubt this type of material, mycelium first before them all, will dramatically impact our material culture."
	P03	"The future will not in the way I approached. It can always be better. Sometimes also makes it vague works. I want people to be healthy, in good proportion, ease their life, change the product cycle."
	P04	"If we do not understand to sustain balance with nature, we ruin our planet anyway. That's, I think, is the main issue. We are at the cross points in building buildings, and every country takes it seriously."
	P05	"I want to reach that people allow to appropriate technology instead of accepting them or adopting them or passive involvement."
	P06	"...usage of plant energy is just taken for granted as something normal."
	P07	"We have environmental issues and social issues in our cities, and nature can solve it all."
	P08	"To solve the problem in the caregiving system by bringing solutions through the implementation of technologies."
	P09	"I think it is easy to accomplish with the potentials that we have."
	P10	"This is an emerging trans-discipline; different disciplines will be more in the future."
	P11	"How I see in the future, in green, growing, growing everywhere."
	P12	"I am convinced it will take off exponentially."
	P13	"I think it would be really interesting if the products that I made would be more common for people to have something like this which is alive, and you need to take care of them."
	P14	"I do have to be optimistic."
	P15	"I am very hopeful in that sense that I think young people do not have a problem. Because they have not established themselves yet, so they are very open things to do outside their idea of who they are...Young people are very much capable of bridging disciplines and willing to take risks."
	P16	"I think the future is telling us that already there is no going on like this as we used to do."
	P17	"We could apply this technology far more often."
	P18	"I think we will have a different world in five years, and the world will be a more technogenic place where specialists make their rules based on their specialisms."
	P19	"...robots will actively collaborate with people rather than independently doing things..."
	P20	"Change is coming anyway. Because the system has at the moment is not sustainable at the moment and will change. How will it change, and what will change? That is the question."

Recommendations for Architects

At the end of the interviews, practitioners were also asked for their recommendations for architects, regardless of their initial expertise (Table 6.12). This was found crucial since architects need to hear something from the perspectives of multiple actors, not particularly from architects.

Table 6.12 The Recommendations of the Practitioners for Architects

Q10b Do you have any recommendations for future designers and architects in particular?		
To be open and aware	P02	"I need to be in a conversation with you (architects) to deliver something for your field. It is inevitably intermingled, and that connects not only specific technical properties but also custom projects for their realization like structural applications. So it is always a dialogue."
	P03	"...trying to achieve the only %1, it is good enough."
	P04	"I think that is my message to architects and especially of the future: Try it, because it has really a lot of potentials. It has good possibilities."
	P05	"We (both for any design field and also architects) should be able to design products that are capable of changing. Designs need to be flexible but also engage people to tell more about them."
	P06	"Look at what is around it?"
	P07	"...architects are usually very conceptual. So they say we apply green, so it is sustainable. And we civil engineers go one step further, and speak to what extent, sustainable, how much sustainability is there? It is because you need the quantification to understand how helpful."
	P10	"I think curiosity is the main thing for all designers and researchers... I would suggest finding the right person to collaborate, and everything is about collaboration, everything is about togetherness."
	P11	"...To keep their eyes open. You (architects) should use nature in your building as a standard."
	P13	"It would be to realize whatever you create. You create it together with nature, not on it with it. Respect for the planet is also important."
	P15	"Be curious and open to new things."
To focus on appropriation	P16	"You (architects) are responsible and accountable in the decisions you make."
	P19	"There is not that much connection between these domains. For designers, it is important if they are aware of these things."
	P09	"...it is about designing a value chain, not the only a product... Designing the system instead of a product is good learning; it brings you holistic inputs, context, technical challenges."
To focus on system thinking	P12	"Change your market, but do not change to please everybody... I think it is crucial to keep in mind: Why are you doing it? How are you doing it? And What is the way to do it?"
	P09	"...it is about designing a value chain, not the only a product... Designing the system instead of a product is good learning; it brings you holistic inputs, context, technical challenges."
	P14	"...be vocal advocates of policy changes, things like evaluations of building energy."
To find economical solutions	P18	"I believe it is crucial to break out the current system, and we should start looking at what is relevant in our sector as in now."
	P14	"And be ok with certain things becoming much more expensive to do."
	P20	"...making it more affordable for people to be able to live that would be amazing in equilibrium with ecosystem and nature."
Others	P17	"...to look back on how they do before. Not for a richer, competitive economy, before that. How did the medieval Romans build their buildings? How are they standing?"
	P01	"In a more practical aspect, the sensor technologies work on radio waves within the electromagnetic spectrum."
	P18	"I think that parametric design is very important, and architects should not underestimate its importance and potential."

The most crucial recommendation underlined in the interviews that the architects should be aware of biobuilding components and related technological

developments. To be open to working with biology and uncertainties in building design while also being open to collaborations across disciplines.

The other recommendations were to see the bigger picture by means of system thinking and appropriation of the technologies. Finding an economical solution is also one recommendation for the architects since making it more affordable could increase the translation of biobuilding components into the buildings and daily lives.

6.1.3 Development of Biobuilding Components and their Integration into Building Design

The study continues with thematic analysis to elaborate more on interviews' data, which focuses on integrating biobuilding components into building design. Because while the experts were answered the questions, they elaborated on how a biobuilding component could be developed, turning into a product, and translations into building design. At this moment, the thematic approach analysis provides an overall conceptualization of the data patterns in this research by discovering the design stages of developing biobuilding components and their integration into building design.

According to Braun & Clarke (2006), there are six phases of thematic analysis; "familiarization," "coding," "searching for themes," "reviewing themes," "defining and naming themes," and "writing up." Based on this, the study applies thematic approach analysis. Firstly, all the narratives were transcribed into text, and be familiarized with the data by reading and re-reading the text. Secondly, the familiarization with the texts leads us to determine several codes such as 'fabrication,' 'creation,' 'invention,' 'application,' 'incubation,' 'nursery,' 'implementation,' 'customization,' 'alteration,' 'domestication,' 'integration,' 'infiltration,' 'adaptation,' 'interaction,' 'maintenance,' 'guidance,' and 'co-existence.' These codes could be followed in the interviews included in the thesis, as in the Appendix A Interview transcripts. Thirdly, the similarities and the connections with these codes lead us to generate specific themes. Finally, reviewing these themes lead us to find out connections and hierarchy in between.

By applying the TA method, the mega theme is determined as ‘design stages,’ while ‘realization,’ ‘production,’ ‘exploration’ and ‘translation’ are the main themes under this mega theme, and also includes sub-themes as (involved) ‘actors,’ ‘sub-stages,’ ‘opportunities,’ and ‘barriers’ for each. These themes could be seen in the following Figure 6.1. Thematic approach analysis map, a demonstration similar to mind-maps, introduces specific themes and sub-themes composed through the clustered codes in the verbal data (Braun and Clarke, 2006).

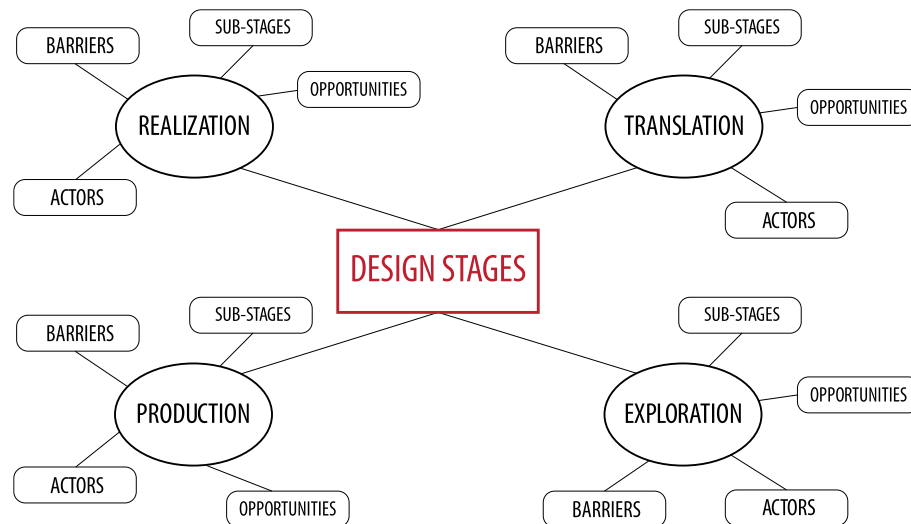


Figure 6.1 Thematic Approach Analysis Map of the Interviews (Mind Map generated by the author)

Figure 6.1 shows four main design stages determined in the design process of the translation of biobuilding into the buildings. Each stage also includes substages, opportunities, and barriers determined in the interviews. At this point, the application of these stages are as follows respectively; realization, production, exploration, and translation. They determine a certain pattern revealing the design process. In other words, each design stage includes an individual design process; simultaneously, they address the design process of the integration of biobuilding components into the buildings.

Hereby, the design process structure includes different processes in the design of products that are further elaborated on in the existing literature. Within these studies, the works of Roozenburg and Eekels come one step forward by revealing basic circles in research and design of the product through their in-depth

evaluation of product design process, methods and development comprehensively (Roozenburg and Enkels, 1994). According to Roozenburg and Enkels (1994), the design process comprises a sequence of intuitive (reductive) steps and discursive (deductive) steps. Between the two, there is often a comparison of the results attained so far and the desired results. The experience gained in the cycle is fed back, both to the design proposal and to the formulation of the problem and requirements list. In this case, the design of biobuilding components includes several stages that emerge at different levels, and each level itself compromises intuitive and discursive steps inherently (Figure 6.2). Meanwhile, the completion of each level triggers to start the other level.

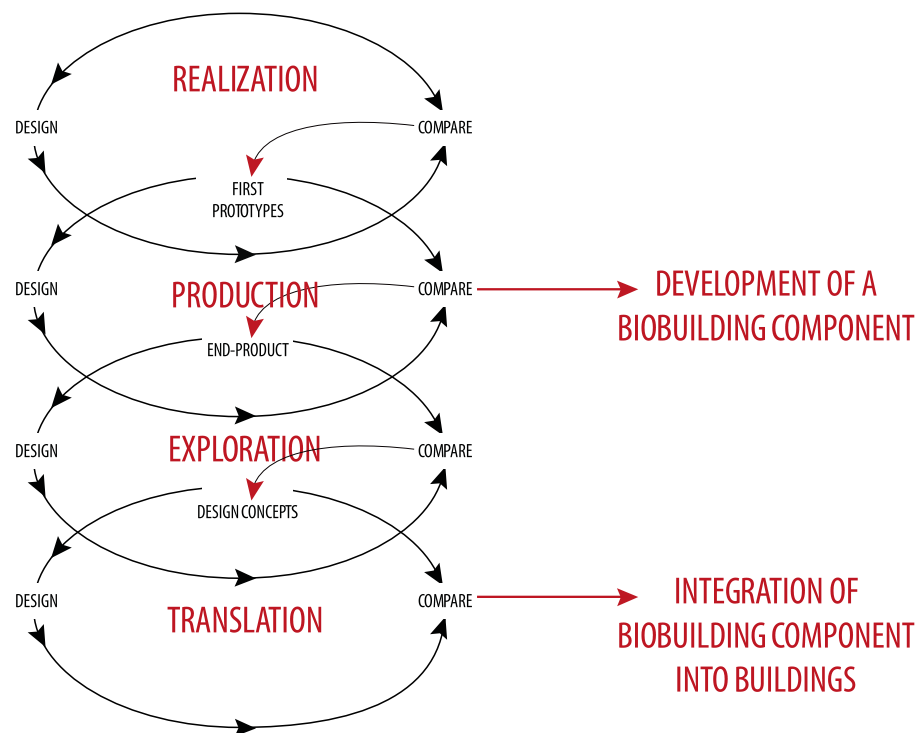


Figure 6.2 The Iterative Design Process of Biobuilding Components (Based on Roozenburg and Enkels, 1994)

The iterative structure of Roozenburg and Enkels helps us overlook the composition of the different stages of the design process and see two main categories; development of biobuilding components (realization and production) and integration of biobuilding components into the buildings (exploration and translation). The stages of realization and production describe how to develop

biobuilding components starting from the creative thinking process, including experiments with the living components, then ends with the production to be realized on the market. Further on, the biobuilding component could be integrated into buildings by following exploration and translation stages. The main difference between the two main categories lies at the intersection of two different design fields; industrial and building design. In this sense, Table 6.13 demonstrates and summarizes the design process that biobuilding components are designed as industrial products and then finding a place as building components, thereby relating to the building design.

These stages (realization, production, exploration, translation) are further elaborated on below subsections under two main categories (development of biobuilding components and the integration of biobuilding components into buildings).

Table 6.13 Design Process of the Development of Biobuilding Components and Their Integrations into the Buildings

		DEVELOPMENT OF BIO-COMPONENT	INTEGRATION OF BIOBUILDING COMPONENTS INTO BUILDINGS
Realization Actors: Researchers in multiple disciplines could involve in this stage, such as biologists and engineers. Envision: An initial idea developed and continues with initial researchers and experiments. Fabricate: This stage is the incubation of the different components (e.g., data technology, bacteria production, mushroom growing). Prototyping: This stage ends when technology turns into a visual, tangible product, thereby completing the first prototypes of the bio component.			
Production Actors: Developers in multiple disciplines could involve in this stage, especially product developers and designers. Pilot studies Demonstrate: This stage starts pilot studies with the first prototypes, e.g., researchers, user tests. This stage is the early introduction of innovation to society, such as design exhibitions, commercials, etc. Produce: Mass production of the bio components			
Exploration Actors: Architects in the main actor in this stage. Curiosity: This stage can only start with curiosity towards the biocomponent from architects. Awareness: This is the stage in which architects compose fundamental knowledge on biocomponent and consider as biobuilding component Association: This stage ends with the development of design concepts by architects.			
Translation Actors: Architects in the main actor in this stage, along with the stakeholders in the building industry (e.g., contractors, builders, etc.). Conceptualize: This is the stage architects explore and develop integration strategies on how to apply design concepts. Mediate: Architects mediate between building industry stakeholders and users by sharing the opportunities and barriers to biobuilding components and their translations. Experience: This is the stage in which the translation of biobuilding components into the buildings is experienced.			

Development of Biobuilding Components

The development of the biobuilding component includes two main stages; realization and production (Table 6.13). These stages emerge in industrial design.

Realization

The process starts with the realization of the technology in terms of transforming into a product. Researchers in multiple disciplines could involve in this stage, such as biologists, physicists, and engineers. This stage could be divided into three (3) phases; 'envision,' fabricate,' and 'prototyping,' as explained in Table 6.13.

This stage represents the creative thinking part of the development of biobuilding components. Therefore, it starts with the initial vision as an idea that encourages the researcher to explore the intersection of living and manufactured components. After research and experiments on exploring the possible ways to fabricate the biocomponent, this stage ends as technology turns into a visual, tangible product, the first prototype.

The practitioners explain the opportunities and barriers in this stage with the following remarks:

Opportunities

- *Technological Achievements*

Performance of the technologies is getting higher in parallel with increasing knowledge of working with living components. Therefore, new technological achievements make it possible to produce more biobuilding components.

- *Growing interest in designing biology*

The growing interest in designing with biology, particularly with living components, increases the current knowledge and research opportunities.

Barriers

- *Lack of regulations*

The lack of knowledge also brings a lack of standards since these products are the initiators of another way of system thinking, besides, lack of ethical

studies. There is always an ethical issue of plants and technologies related to humans, but not bacteria, algae, or fungal.

Production

After developing the first prototypes, the production stage starts with three main phases; ‘pilot studies, ‘demonstrate,’ ‘produce’ as explained in Table 6.13. Developers in multiple disciplines (e.g., fashion designers, engineers, biologists, etc.) could involve in this stage, but especially product developers and designers involved in this stage.

To be accepted as biobuilding components by architects, biocomponents needed to have certain reproduction and mass production standards. Therefore, this stage includes pilot studies (e.g., researches on functionality, implementation, user experience, etc.) exploring the impact of biobuilding components on the market. The pilot studies continue with the first demonstration of the biocomponent (e.g., design exhibitions, commercials), thereby exploring their resonance in the market, and ends with the mass production.

The practitioners explain the opportunities and barriers in this stage with the following remarks:

Opportunities

- *Raising Consciousness*

The problem (climate change) is already visible, indeed tangible. Therefore, the awareness of people on more sustainable choices and new ways of products is higher than in the past. As a result of the rising consciousness, scholarly and non-scholarly publications present circular system thinking and new business models to solve climate change. Thus, this urge designers and developers to create designs together with living organisms.

Barriers

- *Lack of regulations*

Again lack of regulations and standards have often hampers developed products to find a place in the existing market.

Integration of Biobuilding Components into the Buildings

The stages of exploration and translation here explains how to integrate biobuilding components into a building. It includes an exploration process independent from the exploration in the design and development of biobuilding components. It refers to the exploration of the biobuilding components within the framework of building design. The translation stage reveals how biobuilding components could find a place in the current building practice.

Exploration

Through this stage, biobuilding component starts transforming into a biobuilding component by finding a place in the building design industry. This is the explanatory stage that a product is started to be translated into building design. The main actor group of this stage is the architects. This stage includes three main phases; 'curiosity,' 'awareness,' 'association,' as explained in Table 6.13.

This stage can only start after the development of a certain biobuilding component. In this stage, architects compose fundamental knowledge on the relationship between biocomponents and building design, thereby embrace them as biobuilding components. This stage ends when architects associate biobuilding components with certain building parts and when they develop design concepts.

The practitioners mention the opportunities and barriers in this stage with the following remarks:

Opportunities

The main opportunities detected here are the aesthetics and integration strategies (infiltration, adaptation, interaction).

Aesthetics

With the advancements in technology, it is possible to create various types (looks) of the products regarding the aesthetic appeals of the designers as such architects. Biobuilding components can be adapted into different forms, scales, colors, and many more.

Integration Strategies

The interviews lead us to underline the potential of biobuilding components by means of different integration strategies into the different building layers (See Appendix A Interview transcripts). Infiltration and adaptation determine two strategies related to the expanding impacts of the technology itself. On the other side, interaction determines a design strategy considering the impacts of biobuilding components on other building parts, in the sense of creating relationships between building layers. These strategies are concluded from the interviews that can be increased, but what is critical here is that biobuilding components indicate a remarkable ability to alter building design with different strategies.

- *Infiltration*

Biobuilding components can be infiltrated into a building in the form of a building design component. This strategy suggests integrating biobuilding components as building design components behaving and looking like the ordinary parts of a building. In the sense of living organisms, sort of hidden within the manufactured components, only showing its benefits in the production phase. For instance, self-healing concrete looks similar to regular concrete plus its benefits. Thus, this is the unnoticeable way of providing smart and sustainable solutions to the environment.

- *Adaptation*

Biobuilding components can be adapted into different building layers by providing different solutions. For instance, in the case of the *Sniffer nose* system adapted into the sprinkler system of a building, several advantages can be brought into the building, such as early notice of smoke or unhealthy gases.

- *Interaction*

Biobuilding components can interact with the other parts of the building. For example, smart clothes can be designed in a relationship with the service layers of the building; thus, the productivity of HVAC systems can be increased.

Barriers

The main barriers detected here are related to the lack of regulations and current mindset (hygiene phobia, user-product-building relationship, working across disciplines).

Lack of regulations

Again lack of regulations and standards have often hampered developed products to find a place in the existing market.

Current Mindset

The current Mindset is the main barrier. The existing way of thinking on the discipline of architectural design hampers the translation of biobuilding components into building design. Especially on the following matters:

- *Hygiene phobia*

The consideration of the use of living organisms as a threat to human health.

- *User-product-building relationship*

Consideration of product, user, and building as separate entities by ignoring the potential benefits of creating in-between relationships.

- *Working across disciplines*

The current educational system and business models make it difficult to work with interdisciplinary studies and researchers. This creates a considerable barrier to the development of biobuilding components.

Translation

After a certain level of knowledge developed by the architects and design concepts developed, the translation stage starts. This stage includes three main phases; 'conceptualize,' 'mediate,' 'experience' as explained in Table 6.13. The term 'translation' here implies applying any design strategy empowering the adaptation of technologies into the buildings (C. Hammink and Mohammadi, 2018).

In this stage, architects are the main actors, along with the stakeholders in the building industry (e.g., contractors, builders, etc.). In this stage, architects explore

how to apply integration strategies as design concepts. Architects play a mediator role by sharing their knowledge and experience on biobuilding components with the other building industry actors. To convince stakeholders to use biobuilding components and create bridges in the communication between them and the initiator of the biocomponents are the architects' prominent roles. This stage ends with experiencing biobuilding components in building design.

The practitioners explain the opportunities and barriers in this stage with the following remarks:

Opportunities

- *Appropriation*

The increased number of innovative products started to be appropriated into daily life with two (2) main issues.

- *Contextualization*

Biobuilding components can bring solutions to contextual problems by adapting to the requirements and specifications of the subject matter.

- *Alternative solutions*

Biobuilding components present alternative solutions, which in some cases could be low-cost solutions or decrease the estimated time of the construction.

Barriers

- *Current system/model*

The current system and model of the construction process and the lack of regulations might cause stakeholders to decline the involvement of biobuilding components in the building design process.

- *Convincing stakeholders*

Architects always play a mediator role between the user and the stakeholders as such contractors. Therefore, architects needed to have sufficient knowledge of biobuilding components and decrease the concerns of the stakeholders and the users.

In this way, the thematic approach analysis leads us to understand how biobuilding components developed and how they become a design element by being integrated into the building design. The design process above gives insights on the stages that certain actors involved, reveal opportunities and barriers for each stage as well. The findings here do not represent a design model. However, this leads us to understand the dialogue between the industrial and building design, thereby translating the biobuilding components into building design.

A building component can be developed the same as an industrial product (e.g., façade panel, modular wall system, etc.) (Poelman, 2008). Likewise, a biobuilding component can be developed as an industrial product (e.g., mycelium acoustic panels, Appels et al., 2019). Therefore, these different circles could only be adapted to the highlights and summaries of the multiple processes within the current technological transition at the intersection of living and manufactured worlds. What is interesting in this design process is that this pattern visualizes the gap between two different design processes; product and building design (Figure 6.4). This gap between industrial and building design arises from the different concerns in multiple disciplines under various domains. Architects mainly focus on the spatial composition of a building environment; in contrast, industrial designers concentrate on practical solutions for people through materials (Poelman, 2005). This also appears to be a problem since this knowledge gap handicaps the technological development of building components incorporated with living organisms in building design. Therefore, there is a need for further discussions on the development of technology and its implementation bridging between two design fields (Poelman, 2005).

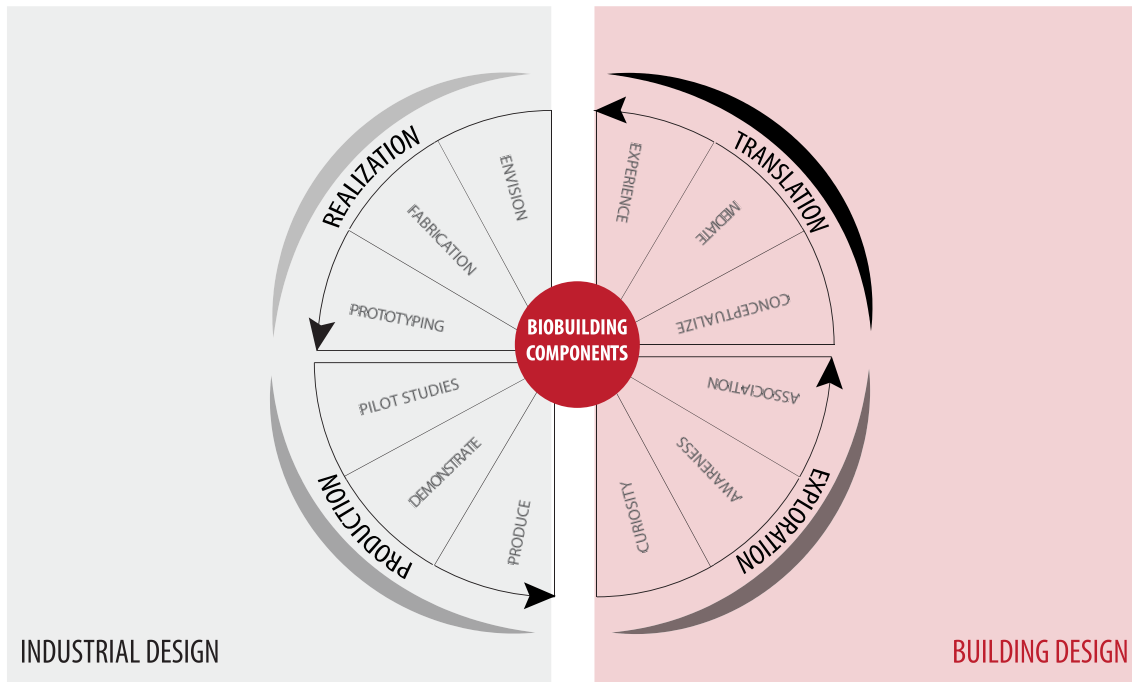


Figure 6.3 Superposition of the Design Stages of Biobuilding Components

Indeed, discussions on the impacts of technological developments through industrial products could be followed in building design after industrialization (Alam et al., 2012; Aldrich, 2003; Arunvivek et al., 2015; Dawid et al., 2017; Hong et al., 2016; Marikyan et al., 2018). The arrival of new technologies into the buildings enables architects to create bridges between industrial and building design and other disciplines such as; engineering (Gibson, 2012) or urban design (Ratti & Claudel, 2016). A very close connection lies between industrial design and building design through the “praxis of design,” its “body of knowledge,” and “design methods,” especially for practitioners (Poelman, 2008). Therefore, building design can provide design strategies acting together with industrial design (Phocas, 2015; Poelman, 2010; Wortham, 2007). This could also be explained in the elaborated examples both in the literature and with their practitioners (Table 6.14). Undoubtedly, the examples are in different stages. Therefore they might not end up with the translation of the biobuilding components into the buildings.

Table 6.14 Demonstration of Design Stages as an Example

Self-Healing Concrete	
	Realization Research on self-healing bacteria.
	Production Development of concrete samples with self-healing bacteria.
	Exploration Experiments on the performance of self-healing concrete.
	Translation Designing and building Zelfherstellend Paviljoen (Self-healing Building).
Mushroom-based Products (Mogu acoustic panels)	
	Realization Research on suitable fungus and mycelium culture.
	Production Development of product samples.
	Exploration Experiments on the performance of mushroom-based acoustic panels in the building environment.
	Translation Integrating acoustic panels into the buildings.
Living Walls with Plants (Cloud garden green wall)	
	Realization Nursery of certain plants and the research on the suitable technology
	Production Development of the living walls
	Exploration Experience the performance of living walls in the building environment by means of thermal comfort and air quality
	Translation Integrating living walls into the buildings

Each circle can continue as a closed-loop, as one circle could conclude with specific outputs. If any success is achieved, a particular product can go through into another circle, which involves different actors, different opportunities, and barriers.

Regarding the experts' statements, certain outputs end one stage and start another. Poelman (2005; 2010) explains the diffusion of information on a design by means of innovations applied by third parties to be translated into (industrial and building) design. He determines two categories of design information; product to design and technology. The product could also become a building through which could be supplied for the development of a design. Technology refers to what is wanted, what is innovated, and ought to be adapted into the design. And their intersection starts the 'association process,' which is referred to in this thesis as the translation of biobuilding components into building design.

In the case of biobuilding components, as shown in Figure 6.4 wider perspectives and long-term targets mainly as smart and sustainable solutions end with new technologies by means of new techniques and materials at the end of the realization stage. This triggers the second stage, 'production' concludes with the first prototypes of biobuilding components. What seems remarkable in the answers of the experts is that the performability of biobuilding components plays a crucial role in their development and translation into the building design. Although significant and long-term motivations like ecosystem thinking and creating a balance between natural and building environments could live behind the initiation of the projects, their performance seems to be critical for them to create linkages between different layers and thereby the transition of technologies. The exploration stage jumps into building design in which architects need to adapt knowledge on biobuilding components. Indeed the exploration stage is embedded into the other stages. However, this stage means exploring the architects on the potential roles of biobuilding components into different building layers. What is remarkable here instead of their long-term motivations to create a balance between nature and building or even transform buildings into living, growing entities, the performability of the biobuilding components play a crucial role. By providing sufficient performance through the needs of the users as well as satisfying the architect and the designers biobuilding components could be translated into the buildings.

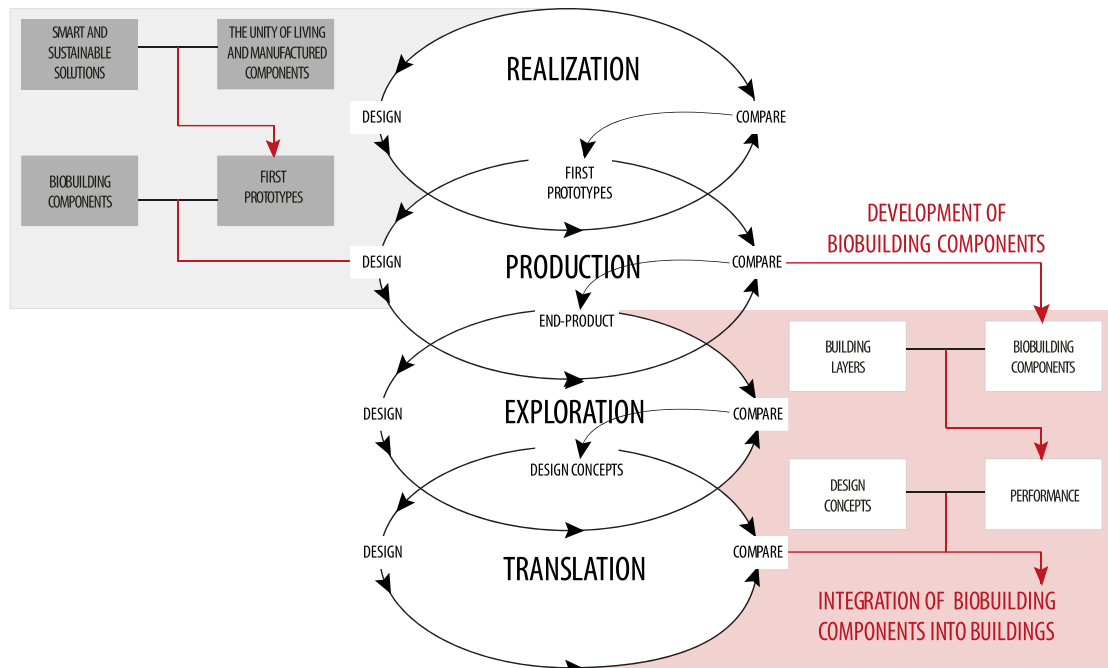


Figure 6.4 The Dialogue between Industrial and Building Design through Biobuilding Products Becoming Biobuilding Components (Based on Poelman & Kelson, 2008 and Iterative Structure of Design process by Roozenburg and Enkels, 1994)

Moreover, Poelman (2005; 2010) emphasized that it is essential to note that technical background information is unnecessary. In the design stage, it is important to know only ‘what might be possible.’ It is not necessary to know ‘how it is possible.’ As shown in the Figure and in the interviews, the biobuilding components' technical attributes have relatively less impact on their translation. What plays a critical role in their performance is more related to their possible advantages and how they affect the current design.

At this point, one can say that this is quite similar to the translation of any smart technologies into building design as already drawn by Poelman & Kelson or in the studies of Mohammadi (2014). This leads us to conclude with a hypothesis that biobuilding components can act as another generation of smart technologies and could be applied to the buildings. The gap between industrial design and building design shall always remain. However, to provide a better understanding of their relationships and the intersections empower the possibility to create linkages in-

between. Moreover, the potential use and benefits of biobuilding components could be empowered with the impact area of the development and design of the biobuilding components.

6.2 Conclusions

This chapter nurtures the existing literature by bringing further information on biobuilding components regarding their characteristics, motivations, novelty, terminology, expected results, impacts, challenges, studies on user experiences. The interviewees explain their projects with a variety of examples. They discuss the development process of ubiquitous technologies like smartphones and computers by underlining a couple of years ago, they were considered ‘futuristic.’ The practitioners from different backgrounds and professions lead us to look through the critical role of biobuilding components in building design and daily lives from different points of view. In this way, this part of the study enhances the existing knowledge of biobuilding components and provides insights into the design and development of biobuilding components. This chapter also gathers recommendations of the practitioners for architects, along with their expectations from the future.

Furthermore, this part of the thesis presents answers to RQ3: How biobuilding components can be integrated into building design (Table 6.13, Figure 6.2, Figure 6.3., Table 6.14. Figure 6.4). This Chapter leads us to understand the meaning of biobuilding components among the bridges between industrial and building design. The integration of biobuilding components can only be done with their translations into building design by bridging two disciplines.

This thesis acknowledges these bridges between industrial and building design by revealing the design process as the combination of different stages within an iterative structure based on the design process by Roozenburg and Enkels, 1994. This design process shows the way of biobuilding components to communicate with different layers and different disciplines. The industrial design process is linked to creating smart and sustainable solutions and presenting various market

products. These products could be integrated into different building layers, while their performance plays a critical role. Thus, this chapter underpins the conjunctive role of biobuilding components between smart and sustainable solutions and building design. In fact, broad, general, long-term targets embody into very small scale product; further on, these small scale products resonate on a bigger scale, building design. In this way, this chapter leads us to conclude the potential of biobuilding components to create a biophilic building environment in which living and manufacture components are united within the harmony of nature, technology, and buildings. Indeed, each design stage can indicate an individual S-curve of the technology by determining an individual design process. By applying these individual design processes through integrating biobuilding components into building design, their technological integration could be increased, respectively. Thus the diffusion of the technology in between might lead society to reach a biophilic environment in which humans, technology, and nature are balanced within harmony.

All in all, this part of the study plays a crucial role in creating knowledge of biobuilding components by giving a further discussion on biobuilding components on their role to create biobuilding design and to reach a biophilic environment on the macro scale. Future studies are indeed necessary, especially with the end-users. However, the interviews underline that, for now, there are only limited studies with the end-users that could be discussed. Since biobuilding components are at the early stages of technological integration, there is a lot to be discovered. Thus, this leads us to decide to end the analysis part and continue with the thesis's conclusions in the following chapter.

CONCLUSIONS AND RECOMMENDATIONS

Biobuilding components are remarkable among the technologies blending into the buildings at varying scales because they promise to transform building components into autonomously active, growing, dynamic entities by incorporating living organisms. Meanwhile, they surround buildings with various technologies in which humans and buildings are more connected and harmonious. They offer various benefits, such as wearable technologies to enhance humans' abilities, self-growing furniture, and self-healing materials. Accordingly, the number of biobuilding components in the product market has been exponentially rising by presenting various smart and sustainable solutions for buildings within current environmental degradation. In this way, it is possible to claim that our buildings, surroundings, and even daily lives and habits—in fact, the entire relationship between humans, nature, and technology—can be affected by biobuilding components soon.

This thesis underlines that designing with living organisms has become a topic of interest in architecture over the past years. In my opinion, designing with living organisms in building design as well as in architecture will remain its importance—in fact, this interest will continue to increase. In other words, buildings will evolve and alter through the following years at the intersection of living and manufactured words. In that sense, with the integration of more and more biobuilding components into the built environment, buildings will become more natural and more technological at the same time. However, there is still a lot to be uncertain about regarding their impact on and meaning for building design. Therefore, this thesis is critically important by taking a reliable step forward in the building design domain by bringing profound knowledge on biobuilding components into this emerging field.

In the scope of this final chapter, the main research question of the thesis is answered by revisiting the entire research and sub-questions under the umbrella of the multi-perspective impact of biobuilding components. This part of the study offers brief and profound answers to the research questions instead of summarizing the findings in the study. In this way, it stresses the important subjects; founded possible meanings of biobuilding components within the created knowledge in this thesis. Further on, recommendations for architects and future research are presented. Finally, the thesis ends with closing remarks, including hypothetical conclusions regarding how building design is affected by the expected impacts of biobuilding components discovered in this thesis. These hypothetical conclusions specify my own perspective, including related questions, assumptions, and future prospects regarding biobuilding components in the building design domain. Therefore, it presents critical claims and statements which reflect my own perspective and contribution to this emerging field of biobuilding components.

7.1 Research Questions Revisited

By answering the main research question, how building design would be affected by biobuilding components, this thesis yields knowledge related to its objective. In the process of creating knowledge, in my opinion, Nietzsche helps this study consider different ideas, concepts, and production systems of biobuilding components by exploring this emerging field in-depth. His approach reminds us that objectivity in knowledge can only be empowered by looking through different perspectives as much as possible. This way of thinking leads me to question objectivity through underlining subjectivity and the value of subjectivity within objectivity. I interpreted this that subjectivity is a fruitful way of creating objectivity, but its value can only be enhanced through their plurality.

I believe it is novel to embrace a philosophical approach in a technology-driven study. In my opinion, in developing studies, contradictory viewpoints and reviews are required to be considered. By this means, variety in literature studies, the

applied methods and conducted studies with different actors can always raise further questions as well as further answers. Accordingly, I underline that there is a lot to be discovered about designing with biobuilding components; therefore, it is necessary to look at this topic from different and more perspectives.

The provided answers below are significant and valuable, but at the same time, it is open to more and different interpretations. At this juncture, it is important to realize the role of perspectivism in this study. That's because the answers to these research questions and the questions themselves indicate my own perspective as the writer of this study towards the interrelation of living and manufactured components in building design. In this way, this thesis creates knowledge by answering these questions but, more importantly, raises more and more questions within this emerging field. By this means, from my interpretation of Nietzsche, knowledge is more valuable through its plurality, subjectivity, and questionability. This does not underestimate the value of the answers; on the other hand, it underlines the novelty of this thesis's contribution to the existing literature.

The research questions in the study are connected to each other by exploring main research on theoretical, and practical aspects. The first question interrogates the theory, practice and further meanings of the interrelation of living and manufactured components on building design. Furthermore, the second question furtherly explores the practical implications of the bio building components. The third question seeks to provide a better understanding of the biobuilding components from a practical point of view.

As an answer to the first research question, it is found out that the biobuilding components could affect building design through the meanings of living building components in building design concerning the concept of nature. To discover the meanings of living building components in building design, it is necessary to remember the studies in social sciences by underlining subjectivity of varying nature concepts. This subjectivity indicates time-bonded and altering interpretations of the 'idea' of nature, and thus gives an understanding of the altering concepts, styles, and approaches in pre-modern to contemporary

architecture. This subjectivity is reflected in building design and concluded with symbolic, analogic, metaphoric understandings, thereby applications and conceptual way of thinking. For example, in the art nouveau style in architecture, nature's concept has shown itself as an ornamental, formal, and structural expression. In this way, phenomenologically and philosophically, buildings could be bonded with nature with the inclusion of living building components at an aesthetical level. In the examples of modern architecture, the concept of nature is embraced by understanding and creating a balance between the building and the natural environment. Thus, this brought a philosophical and phenomenological way of approaching the relationship between nature and buildings, by considering buildings as a part of the natural environment. Now, living building components have started to seek a place in building design through their practical benefits as responding to rising environmental problems, demands for environmentally-friendly structures and the use of local and renewable materials with the concerns regarding energy efficiency, waste management, and lack of resources.

Moreover, the concepts like biomimicry and biophilia show the urge in architecture to create different bonds of nature and technology. In this way, in addition to analogical, symbolic, or metaphorical understandings of nature, thanks to technological developments, it becomes possible to emulate living organisms by thoroughly understanding and mimicking nature's logic. Indeed, the idea of mimesis can be traced back to pre-modern architecture within the works of Quatremère de Quincy, yet with the technological abilities, biomimicry in architecture offers a variety of examples. Notably, sustainable and smart solutions have been provided to current environmental degradation. In other words, historical meanings of nature through symbolic, analogical, and metaphorical interpretations of living building components have been translated into design practices thanks to the latest technological developments.

The reasons that biobuilding components would affect building design lies in the meanings of manufactured building components in building design concerning the developments of technology. Due to its heterogeneity and complexity, various technologies can blend into buildings. The exponential and comprehensive

development of technology has affected daily lives, surroundings, habits, and in fact lifestyles related to their infiltration into the built environment. This argument can be supported by showing that today's vital technologies like the internet, smartphones, and many more were 'hard-to-achieve' just a couple of decades ago. What is highlighted here is that manufactured components can have significant social impacts on building design regardless of their scales, and could affect building design by being integrated into the buildings similar to smart technologies.

Compared to the bond between nature and buildings, the bonds between technology and building design are relatively late. Thus, it makes it difficult to make projections considering the exponential growth and change in technology. It is possible to underline the expected technological impacts on building design by the integration of technologies, yet some impacts can be more noticeable than the others. For example, building design is indirectly affected by the rise of domestic technologies. In contrast, technologies like solar systems and mechanical cores have directly and drastically affected building design. Thus, for now, it is possible to claim that any innovation could affect building design by their practical meanings underlying their promising functions, potential uses, and advantages. However, it is not possible to truly estimate which technologies will affect it.

At this moment, contemporary studies point out the changing dynamics between nature and technology. Considering the time-bounded and subjective impacts of the altering understandings of the concept of nature on building design, these contemporary studies led us to emphasize the influence of the interrelation of living and manufactured components on building design. By this means, the unity of living and manufactured components will bring possible social impacts on daily lives and surroundings.

In my view, the interrelation of living and manufactured components might affect building design by bringing additional significance to the existing meanings of living and manufactured components in building design. Experimental studies in the building design domain have been exploring new phenomenological and

philosophical meanings of nature in architecture in the last decades. Contrary to the historical meaning of living components in pre-modern architecture, recent experiments with biobuilding components in building design. For example, Silk pavilion and Growing Pavilion create visual connections with nature by means of using living organisms at the material level, leading us to experience their dynamism by accepting their initial aesthetical values. This might be evaluated by the similarity of the relation to use and artistic design in modern architecture. However, it is possible to claim that biobuilding components promote something different than the tectonic meanings of any other building components through their liveliness. By this means, biobuilding components bring additional design practices with the use of living organisms. In that sense, biodegradable, growing, and temporary building components in addition to providing alternative ways for the production of space. Therefore, it seems possible to point out the practical impacts of biobuilding components in addition to their theoretical impacts within their expected architectural effects drawn above.

The study discusses the possible social impacts of the practical implications of biobuilding components by embracing the 'fusion' of nature and technology as a starting point. This thesis also discloses that this 'fusion' could have resulted in the integration of biobuilding components into building design in different ways. The incorporation of living organisms can be fused into materials and products. By this means, biobuilding components can become conventional and natural as they are ordinary products. This change may happen in the near future, in fact, very soon with the help of regulations and the acceleration of mass production. Likewise, the interviews with practitioners underpin this argument. For example, Ermi van Oers claims that new behaviors between living organisms and humans could be provided, as discussed in the Living Light project example.

Moreover, self-healing and cleaning materials like in the examples of bio-detecting floor tiles might bring alternative solutions to housing cores, and thereby could indirectly affect building design by first affecting the social life in the buildings. On the other hand, the examples of Fab Three Hab and Growing Pavilion seem to bring a more radical approach since living organisms use unexpected,

unpredictable visuality, performability, and functionality. Thus, in my opinion, it seems that they will not be 'natural' soon in our daily lives. And even if they become more conventional, it seems that they will be stressed through their living, growing, dynamic assets instead of the fusion of nature and technology. In this way, I claim that the integration of biobuilding components could affect building design by triggering different changes in society.

Biobuilding components address long-term goals wider than their objectives and functions to alter the built environment. At this juncture, it is expected that society would be affected by demanding a biophilic environment to strengthen the bonds between humans and the natural world. From this point of view, the integration of biobuilding components into buildings can trigger a technological transition, and firstly this could transform building design into biobuilding design. The statements of the practitioners in the interviews also underpin this argument.

Additionally, the design experiment stresses the design approach's role compared to the technical attributes of the biobuilding components. The design experiment shows that by approaching biobuilding components, embracing their long-term goals has encouraged integrating biobuilding components into building design. I believe reaching a biophilic environment seems unlikely to happen soon. However, this thesis reveals that creating a balance and harmony between humans, nature, and the building environment lies in integrating biobuilding components into building design.

In this way, the necessity to evaluate biobuilding components in building design is answered through its theoretical and practical perspectives. Further on, the study answers its second research question, how could biobuilding components find a place within the current building design practice.

Considering the multidisciplinary aspects of biobuilding components related to multiple domains, insights are provided regarding the related terms, definitions, and concepts on biobuilding components. There is no specific terminology on biobuilding components in the literature. Meanwhile, experts' priority is to express and highlight their designs and ideas. Experts mostly prefer to use contextual

terminology. For example, they might use the smart term for their explanations to the user, and they might use comprehensive concepts such as bionics, biodesign, and biomimicry in their professional practice.

In my opinion, the problem in the terminology will remain and cannot be solved very soon, not even in the next couple of decades. In fact, in the near future, more and more terms and definitions will be added to the current terminology. That's because, along with their increasing numbers of biobuilding components, the intersection of living and manufactured components will be experienced, experimented with, and critiqued in more and more studies. This will have resulted in more and more terms, definitions, concepts, and methodological approaches reflecting various disciplines' codes as such methods, concepts and commonly known terms. In that sense, the plurality, therefore the ambiguity in terminology, will remain as a problem and also a potential for this emerging field.

The variety in the terminology also underlined the multidisciplinary potential of the biobuilding components along with its extensive bonds with fundamental concepts like ecology and sustainability. This variety also underlines the potential of biobuilding components in multiple design fields by being connected to the concepts in multiple disciplines, domains, and studies. The way of answering the question on characteristics of biobuilding components along with their relevance to the building design leads this thesis to discover biobuilding components in current practice by presenting their characteristics, domains, initiators, goals, objectives, implementations, incorporated living components, and integration layers. The expected result of this question is to determine similarities between the examples, such as detecting similar goals, objectives, and related domains.

However, biobuilding components indicate multiple goals, objectives, and implementations with a variety of functions related to multiple domains. These varieties in the findings lead to the conclusion that biobuilding components are not limited/specified technologies, products, or systems. On the contrary, they can be in various forms, products, materials, and systems that could be integrated into buildings by relating to many domains and industries.

Overall, this thesis emphasizes the different uses and benefits of biobuilding components within their practical meanings; multiple functions, goals, objectives, and then their critical roles in multiple domains, disciplines, and design fields. At this point, the knowledge gap between industrial and building design might hamper the integration of biobuilding components in building design. To bridge the knowledge gap, the study asked its third research question focusing on the integration of biobuilding components into building design.

The design experiments demonstrate that architecture students do not face any problem integrating any of the given biobuilding components into their design, since the scope of the building design studio enhances the conceptual way of thinking by translating abstract ideas into the design. Therefore, students could integrate given biobuilding components into their designs regardless of the differences in their design processes. What affects the integration of biobuilding components into the building design is the existence of the knowledge gap between industrial and building design.

The design experiments show us that within the current framework of architecture, education pays little attention to technological developments. Therefore, the opportunity and barrier lie here with the involvement of technological developments and their impacts on building design in architecture education. I believe this could empower the integration of biobuilding components into building design as future architects are faced with biobuilding components in real practice. In this way, despite its limitations, design experiments lead this thesis to draw attention to the potential of biobuilding components in architecture education. Therefore, they are critical and provide credit to the argument of this study on the necessity to create knowledge within the tendency of two different backgrounds; smartness and sustainability growing towards each other.

In addition, the interviews reveal that the performance of biobuilding components plays a crucial role in addition to their novelties and advantages. The other vital discussions, such as technical attributes, ethics, and aesthetics, seem to be less

critical, comparing the performability of biobuilding components as underpinned by the answers of the practitioners.

Furthermore, the study presents the iterative structure of different design stages, Realization, Production, Exploration, Translation. These stages once more underline the multidisciplinary aspects of the study and biobuilding components' altering meanings in different disciplines. Moreover, each stage indicates individual opportunities and barriers. At this juncture, despite their advantages, thematic approach analysis has limitations. It helps to reveal certain design stages and gives an overall understanding of the design process. On the other hand, it seems insufficient to determine the hierarchy between different stages in terms of valuing them through their necessity.

The realization stage is the stage where the technology initially developed concerning disciplines of material technology and product development. Technological achievements and growing interest in designing biology seem to indicate significant opportunities by means of encouraging ongoing studies. In contrast, the lack of regulations, as such, lack of European standards for materials with mushrooms, bacteria, and algae, and missing information on the ethical concerns towards the use of living components, seem to be barriers in the realization stage. The production stage could only start with the development of specific materials and technology. Raising consciousness towards environmental degradation seems to be a significant opportunity by means of increasing interest in new products providing a radical approach. The lack of regulation is also debatable since the lack of standards has often hampered developed products from finding a place in the existing market. After the production stage ends in industrial design, the exploration stage starts in the building design domain. At this point, one can ask why the exploration stage happens so late, even after production, because the gap between different design disciplines remains.

Biobuilding components need to be explored within building design through their possible advantages to the buildings. Since their functions and benefits can change while they are starting to be explored in building design, biobuilding components

gain active roles in building design through increasing interaction between different building layers. For example, the Ministry of Supply Mercury Heated Jacket can have an active role in building design by providing thermal comfort to the user. By that means, servants start acting as service. Therefore, the exploration stage plays a critical role by means of transferring information from industrial design to building design. A variety of opportunities empower this stage, such as integration strategies, infiltration, adaptation, and interaction, presenting the ways to connect the living and manufactured components in building design. In addition, the lack of regulations such as, missing information on current standards for using bacteria and mushrooms, lack of regulations on technologies attached to humans such as ethical and privacy issues is also a barrier for this stage. But more importantly, the current mindset of the professionals seems to be a significant barrier through hygiene phobia, working across disciplines, and the interrupted relationship between the user, product, and building.

In that sense, the exploration stage plays a critical role since it is the initial stage of biobuilding components in building design. When it fails, biobuilding components cannot be integrated into building design. The translation stage implies the translation of technologies into the building design domain from the industrial design domain. The opportunities in this stage are the appropriation of technologies by means of contextualization and providing alternative solutions. In this way, biobuilding components will be smoothly infiltrated into building design. At this stage, the major barrier is to convince stakeholders and current system thinking through current construction technologies and building design processes.

Biobuilding components might indicate a new way of production in which we can change the building design processes entirely. For example, for mushroom-based technologies, there is a need for time to grow the desired material. This is indeed extreme compared to current practice. These design stages and the relationships in between lead us to underline the involvement of multiple actors, a collaboration of multiple disciplines and domains.

In my opinion, design stages give an overview of the design process yet do not provide us an ultimate model to be applied. Biobuilding components can only be integrated into building design after their translations. It is possible to say that these design stages are important by giving an understanding of the connections between industrial and building design, the role of certain actors, and surely the role of architects. However, the current level of technology of biobuilding components is not developed to discuss further their integrations into building design.

All in all, the answers to the research questions discuss the expected impacts of biobuilding components by mainly elaborating on their architectural and social effects. Meanwhile, in light of all different meanings, the importance of biobuilding is attached to multiple domains, studies, and disciplines through their multiple-use benefits and roles in building design. This also indicates the multi-perspective impact on building design. Different perspectives reveal various meanings of biobuilding components instead of concentrating on the same point. All the methods applied in the thesis's scope lead us to conclude with another expected impact of biobuilding components. I entitle this versatility as the 'multi-perspective impact' of biobuilding components as a final answer to the main research question. Meanwhile, this research contributed to the existing literature by yielding knowledge on their architectural and social impacts.

7.2 Recommendations

From this thesis, two types of recommendations could be drawn as the research outputs: recommendations for architects and recommendations for future research and practice on biobuilding components. The interested parties of these recommendations encompass architects, future architects, and researchers, and practitioners who work/intend to work under the building design domain.

7.2.1 Recommendations for architects

In my opinion, these recommendations help architects to enhance their 'consciousness' on their decisions towards biobuilding components in their designs as the final output of the study.

The recommendations concluded in the thesis are discussed within the umbrella of 'awareness' as a result of the practitioners' emphasis on the lack of knowledge of specific issues where architects should enhance their awareness. Initially, the first recommendation is 'the awareness of the multi-perspective impacts of biobuilding components.' This recommendation also implies the necessity to be aware and open-minded towards the number of possibilities and alternative solutions promised through biobuilding components in building design.

Another crucial recommendation is 'to be aware of cross-disciplinary collaborative work.' Biobuilding components address multiple domains with the collaboration of multiple actors in the development and integration process. Therefore, architects need to be aware of this necessity to collaborate with professionals from multiple disciplines.

Moreover, an important recommendation is 'to be aware of the bonds of biobuilding components with the concepts of nature and technology.' Biobuilding components do not just indicate a new material technology or an upgraded technology. They represent niche innovations in the emerging technological transition towards biobuilding design and a biophilic environment. Therefore, they suggest a radical way of thinking towards the current system of views on product development and construction technology as well. Accordingly, architects should consider this prospected system change and apply their designs.

Furthermore, it is essential to recommend architects 'to be aware of the ambiguity and complexity in the terminology.' Indeed, in cross-disciplinary studies, the terminology often seems to be a pitfall. For biobuilding components and their integration into building design, the ambiguity and complexity in terminology indicate both a potential and a problem. The variety of related concepts, terms, and definitions is one of the critical subjects that leads us to underline the multi-

perspective impacts of biobuilding components through bonding with multiple studies, disciplines, and domains. Simultaneously, this variety hampers the detection of biobuilding components to research in the building design domain. Current examples of biobuilding components are discussed under distinct terms and concepts such as smart, sustainability, and biomimicry. To address the incorporation of living organisms under these broad concepts hampers the expression of the novelty of biobuilding components. Architects need to be aware of this versatility in terminology and be careful about using certain concepts and terms to determine their projects and studies.

One of the critical recommendations for architects is ‘to be aware of the bridges between industrial and building design.’ The different perspectives on industrial design and building design creates a gap because of various design focuses. However, through design practice, methods, and guidelines, there is also a close relationship between industrial and building design. In this regard, the design studio experiment underlines the importance of the design approach towards this gap between different disciplines. The design experiments in the building design studio reveal the ability of architecture students to integrate biobuilding components into building design.

Meanwhile, their design approach towards different design domains plays a critical role in the integration of biobuilding components into building design. Moreover, interviews show the design process of the development of biobuilding components within an iterative structure. Biobuilding components play a conjunctive role between industrial design and building design, while they can be integrated into building design after being translated into the building design domain. Therefore, architects should be aware of these bridges for developing their design parallel to the diffusion of technology.

Furthermore, it is crucial to recommend architects ‘to be aware of the multiple designs and integration strategies.’ Architects can apply multiple design strategies to integrate biobuilding components into their designs. Despite its limitations, the interviews with practitioners provide insights on integration strategies by

exemplifying them as ‘interaction,’ ‘infiltration,’ and ‘adaptation’ of biobuilding components into building design. What is crucial here is that architects can develop other design strategies through the multi-perspective impacts of biobuilding components.

7.2.2 Recommendations for Future Research and Practice

By presenting the critical aspects of biobuilding components in building design, this thesis provides insights on further research and practice in the building design domain. These recommendations in this part elucidate the possible directions of future studies on biobuilding components in building design.

Within this emerging field, I believe it is necessary to evaluate the relationships between building design and other fields, such as healthcare, fashion and textile, and many more. In this way, these studies might lead us to understand the dialogue between building design and other domains, such as the emerging number of biobuilding components related to healthcare. By these means, further research and practice can specifically focus on the particular impacts of specific biobuilding examples in building design and could provide insights accordingly. In addition, further studies are necessary to focus on biobuilding components from the material level by elaborating on their tectonic meanings for building design.

In further studies, systematic literature reviews in accordance with the number of studies on this topic can provide an explicit and comprehensive overview. By the guidance of this different and systematic data collection, examining various biobuilding components, further research and practice can specifically focus on limited examples by exploring them through a different methodology, thereby using varying approaches of research and methods.

Moreover, further studies shall focus on the agency aspect of the biobuilding component and the designer or architect in the proposed new approach to architecture and design. This way of approaching this subject will lead us to find more answers on design thinking in architecture.

I suggest the repetition of the design experiments with different actors, thereby presenting further results. The protocol analysis method seems to achieve in depth insights to evaluate the building design process, yet other methods can be applied and discussed. This design experiment embraces biobuilding components as a toolset by giving certain examples to students and expecting them to integrate these into their designs, thereby understanding the design approach and the mindset. However, this could also stay in the toolset by means of students experiencing biobuilding components and their potentials and integrating them by observing, testing, and experiencing their designs. Moreover, the argument of the critical meaning of biobuilding components for architectural education is also underpinned within the interviews. Since practitioners consistently underline the lack of architects' knowledge of biobuilding components, it is necessary to discuss biobuilding components as part of architectural education. Therefore, this thesis underlines the need for further research and practice on biobuilding components in architectural education, which would be a fruitful area for further work.

I also suggest the repetition of the interview study in different contexts, which might lead us to find different results. With the guidance of this thesis and the integration of biobuilding components into building design over time, further studies can apply quantitative research such as surveys with a larger audience and more specific subjects such as user experiences.

In addition to all this, multiple methods and multiple analytical and assistive tools are utilized to achieve the aim of this research. Surely, I also suggest conducting studies by applying other methods, also quantitative methods, in future studies. That's because current methods, along with classifications and categorizations, might seem insufficient to evaluate biobuilding components properly.

7.3 Closing Remarks

The study concludes with hypothetical deductions in relation to the expected architectural and societal impacts of biobuilding components. These hypothetical

deductions indicate my own opinions, understandings, attitude, and future prospects derived from the findings of this study.

In my opinion, building components could be replaced with biobuilding components in the near future, even in the next one and two decades relying on the increasing number of products in the current market. Hereby, what is essential is that biobuilding components lead us to 're-think' current ways of building design and construction while providing solutions by unifying living and manufactured components for ongoing environmental degradation and altering the demands of contemporary society.

From my point of view, this study underlines that biobuilding components create a link between the smart and sustainable built environment and building design. And this link brings new ways of thinking towards the production of any technology. In fact, sustainability and smartness are underway to become the 'added values' of biobuilding components. In this way, the ongoing sustainability and smartness debates in architecture could be introduced with a new design approach and praxis as 'biobuilding design.' Circular system thinking is one of the key benefits of biobuilding components that would not be achieved soon entirely but furtherly advanced. By bringing a new way of possibilities in design thinking and production systems, biobuilding components would play a critical role in solving environmental degradation, especially by replacing growth with production.

In addition to the practical meanings of biobuilding components, their possible contributions to the built environment could also be centered around the philosophical meanings of biobuilding components in relation to their historical and phenomenological meanings. By looking through the historical meanings of biobuilding components, it is possible to claim that different meanings will be added through the interpretation of the concept of nature and technology in the near future. By this means, ideologically, architects could embrace biobuilding components to emphasize their conceptual way of thinking into their designs by

empowering the relationships between nature, humans, and buildings in a philosophical manner.

In the current academic and popular discussions, the incorporation of living organisms might sound new and innovative; even intentionally, this praxis can be presented that way. However, based on this thesis, especially through the historical meanings of biobuilding components, I reveal that this is a misassumption. Indeed, the motivation of designing with living organisms has always remained at the core of the building and architectural space production. In my opinion, in the near future, livability, growth, and temporality would become disciplinary conditions of production of space and building design. Accordingly, design concepts would be centered around favoring these conditions; thereby, building design would be shaped accordingly.

To my way of thinking, the philosophical meanings of biobuilding design would be empowered by various practical benefits like energy efficiency, waste management, human body enhancement, While these practical benefits urge architects to develop their designs accordingly, the integration of biobuilding components in buildings is expected to bring societal impacts. The integration of biobuilding components can accelerate the process of biobuilding components becoming part of our daily lives. As underpinned by practitioners, this might strengthen the relationships between humans, technology, and nature. At this point, this motivates architects to include more biobuilding components into their designs. In the meanwhile, this represents a long-term process. Therefore, the infiltration of biobuilding components might transform buildings into biobuildings without being noticed by society. By the time buildings have become biobuildings, biobuilding components would already be accepted as conventional products. Biobuilding components have already been infiltrating into buildings in various ways, such as wearable technologies, living wall systems, encouraging architects to play more active roles to control and lead this integration by responding to the demands of highly developed Western society.

Likewise, the practitioners suggest their integration into society slowly but gradually. From that point, it is possible to say that biobuilding components are expected to be developed further by appealing to society's demands. In other words, this interrelation of living and manufactured components will be shaped through the demands of society. They can be adapted, redesigned, combined with different techniques and materials as well. For example, the aesthetical concerns of biobuilding components could determine if living organisms should be noticeable or completely fused into technology. In my view, this could change current design aesthetics and concerns of building design.

Biobuilding components' technological meanings will follow two main paths in the near future. The principles of nature and manufacturing can meet each other without denying their essential differences. Therefore, from my viewpoint, it seems possible to see this interrelation turn into a unity by means of merging the concepts of nature and technology in the near future. In the meantime, these essential differences between living and manufactured components could be overcome by technology. By this means, everything could be embraced as technological while nature could be fused into technology. But in both cases, this might be embraced into building design as a new approach or concept.

I believe technological meanings of biobuilding components will trigger societal changes leading the built environment to transform into a biophilic built environment. In my opinion, the agency role in biobuilding components also increases the technological integration level inside any building in the future. As discussed through the interviews, these technologies basically encourage and support people to have more time-agency on their decisions and what they do. Understanding this approach will let designers or architects creating more complex, maintenance-free, circular, and sustainable projects and at the same appealing users' needs and requirements.

Regarding societal changes, I believe that through the integration of biobuilding components, humans can develop new behaviors and relationships with architectural space. For example, biobuilding components present living, growing,

and also dying materials and products. This temporality can affect humans' daily routines, habits, and lifestyles compared to the stability of buildings' conventional understandings. Human dimensions are stable, so there are specific limitations to architectural spaces. However, new technologies can always bring further possibilities in which humans and buildings have dynamic relationships, especially wearable technologies. For example, wearable technologies already provide control and guide certain systems and objects in architectural space, and these can be increased in the near future, such as enabling advanced cleaning, organizing, even replacing and transforming abilities. Architectural spaces can alter the adjustment of suitable human body temperature, preferable interior designs, can play music and present entertainment activities, even release desirable smells. In that sense, their extension to the body might change common abilities and senses, thereby opening up new design possibilities.

All in all, I prospect that building design to be placed in between living and manufactured worlds in the near future. Because, from my point of view, through its multi-perspective impact, biobuilding components will help to reach circular system thinking in building design and construction through innovative material technology, product development systems. This will mean that buildings will contain living organisms, including algae, bacteria, plants, mycelium. Thus, humans, users, will have more connected and interacted relationships with living organisms in building environment where the place will be more dynamic through adapted temporality. This connected relationship could be in the way of current predictions created by the practitioners, but more unexpected relationships are also possible considering the uncertainty of designing with living organisms. In the meanwhile, humans will be a part of a building as well. The building environment will be surrounded by more and more biobuilding components easing daily life tasks, communicating with humans, and answering their needs. While the distinctions between living and manufactured components are fading, I believe technology becomes more 'alive.'

At this juncture, even though material scientists and product designers develop biobuilding components, and engineers and programmers write the code,

architects have the responsibility of integrating them into building design, mediating stakeholders, and considering users' needs and benefits. Therefore, architects' approach to these technologies majorly influences our surroundings as well as our daily lives. In line with their approach, the roles of the architects will also be altered through the changes in daily activities and everyday life. Therefore, I would like to conclude with a final emphasis that architects should be urged to empower their knowledge on biobuilding components and how to integrate them into their designs.

Along with the integration of biobuilding components, an ongoing change in building design is intensively tangible and expected. Within this change, one of the most important added values of this research is to address the critical connections between product and building design, theoretical and practical aspects of buildings and architectural theory behind the current desire toward designing with living organisms in building design.

REFERENCES

- AFASE Solar House / Scottsdale. (n.d.). Retrieved May 11, 2020, from <https://esotericsurvey.blogspot.com/2018/04/afase-solar-house-scottsdale.html>
- Akipek, F. Ö. (2019). Common-action Gardens: Performative and Parametric Prototypes. In F. Bianconi and M. Filippucci (eds.) (Ed.), *Digital Wood Design, Lecture Notes in Civil Engineering* (Vol. 24, pp. 1421–1438). Springer. <https://doi.org/10.1007/978-3-030-03676-8>
- Alam, M. R., Reaz, M. B. I., and Ali, M. A. M. (2012). A Review of Smart Homes—Past, Present, and Future. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*, 42(6), 1190–1203. <https://doi.org/10.1109/TSMCC.2012.2189204>
- Aldersey-Williams, H. (2003). *Zoomorphic: new animal architecture*. London: Laurence King.
- Aldrich, F. (2003). Smart homes: past, present and future. In R. Harper (Ed.), *Inside the smart home* (pp. 17–39). London: Springer-Verlag. <https://doi.org/10.1007/b97527>
- Alhojailan, M. I., and Ibrahim, M. (2012). Thematic Analysis : A Critical Review of Its Process and Evaluation. *WEI International European AcademicConference Proceedings*, 1(2011), 8–21.
- Alter, L. (2016). A look at Alison Smithson's 1956 House of the Future. Retrieved May 10, 2020, from <https://www.treehugger.com/interior-design/look-alison-smithsons-1956-house-future.html>
- Anderson. (1998). Truth and objectivity in perspectivism. *Synthese*, 115(1), 1–32. <https://doi.org/10.1023/A:1004984312166>
- Anderson, J. G. (2007). Social, ethical and legal barriers to E-health. *International Journal of Medical Informatics*, 76(5–6), 480–483. <https://doi.org/10.1016/J.IJMEDINF.2006.09.016>
- Angelini, L., Khaled, O. A., Caon, M., Mugellini, E., and Lalanne, D. (2014). Hugginess. In *Proceedings of the 2014 ACM International Symposium on Wearable Computers Adjunct Program - ISWC '14 Adjunct* (pp. 155–162). New York: ACM Press. <https://doi.org/10.1145/2641248.2641356>
- Aouf, R. S. (2017a). Controllable Third Thumb lets wearers extend their natural abilities. Retrieved May 10, 2020, from https://www.dezeen.com/2017/07/05/controllable-third-thumb-lets-wearers-extend-natural-abilities-royal-college-art-design-graduates/?li_source=LI&li_medium=bottom_block_1

- Aouf, R. S. (2017b). Scroll ring by RCA graduate Nat Martin lets users easily interact with augmented reality. Retrieved May 10, 2020, from <https://www.dezeen.com/2017/07/25/rca-graduate-scroll-ring-lets-users-easily-interact-with-augmented-reality-design-technology/>
- Appels, F. V. W., Camere, S., Montalti, M., Karana, E., Jansen, K. M. B., Dijksterhuis, J., ... Wösten, H. A. B. (2019). Fabrication factors influencing mechanical, moisture- and water-related properties of mycelium-based composites. *Materials & Design*, 161, 64–71. <https://doi.org/10.1016/j.matdes.2018.11.027>
- Arbona, J., Greden, L., and Joachim, M. (2003). Nature's Technology: The Fab Tree Hab House. *Thresholds*, 26, 48–53. https://doi.org/10.1162/thld_a_00359
- Armstrong, R. (2010). Self-Repairing Architecture. Retrieved from <https://www.nextnature.net/2010/06/self-repairing-architecture/>
- Armstrong, R. (2014). Designing with protocells: Applications of a novel technical platform. *Life*, 4(3), 457–490. <https://doi.org/10.3390/life4030457>
- Armstrong, R. (2015). *Vibrant Architecture, Matter as a CoDesigner of Living Structures*. (Monika Michalowicz; & Davina Jackson, Eds.). Berlin: De Gruyter open ltd.
- Armstrong, R. (2016). Embodied intelligence: changing expectations in building performance. *Intelligent Buildings International*, 8(1), 4–23. <https://doi.org/10.1080/17508975.2015.1050581>
- Arunvivek, J., Srinath, S., and Balamurugan, M. S. (2015). Framework Development in Home Automation to Provide Control and Security for Home Automated Devices. *Indian Journal of Science and Technology*, 8(19), 1–10. <https://doi.org/10.17485/ijst/2015/v8i19/76863>
- Atkinson R, and J, F. (2001). Accessing Hidden and Hard-to-Reach Populations: Snowball Research Strategies. *Social Research Update*, 33(April). Retrieved from <http://sru.soc.surrey.ac.uk/SRU33.html>
- Attride-Stirling, J. (2001). Thematic networks: an analytic tool for qualitative research. *Qualitative Research*, 1(3), 385–405. <https://doi.org/10.1177/146879410100100307>
- Atwell, J. E. (1981). Nietzsche's Perspectivism. *The Southern Journal of Philosophy*, 19(2), 157–170. <https://doi.org/10.1111/j.2041-6962.1981.tb01421.x>
- Aziz, M. S., and El sherif, A. Y. (2015). Biomimicry as an approach for bio-inspired structure with the aid of computation. *Alexandria Engineering Journal*, 55(1), 707–714. <https://doi.org/10.1016/j.aej.2015.10.015>
- Bach-y-Rita, P., and W. Kercel, S. (2003). Sensory substitution and the human-machine interface. *Trends in Cognitive Sciences*, 7(12), 541–546. <https://doi.org/10.1016/j.tics.2003.10.013>

- Bader, C., Patrick, W. G., Kolb, D., Hays, S. G., Keating, S., Sharma, S., ... Oxman, N. (2016). Grown, Printed, and Biologically Augmented: An Additively Manufactured Microfluidic Wearable, Functionally Templated for Synthetic Microbes. *3D Printing and Additive Manufacturing*, 3(2), 79–89. <https://doi.org/10.1089/3dp.2016.0027>
- Balta-Ozkan, N., Davidson, R., Bicket, M., and Whitmarsh, L. (2013). The development of smart homes market in the UK. *Energy*, 60, 361–372. <https://doi.org/10.1016/j.energy.2013.08.004>
- Beard, M. R. (2017). Re-thinking oral history—a study of narrative performance. *Rethinking History*, 21(4), 529–548. <https://doi.org/10.1080/13642529.2017.1333285>
- Bedau, M. A. (2009). Living technology today and tomorrow. *Technoetic Arts*, 7(2), 199–206. <https://doi.org/10.1386/tear.7.2.199/1>
- Benyus, J. (2012). A Biomimicry Primer: Resource handbook, 10.
- Benyus, J. M. (1997). *Biomimicry: Innovation Inspired by Nature*. New York: Quill–William Morrow.
- Berkhout, F., Smith, A., and Stirling, A. (2004). Socio-technological Regimes and Transition Contexts. In *System Innovation and the Transition to Sustainability* (Vol. 44, pp. 48–75). Edward Elgar Publishing. <https://doi.org/10.4337/9781845423421.00013>
- Bernabei, R., and Power, J. (2016). Living Designs. In N. F. Lepora, A. Mura, M. Mangan, P. F. M. J. Verschure, M. Desmulliez, & T. J. Prescott (Eds.), *Living Machines 2016: Biomimetic and Biohybrid Systems* (Vol. 9793, pp. 40–47). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-42417-0_4
- Berry, J. N. (2005). Perspectivism as "Ephexis" in Interpretation. *Philosophical Topics*, 33(2), 19–44.
- Between Air installation explores the relation between nature and technology. (n.d.). Retrieved January 5, 2019, from <http://www.ecochunk.com/2092/2012/08/30/between-air-installation-explores-the-relation-between-nature-and-technology/>
- Bhushan, B. (2009). Biomimetics: Lessons from Nature - an overview. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 367(1893), 1445–1486. <https://doi.org/10.1098/rsta.2009.0011>
- Biernacki, P., and Waldorf, D. (1981). Snowball Sampling: Problems and Techniques of Chain Referral Sampling. *Sociological Methods & Research*, 10(2), 141–163. <https://doi.org/10.1177/004912418101000205>
- Bionic Chandelier. (2017). Retrieved July 4, 2019, from <https://www.julianmelchiorri.com/Bionic-Chandelier>

- Birkeland, J. L. (2015). Prospects for nature in proposals for urban growth. *Smart and Sustainable Built Environment*, 4(3), 310–314. <https://doi.org/10.1108/SASBE-10-2015-0033>
- Blumenberg, H., and Wertz, A. (2000). “Imitation of Nature”: Toward A Prehistory of the Idea of the Creative Being. *Qui Parle*, 12(The End of Nature (Spring/Summer 2000)), 17–54. Retrieved from <https://www.jstor.org/stable/20686110>
- Bonenberg, A. (2015). Architecture of exhibition buildings as a tool for strengthening the image of countries and nations – digitally modelled planes and forms in the architecture of Expo 2015 in Milan. *Technological Transactions*, 8(A), 25–31.
- Bookchin, M. (1996). *Toward an Ecological Society*. Montréal: Black Rose Books.
- Bowden, S., and Offer, A. (1994). Household appliances and the use of time: the United States and Britain since the 1920s. *The Economic History Review*, 4(47), 725–748.
- Boyatzis, R. E. (1998). *Transforming qualitative information: Thematic analysis and code development*. Thousand Oaks, California: Sage Publications, Inc.
- Brand, S. (1994). *How Buildings Learn: What Happens After They're Built*. New York: Viking.
- Braun, V., and Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp063oa>
- Brett, D. (1995). *The Grammar of Ornament of Owen Jones in 1859*.
- Buchanan, A. (2007). Energy and CO 2 Advantages of Wood for Sustainable Buildings Sustainability. *Nz Timber Design Journal*, 15(1), 11–21.
- Caglar, N., and Uludag, Z. S. (2006). Architectural design education: Designing a library, public communication and information center in the manufacturing zone of Central Eskişehir Turkey, a case study. *International Journal of Art and Design Education*, 25(2), 231–240. <https://doi.org/10.1111/j.1476-8070.2006.00487.x>
- Camere, S., and Karana, E. (2017). Growing materials for product design. *EKSIG 2017: Alive.Active.Adaptive*, (August), 101–115.
- Caperna, A. (2017). Biophilic Design. *Journal of Biourbanism*, VI(March). Retrieved from <https://derby.openrepository.com/handle/10545/294089>
- Cecchini, C. (2017). Bioplastics made from upcycled food waste. Prospects for their use in the field of design. *The Design Journal*, 20(sup1), S1596–S1610. <https://doi.org/10.1080/14606925.2017.1352684>
- Chan, M., Campo, E., Estève, D., and Fourniols, J.-Y. (2009). Smart homes — Current features and future perspectives. *Maturitas*, 64(2), 90–97. <https://doi.org/10.1016/j.maturitas.2009.07.014>

- Charara, S. (2016). This smart baby hat could save newborn lives in Uganda. Retrieved May 10, 2020, from <https://www.wareable.com/smart-clothing/neopenda-smart-baby-hat-save-newborn-lives-uganda-2599>
- Ciravoglu, A. (2004). A Critical Approach Towards the Idea (L) of Sustainable Architecture. In *Plea2004 - The 21th Conference on Passive and Low Energy Architecture*. (pp. 19–22). Eindhoven.
- Ciravoğlu, A. (2008). Sürdürülebilir Mimarlık: Eskimiş Kavrayışlarla Yeni Söylemler Arasında (Sustainable Architecture in between Worn Comprehensions and New Discourses). *Mimarlık Dergisi*, (340), 13–16.
- Çıkış, Ş., and Çil, E. (2009). Problematization of assessment in the architectural design education: First year as a case study. *Procedia Social and Behavioral Sciences*, 1(1), 2103–2110. <https://doi.org/10.1016/j.sbspro.2009.01.369>
- Clarke, V., and Braun, V. (2013). Teaching thematic analysis : Overcoming challenges and developing strategies for effective learning. *The Psychologist*, 26(2), 120–123.
- Clarke, V., and Braun, V. (2018). Using thematic analysis in counselling and psychotherapy research: A critical reflection. *Counselling and Psychotherapy Research*, 18(2), 107–110. <https://doi.org/10.1002/capr.12165>
- Clegg, A., Yu, W., Erickson, Z., Tan, J., Liu, C. K., and Turk, G. (2017). Learning to navigate cloth using haptics. In *2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)* (pp. 2799–2805). Vancouver: IEEE. <https://doi.org/10.1109/IROS.2017.8206110>
- Collingwood, R. . (1945). *The Idea of Nature*. Oxford: Clarendon Press.
- Computer programmer from Finland has lost finger replaced with USB drive. (2009). Retrieved May 10, 2020, from <https://www.telegraph.co.uk/news/newstopics/howaboutthat/5005118/Computer-programmer-from-Finland-has-lost-finger-replaced-with-USB-drive.html>
- Cook, D. J., and Das, S. K. (2007). How smart are our environments? An updated look at the state of the art. *Pervasive and Mobile Computing*, 3(2), 53–73. <https://doi.org/10.1016/j.pmcj.2006.12.001>
- Cowan, R. S. (1983). *More Work for Mother: The Ironies of Household Technology from the Open Hearth to the Microwave*. New York: Basic Books, Inc.
- Cross, N. (2001). Design cognition : results from protocol and other empirical studies of design activity Book Chapter Design Cognition : *Design Knowing and Learning: Cognition in Design Education*, 79–103. <https://doi.org/10.1162/074793601750357196>
- Dalsgaard, C., and Sterrett, R. (2014). White paper on smart textile garments and devices : a market overview of smart textile wearable technologies. In *Market Opportunities for Smart Textiles 2014* (pp. 1–11). Aarhus. Retrieved from <http://www.innovationintextiles.com/uploads/2772/Ohmatex>

- Daly Bezerra de Melo, G. (2012). Nature and culture intertwined or redefined? On the challenges of cultural primatology and sociocultural anthropology. *Revue de Primatologie*, (4), 1–41. <https://doi.org/10.4000/primatologie.1020>
- Davies, C. (2011). *Thinking About Architecture: An Introduction to Architectural Theory*. London: Laurence King.
- Dawid, H., Decker, R., Hermann, T., Jahnke, H., Klat, W., König, R., and Stummer, C. (2017). Management science in the era of smart consumer products: challenges and research perspectives. *Central European Journal of Operations Research*, 25(1), 203–230. <https://doi.org/10.1007/s10100-016-0436-9>
- Derringer, J. (2018). Bacterioptica Chandelier by MADLAB - Design Milk. Retrieved February 10, 2019, from <https://design-milk.com/bacterioptica-chandelier-by-madlab/>
- Descola, P., Lloyd, J., and Sahlins, M. (2014). *Beyond Nature and Culture* (Reprint ed). Chicago: The University of Chicago Press.
- Desolda, G., Ardito, C., and Matera, M. (2017). Empowering End Users to Customize their Smart Environments: Model, Composition Paradigms, and Domain-Specific Tools. *ACM Transactions on Computer-Human Interaction*, 24(2), 1–52. <https://doi.org/10.1145/3057859>
- Deuerling, S., Kugler, S., Klotz, M., Zollfrank, C., and Van Opdenbosch, D. (2018). A Perspective on Bio-Mediated Material Structuring. *Advanced Materials*, 30(19), 1–18. <https://doi.org/10.1002/adma.201703656>
- Dorst, K., and Dijkhuis, J. (1995). Comparing paradigms for describing design activity. *Design Studies*, 16(2), 261–274. [https://doi.org/10.1016/0142-694X\(94\)00012-3](https://doi.org/10.1016/0142-694X(94)00012-3)
- Duffy, F. (1990). Measuring building performance. *Facilities*, 8(5), 17–20. <https://doi.org/10.1108/eum0000000002112>
- Dunne, A., and Raby, F. (2013). *Speculative Everything: Design, Fiction, and Social Dreaming*. Cambridge: MIT Press.
- Dysart, J. (2017). Smart Earbuds. *The Hearing Journal*, 70(3), 30. <https://doi.org/10.1097/01.HJ.0000513790.21557.fc>
- Ecologic Studio. (2019). Retrieved May 10, 2020, from <http://www.ecologicstudio.com/v2/projects.php?idsubcat=59>
- Ehrenhard, M., Kijl, B., and Nieuwenhuis, L. (2014). Market adoption barriers of multi-stakeholder technology: Smart homes for the aging population. *Technological Forecasting and Social Change*, 89, 306–315. <https://doi.org/10.1016/j.techfore.2014.08.002>
- Enger, E., and Smith, B. (2006). *Environmental Science: A Study of Interrelationship*. McGraw-Hill Higher Education.

- Ericsson, K. A. (1987). Theoretical Implications from Protocol Analysis on Testing and Measurement. In R. R. Ronning, J. A. Glover, J. C. Conoley, & J. C. Witt (Eds.), *The Influence of Cognitive Psychology on Testing* (pp. 191–226). New Jersey.
- Eryildiz, S., and Mezini, L. (2012). Bioarchitecture - Inspirations from nature. *Gazi University Journal of Science*, 25(1), 263–268.
- Eu, M. (2019). The buildings are alive: in biology, designers and architects seek answers. *Smart Planet*, (6360631), 1–31. Retrieved from <http://www.smartplanet.com/blog/pure-genius/the-buildings-are-alive-in-biology-designers-and-architects-seek-answers/7310>
- Evans, C., and Lewis, J. (2017). Analysing Semi-Structured Interviews Using Thematic Analysis: Exploring Voluntary Civic Participation Among Adults. *Analysing Semi-Structured Interviews Using Thematic Analysis: Exploring Voluntary Civic Participation Among Adults*. <https://doi.org/10.4135/9781526439284>
- Falk, W. W., and Lyson, T. A. (1988). *High tech, low tech, no tech: recent industrial and occupational change in the South*. New York: SUNY Press.
- Falke, O., Rukzio, E., Dietz, U., Holleis, P., and Albrecht, S. (2007). *Mobile services for near field communication*. University of Munich Department of Computer Science Media Informatics Group. Retrieved from <http://www.mmi.ifi.lmu.de/pubdb/publications/pub/falke2007mobileServicesTR/falke2007mobileServicesTR.pdf>
- Farmer, J. (1999). *Green Shift: Changing Attitudes in Architecture to the Natural World*. (K. Richardson, Ed.) (2nd ed.). Oxford: Architectural Press.
- Faugier, J., and Sargeant, M. (1997). Sampling hard to reach populations. *Journal of Advanced Nursing*, 26(4), 790–797. <https://doi.org/10.1046/j.1365-2648.1997.00371.x>
- Federer, N. L. (2015). The use of oral history and narrative research in broadening the historical foundation of the agricultural communication field. *ProQuest Dissertations and Thesis*, 203. Retrieved from https://search.proquest.com/docview/1709257607?accountid=26642%0Ahttp://link.periodicos.capes.gov.br/sfxlcl41?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:dissertation&genre=dissertations+%26+theses&sid=ProQ:ProQuest+Dissertations+%26+Theses+Globa
- Fereday, J., and Muir-Cochrane, E. (2006). Demonstrating Rigor Using Thematic Analysis: A Hybrid Approach of Inductive and Deductive Coding and Theme Development. *International Journal of Qualitative Methods*, 5(1), 80–92. <https://doi.org/10.1177/160940690600500107>
- Flick, U. (2009). *An introduction to qualitative research* (6th ed.). London: SAGE Publishing.

- Forgacs, G., and Sun, W. (Eds.). (2013). *Biofabrication: Micro- and Nanofabrication, Printing, Patterning and Assemblies (Micro and Nano Technologies)* (1st ed.). Norwich, NY: Elsevier.
- Forty, A. (1986). *Objects of desire: Design and Society Since 1750*. London: Thames and Hudson.
- Fox, J. L., O'Grady, C. J., Scanlan, A. T., Sargent, C., and Stanton, R. (2019). Validity of the Polar Team Pro Sensor for measuring speed and distance indoors. *Journal of Science and Medicine in Sport*, 22(11), 1260–1265. <https://doi.org/10.1016/j.jsams.2019.06.012>
- Frearson, A. (2017). Fungus used to build arching pavilion in Kerala. Retrieved April 25, 2020, from <https://www.dezeen.com/2017/08/26/shell-mycelium-fungus-pavilion-beetles-3-3-yassin-arredia-design-kerala-india/>
- Frearson, Amy. (2014). Bioluminescent lamp by Teresa van Dongen glows blue with octopus bacteria. Retrieved May 12, 2020, from <https://www.dezeen.com/2014/09/26/bioluminescent-glowing-lamp-ambio-teresa-van-dongen-octopus-bacteria/>
- Freire, R., Honnet, C., and Strohmeier, P. (2017). Second Skin. In *Proceedings of the Tenth International Conference on Tangible, Embedded, and Embodied Interaction - TEI '17* (pp. 653–658). New York, New York, USA: ACM Press. <https://doi.org/10.1145/3024969.3025054>
- Gale, B. (2011a). The potential of living willow structures in the landscape. *ProQuest Dissertations and Theses*, 50. Retrieved from http://libresources.sait.ab.ca/login?url=https://search.proquest.com/docview/1030283815?accountid=13652%0Ahttp://resolver.ebscohost.com/openssl?url?ctx_ver=Z39.88-2004&ctx_enc=info:ofi/enc:UTF-8&rft_id=info:sid/ProQuest+Dissertations+%26+Theses+Global&rft_val
- Gale, B. (2011b). *The potential of living willow structures in the landscape*. State University of New York College. Retrieved from http://libresources.sait.ab.ca/login?url=https://search.proquest.com/docview/1030283815?accountid=13652%0Ahttp://resolver.ebscohost.com/openssl?url?ctx_ver=Z39.88-2004&ctx_enc=info:ofi/enc:UTF-8&rft_id=info:sid/ProQuest+Dissertations+%26+Theses+Global&rft_val
- Gann, D., Barlow, J., and Venables, T. (1999). *Digital Futures: Making Homes Smarter*. Coventry: Chartered Institute of Housing. Retrieved from <https://www.jrf.org.uk/sites/default/files/jrf/migrated/files/1900396149.pdf>
- Gatland, K., W., and Jefferis, D. (1979). *World of the Future: Future Cities*. Usborne Publishing Ltd.
- Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research Policy*, 31(8–9), 1257–1274. [https://doi.org/10.1016/S0048-7333\(02\)00062-8](https://doi.org/10.1016/S0048-7333(02)00062-8)

- Geels, F. W., and Schot, J. (2007). Typology of sociotechnical transition pathways. *Research Policy*, 36(3), 399–417.
<https://doi.org/10.1016/j.respol.2007.01.003>
- Gieselmann, R. (1996). Mimaride Üslup Arayışı. In *Mimari Akımlar I* (pp. 10–12). Istanbul: Yem.
- Gilmour, J. C. (1990). Perspectivism and Postmodern Criticism. *The Monist*, 73(2), 233–246. Retrieved from <http://www.jstor.org/stable/27903183>
- Ginsberg, A. D., Calvert, J., Schyfter, P., Elfick, A., and Endy, D. (2014). *Synthetic Aesthetics: Investigating Synthetic Biology's Designs on Nature*. (A. D. Ginsberg, Ed.) (Reprint ed). Cambridge: MIT Press.
- Gissen, D. (2012). *Subnature: Architecture's Other Environments*. New York: Princeton Architectural Press.
- Glacken, C. J. (1967). *Traces on the Rhodian Shore. Nature and Culture in Western Thought from Ancient Times to the End of the Eighteenth Century*. Berkeley: University of California Press.
- Gössel, P., and Leuthauser, G. (1991). *Architecture in the Twentieth Century*. Cologne: Benedikt Taschen.
- Gosselin, A., Blanchet, P., Lehoux, N., and Cimon, Y. (2016). Main Motivations and Barriers for Using Wood in Multi-Story and Non-Residential Construction Projects. *BioResources*, 12(1), 546–570.
<https://doi.org/10.15376/biores.12.1.546-570>
- Grady, J. (1955). Nature and the Art Nouveau. *The Art Bulletin*, 37(3), 187–192.
- Green Wall - Cloud Garden - Circular wall system. (2018). Retrieved May 20, 2020, from <https://www.cloudgarden.nl/en/product/green-wall/>
- Grose, T. (2014). Natural Glow. *ASEE Prism*, 23(7), 16.
- Gruber, P. (2011). *Biomimetics in Architecture*. Vienna: Springer Vienna.
<https://doi.org/10.1007/978-3-7091-0332-6>
- Gruber, P. (2013). Biornametics — Architecture Inspired by Natural Patterns. In B. Imhof & P. Gruber (Eds.), *What is the Architect Doing in the Jungle? Biornametics* (Angewandte). Vienna: Springer Vienna.
<https://doi.org/10.1007/978-3-7091-1529-9>
- Gruber, P., and Imhof, B. (2017). Patterns of Growth—Biomimetics and Architectural Design. *Buildings*, 7(2), 32.
<https://doi.org/10.3390/buildings7020032>
- Gruber, P., and Jeronimidis, G. (2012). Has biomimetics arrived in architecture? *Bioinspiration & Biomimetics*, 7(1), 010201. <https://doi.org/10.1088/1748-3182/7/1/010201>

- Gruber, P., McGinley, T., and Muehlbauer, M. (2018). Towards an Agile Biodigital Architecture: Supporting a Dynamic Evolutionary and Developmental View of Architecture. In *Interdisciplinary Expansions in Engineering and Design With the Power of Biomimicry*. InTech. <https://doi.org/10.5772/intechopen.72916>
- Guest, G., Bunce, A., and Johnson, L. (2006). How Many Interviews Are Enough? *Field Methods*, 18(1), 59–82. <https://doi.org/10.1177/1525822X05279903>
- Guided Growth When the ‘built’ becomes the ‘born.’ (n.d.). Retrieved December 12, 2020, from <https://nextnature.net/magazine/themes/guided-growth>
- Guy, S. (2010). Introduction: Whither “Earthly” Architectures: Constructing Sustainability. In H. Crysler, C. G., Cairns, S., Heynen (Ed.), *The SAGE Handbook of Architectural Theory* (pp. 555–572). London: Sage Publication.
- Hagan, S. (2001). *Taking Shape - A new contract between architecture and nature*. Architectural Press. Woburn: Elsevier.
- Hahn, J. (2019). Bio-ID Lab designs DIY algae-infused tiles that can extract toxic dyes from water. Retrieved April 30, 2020, from <https://www.dezeen.com/2019/09/21/bio-id-lab-indus-algae-tiles-water/>
- Haila, Y. (2000). Beyond the Nature-Culture Dualism. *Biology and Philosophy*, 15, 155–175.
- Hammink, C., and Mohammadi, M. (2018). Research Methods for the Design of Smart Environments : a Comparison between Two Types of Buildings. In *Proceedings IFKAD 2018* (pp. 1122–1136). Delft.
- Hammink, Coosje, Moor, N., and Mohammadi, M. (2019). A Systematic Literature Review of Persuasive Architectural Interventions for Stimulating Health Behaviour. *Facilities*, 37(11–12), 743–761. <https://doi.org/10.1108/F-07-2017-0065>
- Haraway, D. J. (2015). *Simians, Cyborgs, and Women: The Reinvention of Nature* (1th ed.). London: Routledge.
- Harper, R. (2003). *Inside the Smart Home*. Springer-Verlag London (Vol. 5). <https://doi.org/10.1057/palgrave.im.4340249>
- Heinrich, M. K., Von Mammen, S., Hofstadler, D. N., Wahby, M., Zahadat, P., Skrzypczak, T., ... Hamann, H. (2019). Constructing living buildings: A review of relevant technologies for a novel application of biohybrid robotics. *Journal of the Royal Society Interface*, 16(156). <https://doi.org/10.1098/rsif.2019.0238>
- Heisel, F., Lee, J., Schlesier, K., Rippmann, M., Saeidi, N., Javadian, A., ... Hebel, D. E. Design, Cultivation and Application of Load-Bearing Mycelium Components: The MycoTree at the 2017 Seoul Biennale of Architecture and Urbanism. *International Journal of Sustainable Energy Development (IJSED)*, 6(1), 296–303. <https://doi.org/10.20533/ijsed.2046.3707.2017.0039>

- Hendrix, J. S. (2012). *Topological Theory in Bioconstructivism* (No. 28). *Architecture, Art, and Historic Preservation Faculty Publications*. Retrieved from https://docs.rwu.edu/saahp_fp/28
- Herzog, C., Handke, C., and Hitters, E. (2019). Analyzing Talk and Text II: Thematic Analysis. *The Palgrave Handbook of Methods for Media Policy Research*, (April), 385–401. https://doi.org/10.1007/978-3-030-16065-4_22
- Hesse-Biber, S. N., and Leavy, P. (2005). Oral History: A Collaborative Method of (Auto)Biography Interview. In *The Practice of Qualitative Research* (pp. 149–194). London: Sage Publications, Inc. Retrieved from <http://www.sagepub.co.uk/booksProdDesc.nav?prodId=Book224935>
- Hong, J., Shin, J., and Lee, D. (2016). Strategic management of next-generation connected life: Focusing on smart key and car-home connectivity. *Technological Forecasting and Social Change*, 103, 11–20. <https://doi.org/10.1016/j.techfore.2015.10.006>
- Hobson, B. (2014). Growing a “giant artificial reef” could stop Venice sinking. <https://www.dezeen.com/2014/05/30/movie-rachel-armstrong-future-venice-growing-giant-artificial-reef/>
- Horvath, I. (2001). A contemporary survey of scientific research into engineering design. In *International Conference on Engineering Design ICED 01* (pp. 13–20). Glasgow.
- HQ Sempergreen. (n.d.). Retrieved April 10, 2019, from <https://www.sempergreen.com/en/references/head-office-sempergreen>
- Hurford, R. D. (2009). Types of smart clothes and wearable technology. In *Smart Clothes and Wearable Technology* (pp. 25–44). Elsevier. <https://doi.org/10.1533/9781845695668.1.25>
- I’m lost in Paris. (2009). Retrieved April 30, 2020, from <https://new-territories.com/lostinparis.htm>
- Imani, M., Donn, M., and Vale, B. (2017). Biomimicry as Innovation : a systematic review. In M. A. Schnabel (Ed.), *Back to the Future: The Next 50 Years, (51st International Conference of the Architectural Science Association (ANZAScA)* (pp. 635–644). Architectural Science Association (ANZAScA).
- Imhof, B., and Gruber, P. (2015). *Built to Grow: Blending Architecture and Biology*. Birkhauser (Angewandte). Basel: Book Series of the University of Applied Arts Vienna.
- Ivanić, K.-Z., Tadić, Z., and Omazić, M. A. (2015). Biomimicry: An Overview. *The Holistic Approach to Environment*, 5(1), 19–36. Retrieved from https://hrcak.srce.hr/index.php?show=clanak&id_clanak_jezik=200540
- Jacobsson, A., Boldt, M., and Carlsson, B. (2016). A risk analysis of a smart home automation system. *Future Generation Computer Systems*, 56, 719–733. <https://doi.org/10.1016/j.future.2015.09.003>

- Jayathilake, B. (2008). *Development of mushroom based sausage*. University of Sri Jayewardenepura.
- Jencks, C. (1995). *The architecture of the jumping universe, a polemic: how complexity science is changing architecture and culture*. London: Academy Editions.
- Jencks, C. (2002). *The New Paradigm in Architecture*. New Haven: Yale University Press.
- Jiang, H., and Ching-Chiuan, Y. (2009). Protocol Analysis in Design Research: a review. In *International Association of Societies of Design Research (IASDR) Conference* (pp. 147–156). Seoul. Retrieved from <http://www.iasdr2009.org/ap/Papers/Orally>
- Joachim, M. (2010). Don't build your home, grow it! Retrieved April 1, 2018, from https://www.ted.com/talks/mitchell_joachim_don_t_build_your_home_grow_it/footnotes
- Jodi, A. (1994). A Pragmatic View of Thematic Analysis. *The Qualitative Report*, 2(1), 1–5. Retrieved from <https://nsuworks.nova.edu/tqr/vol2/iss1/3>
- Joffe, H., & Yardley, L. (2004). Content and thematic analysis. In *Research methods for clinical and health psychology* (pp. 56–68). London: Sage Publication.
- Joffe, H. (2011). Thematic Analysis. In *Qualitative Research Methods in Mental Health and Psychotherapy* (pp. 209–223). Chichester, UK: John Wiley & Sons, Ltd. <https://doi.org/10.1002/9781119973249.ch15>
- Johnson, P.-A. (1994). *The Theory of Architecture: Concepts Themes & Practices* (1st ed.). New York: John Wiley & Sons.
- Jonkers, H. M. (2007). Self Healing Concrete: A Biological Approach. In S. van der Zwaag (Ed.), *Self Healing Materials. An Alternative Approach to 20 Centuries of Materials Science* (pp. 195–204). Springer. https://doi.org/10.1007/978-1-4020-6250-6_9
- Jonkers, H. M. (2011). Bacteria-based self-healing concrete. *Heron*, 56(1/2), 1–12.
- Kallio, H., Pietilä, A. M., Johnson, M., and Kangasniemi, M. (2016). Systematic methodological review: developing a framework for a qualitative semi-structured interview guide. *Journal of Advanced Nursing*, 72(12), 2954–2965. <https://doi.org/10.1111/jan.13031>
- Karafyllis, N. C. (2006). Biofakte - Grundlagen, Probleme, Perspektive. *Erwägen Wissen Ethik*, 17(4), 547–558. Retrieved from https://www.tu-braunschweig.de/Medien-DB/philosophie/phil_karafyllis_2006_biofakte_grundlagen_probleme_perspektiven.pdf
- Kasier, G. (2015). Wired Infrastructure in Smart Homes. *Handbook of Smart Homes, Health Care and Well-Being*, (January 2015), 1–9.

- Kaufmann, E. (1939). Étienne-Louis Boullée. *The Art Bulletin*, 21(3), 213–227. <https://doi.org/10.1080/00043079.1939.11408969>
- Kawaguchi, D., and Guimarães, D. S. (2019). Is everybody human? The relationship between humanity and animality in Western and Amerindian myth narratives. *Culture & Psychology*, 25(3), 375–396. <https://doi.org/10.1177/1354067X18779058>
- Kellert, S. R., and Winson, E. O. (Eds.). (1993). *The Biophilia Hypothesis*. Washington, D.C.: Island Press.
- Kemp, R., Schot, J., and Hoogma, R. (1998). Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management. *Technology Analysis & Strategic Management*, 10(2), 175–198. <https://doi.org/10.1080/09537329808524310>
- Kirbas Akyürek, B., Ciravoğlu, A., Mohammadi, M., and Yegenoglu, H. (2020). Building Design in between Living and Manufactured : A Research on Terminology. *Online Journal of Art and Design*, 8(3), 75–89. Retrieved from <http://www.adjournal.net/articles/83/836.pdf>
- Kirbas Akyurek, B., Kortekaas, S., Fisscher, J. L., and Mohammadi, M. (2018). Technological integration of the ' house of the future '. In J. Veuger (Ed.), *Barometer Public Real Estate Special Issue 2018* (pp. 127–144). Groningen: Spryg Real Estate Academy En Bariet Ten Brink.
- Klarenbeek, E. (2019). Biobased paviljoen groot succes. *Persbericht*.
- Kleinert, J. (2018). The apple sorting site : A case of design of living things. *International Journal of Food Design*, 3(1), 21–39. <https://doi.org/10.1386/ijfd.3.1.21>
- Koelman, O. (2004). Building the Future of Buildings. *BioInspire*, 20.
- Koivunen, H. (2005). Biodesign products - Co-design with nature? In *Joining Forces | University of Art and Design Helsinki | September 22-24, 2005 BIODESIGN* (pp. 22–25).
- Kshirsager, A., Malani, S., and Tiware, V., S. (2017). Biomimicry – Nature Inspired Building Structures. *International Journal of Engineering Research and Technology*, 10(1), 162–166. Retrieved from <http://portal.acm.org/citation.cfm?doid=217279.215266>
- Kurokawa, K. (1987). *Metabolism in Architecture Introduction by Charles Jencks*. Boulder, Colorado: Westview Press. Retrieved from https://monoskop.org/images/9/94/Kurokawa_Kisho_Metabolism_in_Architecture_1977.pdf
- Lähde, V. (2006). Gardens, Climate Changes and Cultures. In *How Nature Speaks: The Dynamics of the Human Ecological Condition* (pp. 78–105). Durham and London: Duke University Press Books.
- Latour, B. (1993). *We Have Never Been Modern (translated by Catherine Porter)*. Cambridge, Massachusetts: Harvard University Press.

- Laugier, M.-A. (1755). *Essay on Architecture*. London: Gray's Inn.
- Lavirotte, S., Tigli, J., Rocher, G., Beze, L. El, Lavirotte, S., Tigli, J., ... Vi-, A. P. A. D. (2015). A Dynamic Visual Simulation Environment for Internet of Things. *Research Report on Works Done on Simulation Framework for Internet and Web of Things*.
- Lawson, B. (1997). (2005). *How designers think: The Design Process Demystified. Design Studies* (4th ed.). Oxford: Elsevier. Retrieved from <http://linkinghub.elsevier.com/retrieve/pii/0142694X81900338>
- Leupen, B. (2004). *The Frame And The Generic Space, A New Way Of Looking To Flexibility*. Retrieved from <https://www.irbnet.de/daten/iconda/CIB12026.pdf>
- Lloyd, P., Lawson, B., and Scott, P. (1995). Can concurrent verbalization reveal design cognition? *Design Studies*, 16(1993), 237–259. [https://doi.org/10.1016/0142-694X\(94\)00011-2](https://doi.org/10.1016/0142-694X(94)00011-2)
- Loek Kusiak. (n.d.). De woonomgeving die “meevoelt” - Empathische Woning. Retrieved May 10, 2019, from <https://www.empathischewoning.nl/de-woonomgeving-die-meevoelt/>
- Ludwig, F. (2016). Baubotanik: designing with living material. In S. K. Loschke (Ed.), *Materiality and Architecture* (pp. 182–191). London: Routledge.
- Ludwig, F., Schwertfeger, H., and Storz, O. (2012). Living Systems: Designing Growth in Baubotanik. *Architectural Design*, 82(2), 82–87. <https://doi.org/10.1002/ad.1383>
- Ludwig, Ferdinand;, and Schönle, D. (n.d.). Baubotanik (con)fusing trees and architecture. Retrieved May 1, 2020, from <http://futurearchitectureplatform.org/projects/537905c7-70ab-4bbb-a4a9-3ef833f1c078/>
- Lv, Z., Feng, L., Li, H., and Feng, S. (2014). Hand-free motion interaction on Google Glass. In *SIGGRAPH Asia 2014 Mobile Graphics and Interactive Applications on - SA '14* (pp. 1–1). New York, New York, USA: ACM Press. <https://doi.org/10.1145/2669062.2669066>
- Lyall, S. (1992). *Santiago Calatrava*. (D. Sharp, Ed.). London: E&FN Spon.
- Lynass, R., Pykhtina, O., and Cooper, M. (2012). A thematic analysis of young people's experience of counselling in five secondary schools in the UK. *Counselling and Psychotherapy Research*, 12(1), 53–62. <https://doi.org/10.1080/14733145.2011.580853>
- Marikyan, D., Papagiannidis, S., and Alamanos, E. (2019). A systematic review of the smart home literature: A user perspective. *Technological Forecasting and Social Change*, 138, 139–154. <https://doi.org/10.1016/j.techfore.2018.08.015>

- Marshall, A., and Lozeva, S. (2009). Questioning the theory and practice of biomimicry. *International Journal of Design & Nature and Ecodynamics*, 4(1), 1–10. <https://doi.org/10.2495/DNE-V4-N1-1-10>
- Masi, E., Taiti, C., and Pandolfi, C. (2015). Clairry and its ability to filter volatile compounds of indoor air. *Pnat Inspired by Plants*, 6–9.
- Maslakovic, M. (2018). Moving away from the wrist - smart clothing you'll actually want to wear. Retrieved May 10, 2020, from <http://gadgetsandwearables.com/2018/04/14/best-smart-clothing/>
- Mathews, F. (2011). Towards a Deeper Philosophy of Biomimicry. *Organization & Environment*, 24(4), 364–387. <https://doi.org/10.1177/1086026611425689>
- Mensvoort, K. Van. (2013a). Koert van Mensvoort Pyramid of Technology, 1–29. Retrieved from http://www.researchgate.net/publication/259979988_Pyramid_of_Technology_How_Technology_Becomes_Nature_in_Seven_Steps%5Cnpapers3://publication/uuid/423C669D-465B-4D23-8FD5-3D613FD0076A
- Mensvoort, K. Van. (2013b). Sniffer-Meet the Google Nose. Retrieved May 20, 2020, from <https://nextnature.net/2013/06/sniffer-meet-the-google-nose>
- Mensvoort, K. Van, and Grievink, H. J. (2012). *Next Nature: Nature Changes Along with Us*. (K. Van Mensvoort & H. J. Grievink, Eds.) (English). Amsterdam: Actar.
- Merchant, C. (1990). *The Death of Nature: Women, Ecology and the Scientific Revolution* (2nd ed.). San Francisco: Harper & Row.
- Metcalf, D., Milliard, S. T. J., Gomez, M., and Schwartz, M. (2018). Wearables and the Internet of Things for Health: Wearable, Interconnected Devices Promise More Efficient and Comprehensive Health Care. In *IEEE Pulse* (pp. 1–38). London: Institute & Faculty of Actuaries. <https://doi.org/10.1109/MPUL.2016.2592260>
- Michael, D. (2011). Toward a Dark Nature Recording. *Organised Sound*, 16(3), 206–210. <https://doi.org/10.1017/S1355771811000203>
- Middleton, W., Habibi, A., Shankar, S., and Ludwig, F. (2020). Characterizing Regenerative Aspects of Living Root Bridges. *Sustainability*, 12(8), 3267. <https://doi.org/10.3390/su12083267>
- Miller-Rosser, K., Robinson-Malt, S., Chapman, Y., and Francis, K. (2009). Analysing oral history: A new approach when linking method to methodology. *International Journal of Nursing Practice*, 15(5), 475–480. <https://doi.org/10.1111/j.1440-172X.2009.01793.x>
- Mittelstraß, J. (2014). *Evolving Concepts of Nature PAS Plenary Session 24-28 October 2014*. Retrieved from https://www.youtube.com/watch?v=Kwrz1ass0nM&feature=emb_title
- Modern Meadow. (2017). Materials Reimagined. Retrieved June 10, 2020, from <http://www.modernmeadow.com/>

- Mohammadi, M. (2014). *DomoticaKompas: Inzichten uit een decennium slimme zorgprojecten in Nederland*. (B. van der Does, Ed.) (1st ed.). Eindhoven.: Van Litsenburg BV.
- Mohammadi, M., Dominicus, M., van Buuren, L., Hamers, K., Hammink, C., and Yegenoglu, H. (2019). The Evolution of Housing Typologies for Older Adults in The Netherlands From 1945 to 2016: An Analysis in the Context of Policy, Societal, and Technological Developments. *Journal of Housing For the Elderly*, 33(3), 205–226. <https://doi.org/10.1080/02763893.2018.1561590>
- Mohammadi, M., and Hammink, C. (2015). Standards for Smart Living: A Historical Overview. In J. van Hoof, G. Demiris, & E. J. M. Wouters (Eds.), *Handbook of Smart Homes, Health Care and Well-Being* (pp. 1–14). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-01904-8_30-1
- Montana Hoyos, C., and Fiorentino, C. (2016). Bio-utilization, Bio-inspiration, and Bio-affiliation in Design for Sustainability: Biotechnology, Biomimicry, and Biophilic Design. *The International Journal of Designed Objects*, 10(3), 1–18. <https://doi.org/10.18848/2325-1379/CGP/v10i03/1-18>
- Muhammad Sayem, A. S., Hon Teay, S., Shahariar, H., Luise Fink, P., and Albarbar, A. (2020). Review on Smart Electro-Clothing Systems (SeCSs). *Sensors*, 20(3), 587. <https://doi.org/10.3390/s20030587>
- Mumford, M. (1989). Form Follows Nature: The Origins of American Organic Architecture. *Journal of Architectural Education*, 42(3), 26–37. <https://doi.org/10.1080/10464883.1989.10758528>
- Myers, W. (2018). *Biodesign : Nature + Science + Creativity* (Revised an). London: Thames & Hudson.
- Nanosupermarket. (n.d.). Retrieved May 10, 2020, from <https://www.nanosupermarket.org/>
- Nelson, R. R., and Winter, S. G. (1982). *An Evolutionary Theory of Economic Change*. Cambridge, MA.: Bellknap Press: An Imprint of Harvard University Press.
- Nkandu, M. I., and Alibaba, H. Z. (2018). Biomimicry as an Alternative Approach to Sustainability. *Architecture Research*, 8(1), 1–11. <https://doi.org/10.5923/j.arch.20180801.01>
- Nola, R. (1987). Nietzsche's Theory of Truth and Belief. *Philosophy and Phenomenological Research*, 47(4), 525–562.
- Nowell, L. S., Norris, J. M., White, D. E., and Moules, N. J. (2017). Thematic Analysis: Striving to Meet the Trustworthiness Criteria. *International Journal of Qualitative Methods*, 16(1), 1–13. <https://doi.org/10.1177/1609406917733847>

- Oguntona, O. A., and Aigbavboa, C. O. (2017). Biomimicry principles as evaluation criteria of sustainability in the construction industry. *Energy Procedia*, 142, 2491–2497. <https://doi.org/10.1016/j.egypro.2017.12.188>
- Önal, G. K. (2015). Tasarım Aktivitelerini Araştırmak: Protokol Analizi Yönetimi. *Sanat ve Tasarım Dergisi*, 1(14). <https://doi.org/10.18603/std.24481>
- Ong, T. (2017). This gorgeous pocket-sized greenhouse is also an air purifier. Retrieved June 21, 2019, from <https://www.theverge.com/tldr/2017/8/7/16106118/livesglass-che-design-pocket-sized-greenhouse-air-purifier>
- Owen, C. (2008). Architecture Between the Culture-Nature Dualism : a Case Study of Geoffrey Bawa' S Kandalama Hotel. *Archnet-IJAR, International Journal of Architectural Research*, 2(1), 40–56. Retrieved from <http://discovermagazine.com/2014/oct/17-natures-technician>
- Oxman, N. (2015). Templating Design for Biology and Biology for design. *Architectural Design*, 85(5), 100–107. <https://doi.org/10.1002/ad.1961>
- Özdemir, B., and Selcuk, S. A. (2016). Tree Metaphor in Architectural Design. *Architecture and Nature*, 1(September 2016), 61–76.
- Pan, S., Yang, Z., Chen, P., Deng, J., Li, H., and Peng, H. (2014). Wearable Solar Cells by Stacking Textile Electrodes. *Angewandte Chemie International Edition*, 53(24), 6110–6114. <https://doi.org/10.1002/anie.201402561>
- Papanek, V. (1974). *Design for the real world : human ecology and social change*. Paladin: St Albans, Herts.
- Passmore, J. (1974). *Man's Responsibility for Nature: Ecological Problems and Western Traditions*. Duckworth, London: Scribner.
- Paulin, A. (n.d.). Thin Ice: The Very First Weight-Loss Clothing Line. Retrieved January 2, 2020, from <https://www.indiegogo.com/projects/thin-ice-the-very-first-weight-loss-clothing-line#/>
- Pawlyn, M. (2011). *Biomimicry in Architecture* (1st ed.). London: RIBA Publishing.
- Pedersen Zari, M., and Storey, J. B. (2007). An ecosystem based biomimetic theory for a regenerative built environment. In *Portugal SB 2007 - Sustainable Construction, Materials and Practices: Challenge of the Industry for the New Millennium* (pp. 620–627). Lisbon.
- Pernice, R. (2004). Metabolism Reconsidered Its Role in the Architectural Context of the World. *Journal of Asian Architecture and Building Engineering*, 3(2), 357–363. <https://doi.org/10.3130/jaabe.3.357>
- Plant microbial energy & the cycle of conversion. (n.d.). Retrieved June 10, 2019, from <https://livinglight.info/technology/>
- Plumwood, V. (1993). *Feminism and the Mastery of Nature*. London: Routledge.
- Poelman, W A. (2005). Technology Diffusion in Product Design - Towards an Integration of Technology Diffusion in the Design Process.

- Poelman, Wim A. (2008). Faculty of Architecture : a source for innovation? "An Englishman in New York." *RuMoer*, 43(Destination: Innovation), 8–11.
- Pohl, W. (2004). Gemeinschaftsbauten, die gepflanzt werden. *Stadt+Grün*, 3, 7–11.
- Portelli, A. (2009). What Makes Oral History Different. In L. D. Giudice (Ed.), *Oral History, Oral Culture, and Italian Americans* (pp. 21–30). New York: Palgrave Macmillan US. https://doi.org/10.1057/9780230101395_2
- Pourjafar, M. R., and Branch, M. (2011). Design with Nature in Bio-Architecture with emphasis on the Hidden Rules of Natural Organism. *International Journal of Applies Science and Technology*, 1(4), 74–83. Retrieved from www.ijastnet.com
- Proctor, J. D. (1998). The Social Construction of Nature: Relativist Accusations, Pragmatist and Critical Realist Responses. *Annals of the Association of American Geographers*, 88(3), 352–376. <https://doi.org/10.1111/0004-5608.00105>
- Pushkar, S., and Shaviv, E. (2016). Using shearing layer concept to evaluate green rating systems. *Architectural Science Review*, 59(2), 114–125. <https://doi.org/10.1080/00038628.2014.966051>
- Quatremère de Quincy, and Younés, S. (1999). *The Historical Dictionary of Architecture of Quatremère de Quincy*. London: Andreas Papadakis Publisher.
- Radwan, G. A. N., and Osama, N. (2016). Biomimicry, an Approach, for Energy Effecient Building Skin Design. *Procedia Environmental Sciences*, 34, 178–189. <https://doi.org/10.1016/j.proenv.2016.04.017>
- Raman, R., and Bashir, R. (2017). Biomimicry, Biofabrication, and Biohybrid Systems: The Emergence and Evolution of Biological Design. *Advanced Healthcare Materials*, 6(20), 1700496. <https://doi.org/10.1002/adhm.201700496>
- Ratti, C., and Claudel, M. (2016). *The City of Tomorrow: Sensors, Networks, Hackers, and the Future of Urban Life (The Future Series)*. New Haven and London: Yale University Press.
- Rawlings, A. E., Bramble, J. P., and Staniland, S. S. (2012). Innovation through imitation: biomimetic, bioinspired and biokleptic research. *Soft Matter*, 8(25), 6675. <https://doi.org/10.1039/c2sm25385b>
- Rice, P. L., and Ezzy, D. (1999). *Qualitative Research Methods A Health Focus*. Oxford: Oxford University Press.
- Ripley, R. L., and Bhushan, B. (2016). Bioarchitecture: bioinspired art and architecture—a perspective. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 374(2073), 20160192. <https://doi.org/10.1098/rsta.2016.0192>

- Roepstorff, Andreas, and Bubandt, N. (2003). General introduction: The critique of culture and the plurality of nature. In A. Roepstorff, N. Bubandt, & K. Kull (Eds.), *Imagining Nature. Practices of Cosmology and Identity* (pp. 9–26). Oakville, Conn: Aarhus University Press. Retrieved from http://en.unipress.dk/media/imported/9788772889450/9788772889450_excerpt.pdf
- Rogers, E. M. (2003). *Diffusion of Innovations* (5th ed.). New York: The Free Press.
- Rouse, W. B. (1993). *Catalysts for Change: Concepts and Principles for Enabling Innovation* (1st ed.). New York: Wiley-Interscience.
- SAHLINS, M. (2014). On the ontological scheme of Beyond nature and culture. *HAU: Journal of Ethnographic Theory*, 4(1), 281–290. <https://doi.org/10.14318/hau4.1.013>
- Sawh, M. (2018). The best smart clothing: From biometric shirts to contactless payment jackets. Retrieved May 10, 2020, from <https://www.wareable.com/smart-clothing/best-smart-clothing>
- Schön, D. A., and Rein, M. (1995). *Frame Reflection: Towards the Resolution of Intractable Policy Controversies*. New York: Basic Books.
- Schot, J., Hoogma, R., and Elzen, B. (1994). Strategies for Shifting Technological Systems. *Futures*, 26(10), 1060–1076. [https://doi.org/10.1016/0016-3287\(94\)90073-6](https://doi.org/10.1016/0016-3287(94)90073-6)
- Sepehri, F. (2016). Lighting and energy supply for heating in building using algae power. *Journal of Fundamental and Applied Sciences*, 8(3), 1021. <https://doi.org/10.4314/jfas.v8i3s.13>
- Seung, W., Gupta, M. K., Lee, K. Y., Shin, K.-S., Lee, J.-H., Kim, T. Y., ... Kim, S.-W. (2015). Nanopatterned Textile-Based Wearable Triboelectric Nanogenerator. *ACS Nano*, 9(4), 3501–3509. <https://doi.org/10.1021/nn507221f>
- Sharma, A., Jethani, B., and Sethi, S. (2017). A Review on Prevention against Sun Damage. *International Journal on Recent and Innovation Trends in Computing and Communication*, 5(5), 722–725. <https://doi.org/10.17762/ijritcc.v5i5.595>
- Shu, L. H., Ueda, K., Chiu, I., and Cheong, H. (2011). Biologically inspired design. *CIRP Annals - Manufacturing Technology*, 60(2), 673–693. <https://doi.org/10.1016/j.cirp.2011.06.001>
- Singh, S., and Kumar, A. (2018). Review of Skinput Technology: Input Through Skin. In *2018 International Conference on Sustainable Energy, Electronics, and Computing Systems (SEEMS)* (pp. 1–5). IEEE. <https://doi.org/10.1109/SEEMS.2018.8687378>
- Slaats, E. (2017). The Future of Living. In *Handbook of Smart Homes, Health Care and Well-Being* (pp. 443–455). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-01583-5_42

- Smith, N., and Harvey, D. (1990). *Uneven Development. Nature, Capital and the Production of Space*. Athens;London: University of Georgia Press. Retrieved from <http://www.jstor.org/stable/j.ctt46nmvk>
- Solaimani, S., Bouwman, H., and Baken, N. (2011). The Smart Home Landscape: A Qualitative Meta-analysis. In B. Abdulrazak, S. Giroux, B. Bouchard, H. Pigot, & M. Mokhtari (Eds.), *Toward Useful Services for Elderly and People with Disabilities, ICOST 2011* (pp. 192–199). Berlin, Heidelberg: Springer. https://doi.org/10.1007/978-3-642-21535-3_25
- Soper, K. (1995). *What is Nature? Culture, Politics and the Non- human* (1st ed.). Oxford: Wiley-Blackwell.
- Speck, O., Speck, D., Horn, R., Gantner, J., and Sedlbauer, K. P. (2017). Biomimetic bio-inspired biomorph sustainable? An attempt to classify and clarify biology-derived technical developments. *Bioinspiration & Biomimetics*, 12(1), 011004. <https://doi.org/10.1088/1748-3190/12/1/011004>
- Stelline, P. delle. (2013). BIQ House + SolarLeaf – the use of microalgae. *Smart Cities – Good Practice Buildings*, 1–4.
- Stewart, L. (2016). Amazing Grove aquaponic ecosystem can grow you a salad every day. Retrieved February 10, 2019, from <https://inhabitat.com/search/amazing+grove+aquaponic+ecosystem+can+grow+you+a+salad+/ckct-sized-greenhouse-air-purifier>
- Stewart, R. M. (1986). Nietzsche 's Perspectivism and the Autonomy of the Master Type. *Wiley*, 20(3), 371–389.
- Stott, R. (2014). Hy-Fi, The Organic Mushroom-Brick Tower Opens At MoMA's PS1 Courtyard. Retrieved May 10, 2020, from <https://www.archdaily.com/521266/hy-fi-the-organic-mushroom-brick-tower-opens-at-moma-s-ps1-courtyard>
- Suwa, M., and Tversky, B. (1997). What do architects and students perceive in their design sketches? A protocol analysis. *Design Studies*, 18(4), 385–403. [https://doi.org/10.1016/S0142-694X\(97\)00008-2](https://doi.org/10.1016/S0142-694X(97)00008-2)
- Tam, K.-P. (2013). Concepts and measures related to connection to nature: Similarities and differences. *Journal of Environmental Psychology*, 34, 64–78. <https://doi.org/10.1016/j.jenvp.2013.01.004>
- Taylor, P. W. (1986). *Respect for Nature: A Theory of Environmental Ethics* (REV- Revi). Oxford: Princeton University Press. <https://doi.org/10.2307/j.ctt7sk1j>
- Terreform. (2020). Retrieved May 10, 2020, from <http://terreform.org/>
- The Circular Garden. (n.d.). Retrieved April 30, 2020, from <https://carloratti.com/project/the-circular-garden/>
- The Ring. (n.d.). Retrieved April 2, 2020, from <https://tokenring.com/pages/the-ring>

- Thomson, P. (2015). *The voice of the past: oral history*. (R. Perks & A. Thomson, Eds.), *The Oral History Reader* (Taylor & F). London and New York: Routledge. <https://doi.org/10.4324/9781315671833>
- Todd, J., and Todd, N. (1994). *From Eco-Cities to Living Machines: Principles of Ecological Design* (2nd ed.). Berkeley, CA: North Atlantic Books.
- Tomico, O., Wensveen, S. A., Kuusk, K., ten Bhömer, M., Ahn, R., Toeters, M., and Versteeg, M. (2014). Wearable Senses, Department of Industrial Design, TU Eindhoven. *Interactions*, 21(4), 16–19. <https://doi.org/10.1145/2628193>
- Tracada, E., and Caperna, A. (2012). Biourbanism for a Healthy city: Biophilia and sustainable urban theories and practices. In *Proceedings of the International Convention on Innovations in Engineering and Technology for Sustainable Development* (Vol. VI). Bannari: Bannari Amman Institute of Technology, Erode District, Tamil Nadu, India. Retrieved from <http://hdl.handle.net/10545/294089>
- Tucker, E. (2017). Drop by Drop is a plan-based water filter that works as mini Amazon. Retrieved May 10, 2018, from <https://www.dezeen.com/2017/07/10/drop-by-drop-plant-based-water-filtration-system-works-as-mini-amazon-rca-graduate-pratik-ghosh/>
- Tuckett, A. G. (2005). Applying thematic analysis theory to practice: a researcher's experience. *Contemporary Nurse: A Journal for the Australian Nursing Profession*, 19(1–2), 75–87. <https://doi.org/10.5172/conu.19.1-2.75>
- Uggla, Y. (2009). What is this thing called “natural”? The nature-culture divide in climate change and biodiversity policy. *Journal of Political Ecology*, 17, 80–91.
- Valdecasas, A. G., and Wheeler, Q. D. (2018). *Biomimicry/Bioprospecting. Encyclopedia of the Anthropocene*. Elsevier Inc. <https://doi.org/10.1016/B978-0-12-809665-9.09862-1>
- Vallas, T., and Courard, L. (2017). Using nature in architecture: Building a living house with mycelium and trees. *Frontiers of Architectural Research*, 6(3), 318–328. <https://doi.org/10.1016/j.foar.2017.05.003>
- Vegesack, A. and Eisenbrand, J. (Ed.). (2006). *Open House Architecture and Technology for Intelligent Living*. Weil am Rhein: Vitra Design Museum.
- Venkatesh, A., Kruse, E., and Shih, E. C.-F. (2003). The networked home: an analysis of current developments and future trends. *Cognition, Technology & Work*, 5(1), 23–32. <https://doi.org/10.1007/s10111-002-0113-8>
- Veske, P., Kuusk, K., Toeters, M., and Scholz, B. (2019). Environmental Sustainability of E-textile Products for Makers and Manufacturers. *Textile Intersections:12-14th September 2019*, 1–9. <https://doi.org/10.17028/rd.lboro.9724664>

- Vincent, J. F. V. (2016). Biomimetics in Architectural Design. *Intelligent Buildings International*, 8(2), 138–149.
<https://doi.org/10.1080/17508975.2014.911716>
- Vogel, S. (2000). *Cats' Paws and Catapults: Mechanical Worlds of Nature and People*. (Norton, Ed.). New York: WW Norton & Co.
- Wahl, D. C. (2006). Bionics vs. Biomimicry: From Control of Nature to Sustainable Participation in Nature. *WIT Transactions on Ecology and the Environment*, 289–298.
- Wang, X. Q., Jin, Z. M., and Zhang, A. D. (2012). Innovation for Transformation of Textile Industry Moving from Material to Finished Good Supplier. *Advanced Materials Research*, 482–484, 2551–2554.
<https://doi.org/10.4028/www.scientific.net/AMR.482-484.2551>
- Welshon, R. (2009). Saying Yes to Reality: Skepticism, Antirealism, and Perspectivism in Nietzsche's Epistemology. *Journal of Nietzsche Studies*, 37(37), 23–43.
- Wensveen, S. (2018). *Constructive Design Research*. Eindhoven: Eindhoven: Technische Universiteit Eindhoven.
- Williams, R. (1980). Ideas of Nature. In *Problems in Materialism and Culture* (pp. 67–85). London: Verso Press.
- Winn, K., Vollen, J., and Dyson, A. (2012). Re-Framing Architecture for Emerging Ecological and Computational Design Trends for the Built Ecology. In *ACADIA 12: Synthetic Digital Ecologies [Proceedings of the 32nd Annual Conference of the Association for Computer Aided Design in Architecture]* (pp. 250–258).
- Wolter, D., and Kirsch, A. (2017). Smart Environments: What is it and Why Should We Care? *KI - Künstliche Intelligenz*, 31, 231–237.
<https://doi.org/10.1007/s13218-017-0498-4>
- Yang, J., Brandon, P., and Sidwell, A. (2008). *Smart and Sustainable Built Environments*. Chichester: Wiley.
- Yasin, R. M. (2018). Petit Pli: Clothes that Grow. *Utopian Studies*, 28(3), 576.
<https://doi.org/10.5325/utopianstudies.28.3.0576>
- Yedeki Arslan, G. (2014). Biomimetic Architecture: A New Interdisciplinary Approach to Architecture. *Alam Cipta, International Journal of Sustainable Tropical Design Research and Practice*, 7(2), 29–36. Retrieved from <http://frsb.upm.edu.my/alamcipta/index.php/alamcipta/article/view/157>
- Yelavich, S. (2019). Domesticity: Cleaning, Mending, Caring. In *Thinking Design Through Literature* (1st ed., pp. 180–221). Oxon: Routledge.
<https://doi.org/10.4324/9781315200071-5>
- Zelfherstellend paviljoen. (n.d.). Retrieved April 10, 2020, from <https://www.marcus-architecten.nl/012-paviljoen-reddingsbrigade-breda/>

A

INTERVIEW TRANSCRIPTS

This part of the thesis presents verbal data of the interviews, excluding the two (2) of them requested to be kept confidential; therefore, eighteen (18) interviews are included in this part. Transcripts do not include any sensitive data. Concerning the method (i.e., oral history) applied in the thesis, transcriptions were kept as natural as much as possible by reflecting generous contents emerging from a dialogue.

No part of these transcriptions may be directly quoted or reproduced in any form or by any means without permission in writing form from the author.

Interview I

Place: Helmond/NL

Date: 16th July 2019

Should I start by showing the examples of products first?

Berrak Kirbas Akyurek: Sure.

Here you can see an example of ice skating (simulation). We have taken it as a ski board, an indoor object. It depends on the age of the user. So, we have two different versions. It is an ice skating board in the interior with a game you can interact with it.

Here is another example, *Smart Wall* project. It has smart sensor technology with a beam projector. You can see the sensor technology that you can connect to. That will be reflected on a black wall. The application we designed primarily focused on primary schools where there is a white wall. It can be either a gym or any room where a child can play games about learning a language, or teaching geography, or anything you can imagine. For example, we have a setting for incomplete words, and you see many letters that the children can select.

You can now incorporate (sensor) technology with your smartphone. The technologies here we have are currently focused on sport, education, and different domains, reactions, and specific applications. For example, the idea behind this *Smart Bicycle* is to put a smart tablet with an audiobook application. If you are cycling, the sensor triggers the book. If you stop, the book also stops. The first product was in Helmond, NL, primarily focusing on helping people having accessibility to disabilities in reading, for example.

Berrak Kirbas Akyurek: Do you utilize the energy releasing from riding a bike, as well?

Currently not. They are two separate applications. It is quite difficult to set the electricity of the cycling of the controls because of the voltage. It is easier to apply this now. You can install a generator for energy, but a generator is not always

consistent as we expect it to be. For example, people are requesting to adopt this technology into their own bikes. Asking people to buy a new bike sounds expensive.

This is also another example we call *Smoothie Bike*. Here you see a blender at the end of the bike. When you cycle, you can prepare your smoothie. It is mainly rented out to offices to provide a distraction to the employees. Currently, I am working on the technical parts of this project. One of those wheels, there is a built-in generator. I am currently working on how I could get voltage out of this. Through a cable, of course, a proper voltage can be converted. I am also working on how we could use this energy, like charging mobile and iPad or even turning it into a game.

Berrak Kirbas Akyurek: It sounds like you are working in different domains. Could I ask why?

We do not specialize in a specific domain. It might be a weakness or strength. It depends on how you look at it. The focus always needs to be in general, so we could always find a market for it.

Berrak Kirbas Akyurek: Considering that we have limited time, Could we continue with my questions mainly related to Sniffer Nose project?

Sure, I did that project when I was at the University (Eindhoven Technical University). It got quite an attention. I won first place. It was a preliminary concept. Back then, google glasses was so popular. So, at the University, we have ongoing discussions on the apprehended reality of how we could apply it and what it is all for.

Berrak Kirbas Akyurek: Can you tell me about your background? How do you describe yourself professionally?

On paper, I call myself an industrial designer. Because it is the easiest way to describe myself, but in practice, I cannot place a label on it. Since I do more things in product development, I am more into product development than industrial design and believe more into the visible spectrum. But I also work in electronics

and mechanics. For example, for *Smart Wall*, I built a red box on the top that gives strength and does not shock you when you touch it. So I kind of work more on product development. That's why I also see myself as a general engineer with a bit of mechanical expertise, a bit of practice, and an invention field. I like to think about new things, but I also want it to be a reality. That is possible and feasible to develop. Through that aspect, I see more self as an engineer spectrum than the artist spectrum. For example, if you think about a designer, it would be someone between designer and art.

Berrak Kirbas Akyurek: Can you tell me the motivation behind the development of Sniffer Nose project and your other projects as well?

My motivation behind is... We use all kinds of technology to improve our sight to see everything in the World. Listening is also important. However, within all senses, smelling is underused. And I thought that we could apply some kind of sense something despite this. But that is quite complex because the scent is a complex sense. For example, to develop a design for a screen is easy to accomplish. Because we see the effect, the three colors, red, green, and blue, and combining these colors, you can get an image. But for scent, you do not really have three primary smells. There are millions of different smells. So my motivation perhaps to improve our scent, maybe with something on our nose. So I came up with an idea to use google glasses with an extra attachment to help them sense all these smells and translate them into data. What could we do with this data?

Do you know what is synesthesia is?

Berrak Kirbas Akyurek: Kind of. Could you explain a bit?

It is a primary condition that people link their senses. For instance, if I tell you a name, you can have an idea behind the color or scent of that name. It does not have to be a scent; your brain just gives it. My main purpose perhaps we could use smells and add color code in terms of categorizing the smells. Or for example, when you walk around it, you notice a smell, and the device can say your uncle was here just about ten minutes ago. Or more private information such as by sensing someone is pregnant or so. So a lot of discussions can come from this. I

can imagine that if this technology is developed further, it can be used in many different ways by shaping the behaviors of society.

Berrak Kirbas Akyurek: Depending on these many different ways, as you said, do you foresee any possible use(s) in building design?

For example, you can use scent technology as a set of fire alarms that you can set a general sense. Because the interesting thing about scent is, for example, you can trace the animal with a kind of footprint of smell. It gives information about where it was there, and also the conditions. So if you have a chance to place that kind of technology on a building that you can affect a similar recording who was there, who walked around, I can imagine it can be applied to that aspect. Other things can also be revealed in terms of a more private image.

If you look at current building designs, the focus is on heat isolation. Because preserving the heat is environmentally friendly. But, we also need air circulation, since the air in the building is not fresh. I can imagine that scent technology can make it quite easy to detect polluted air. But I do not think that scent is logical to utilize right now.

Berrak Kirbas Akyurek: For example, it is always hard for visual data to record it, deposit it, and re-watch it because of the data size. Do you think scent can be an option?

Definitely, all the crimes always happen at an angle where the cameras could not see. So I can imagine the possibilities. You can use multiple (scent) sensors in one room, and it will be recorded.

Berrak Kirbas Akyurek: Could you tell me the novelty of Sniffer Nose project?

Through google glass, you could see through applications. As an extension to google glass, I aimed to amplify the scent's sense to give it an extra boost. For example, you can press, and the application leads to see the smoke on the streets. If you download a new app, you could see the traces of somebody familiar to you or celebrities. Moreover, for example, as you smell something or someone when you walk around, but you cannot identify it, you could just ask the application.

Primarily, the focus was on the improvement of the human scent by using technology.

Berrak Kirbas Akyurek: Human enhancement, you mean?

Yes, definitely.

Berrak Kirbas Akyurek: What would you like to achieve with the development of Sniffer nose project?

It is also a human enhancement. For example, scenting someone is pregnant, or someone has a disease in a room. You can imagine that if I developed a sensor on that, I could check someone's disease because certain scents heightened or lowered. And if I have germophobia, I can refuse to be in that room. These kinds of behaviors can be developed. Besides, privacy is also an important issue. For example, if you want to keep something hidden, someone can detect it via scent. Suppose you had cancer, and you would like to keep it secret. A person with a sensor would confront it.

Berrak Kirbas Akyurek: It sounds like privacy is a big issue; for instance, you cannot even hide your feelings. Since the human body releases a different kind of scents by being nervous, angry, or happy.

You can imagine maybe something we developed specifically to detect this scent particulars and remove it. You can see that whole new cosmetic products could come on the market.

Berrak Kirbas Akyurek: So you are saying there is a possibility of this concept to bring 'openness,' but also privacy issues. But at the end of the day, if we could manage to develop these technologies, lots of things could change.

Similar consequences have already happened. For example, for Facebook, if you regret all the data, photos, and information. It is already there, and hard to remove it. Imagine those certain companies removing your data from the internet. So that is a similar concept. So you are saying there is a possibility of this concept to bring 'openness,' but also privacy issues. But at the end of the day, if we could manage to develop these technologies, lots of things could change.

Berrak Kirbas Akyurek: And the recognition of the scents could be with color-coding?

Yes, you can do it already; they already do some actions. Many people are developing these technologies, such as researching the scent of purple. That's why I give the example of someone with synesthesia. For example, if I imagine purple, I imagine forest berries; I imagine something sweet.

Berrak Kirbas Akyurek: But another person can imagine something s/he dislikes?

Maybe you can also give a shape with it, and you see something overall.

Berrak Kirbas Akyurek: Could you tell me the challenges that you faced in the design of the project?

The challenges are more about design, such as google glass implementation and personal use. I had to present as a fleshy project; back then, google glass itself was fleshy. But the whole idea about the scent, I did not get much criticism about it, more about the implementation. If they do not like the product, it was their own problem.

Berrak Kirbas Akyurek: So, you mean your challenges more likely about the technical part of the project?

More how I presented it back then. In the technical part, I did not develop a working prototype. It was about future technologies and how they could shape society. I came with scent sensors that have potential and presented as a product. I think everybody that I am working with knows that these sensors will come. That is always a question between the technology we hope that people will use and how it will be useful.

In building design, you can do models, but you can look from the top. In reality, no one would look at a building from the top. And the prototype is already a finished building. But I can provide a prototype; you can touch it, play with it. There are constant alteration and development of custom issues.

Berrak Kirbas Akyurek: Nowadays, these innovations are described with a variety of terms such as; sustainability, natural, organic, smart, bio, etc.: Which terminology do you prefer to refer to your designs?

Currently, we use the term 'smart' a lot. Sometimes, we put smart before the name of the product like *Smart Wall*. Sometimes we use smart to describe the action on it. It depends on which is more catchy. For example, smart jump is more memorable than smart trampoline. In the past, we faced it, like iPod, iPhone. We have a similar approach to terminology. For me, the important thing is the customer to understand it. I can find really fancy words, but it is hard to guess.

You gave other examples like sustainable... Right now, they indicate environmentally friendly production.

Berrak Kirbas Akyurek: If your product is environmentally friendly, do you prefer to use sustainable instead of smart?

It depends. For example, in the case of *Smart Wall*, smart seems suitable with sensor technology that gives visual feedback. And if we have an option to make it solar powered, we want to use that aspect on it. We will use sustainable.

Berrak Kirbas Akyurek: For the product name or description of the project?

More in intercell. We go to (Dutch) municipalities and other organizations for the smart wall concept. And we use the sustainable term, which also sounds smart, and people want to be smart. To me, the difference between environment friendly and sustainable is that sustainable is short and currently trendy and symbolic. Maybe some people claim that there are differences, although the environment friendly for me seems more general. Besides, sustainability is more related to durability.

Smart, on the other hand, does not have to be sustainable. But, it is about the improvement of the product. Like the smartphone, it is the improvement of a phone. Smart is an attachment to make products more intelligent. For example, when I talk about smart wall, you immediately understand what is smart wall. I do not really offend it, and I can simply express the improvement. For example, if

I say smart tree, you would understand there is something like interactive, superior, different. Also, it is the current trend. I can imagine ten years in the past if I added smart before a product name, people would say, what does it mean. You can imagine ten (10) to twenty (20) years in the future, and the smart term would be meaningless.

Berrak Kirbas Akyurek: I think what's important to you is to be understandable?

Yes.

Berrak Kirbas Akyurek: Could you tell me the potential impact(s) of these products?

I would indeed say it would have an impact on social behavior. I would also add an infringement of privacy due to the capability to gather information through scent, which others would like to hide. Think of pregnancies, diseases, where you have been, and with whom or other scenarios that smell involves.

Berrak Kirbas Akyurek: You told us that if we start developing technologies with scent, we could create new behaviors. Do you think that will bring further impacts on society?

I could imagine that I could categorize certain friends like 2.0 and 3.0. For example, if you do not want to see them, you will not enter that room. If sensors could pick up the scents and detect them, it will affect your decisions. It is about future technologies and how they could shape society.

Berrak Kirbas Akyurek: Regarding what we discussed here, Could you tell me about your expectations for the future?

It is always a bit complicated to talk about the future. I think sensor technology will be developed further. Currently, you can see lots of problems with Alexa and google home systems, especially with sound sensors. The data sensor technology could work through the movement as well. If I walk into a room, instead of saying lights on, I will look at the light, and the lights will be on.

Berrak Kirbas Akyurek: What is the main advantage that you see in this example?

Because it is easier, in design, you have to look into actions. If you do multiple actions, people might not use it. It is two actions that have to take. For example, for the light, if you want 50% of brightness, you have to say: Alexa, turn on the light! Make brightness 50%. It needs specific steps.

Berrak Kirbas Akyurek: Do you have any recommendations for future designers, particularly the architects?

In a more practical aspect, the sensor technologies work on radio waves within the electromagnetic spectrum. You can imagine if you have a lot of electronics in a space, it becomes quite hard to utilize. In building design, I do not think it is a big deal. I do not know how much noise they make. I can imagine that maybe something that can influence the whole design. For example, wi-fi became a vital thing only a few years ago, and everything has started to be centered around wi-fi technology in buildings.

Berrak Kirbas Akyurek: Do you have to develop your designs accordingly?

Yes, let me think aloud about how these technologies could affect buildings. Maybe I am thinking more like a building is already there, and I am designing it. Since my profession works like that, it is currently my mindset. Maybe I need to think about the building design process.

Berrak Kirbas Akyurek: Which building process do you think these products could be applied for that matter?

Let's take the interior ice skate product. If I go to a place with a lot of sunlight interfering with sensor technology. I have to change the product. I cannot change the building. For example, Smart Wall requires a dark room, but no one wants a dark room building. In my experience, I have to adapt to the building. In that sense, the industrial practice should find a way to compromise with the buildings.

Interview II

Place: Utrecht /NL

Date: 18th July 2019

Berrak Kirbas Akyurek: Can you tell me about your background? How do you describe your profession?

What I do is on wearable technology mainly as I call it to fashion innovation and try to apply innovative thing on the material level on production process level so how it has been made, and also embedded electronics. Those three areas I try to cover. I do that mainly on a human scale and as a fashion designer. I know how to make it better by looking at how to work with the dynamics of a skin. My main experience is applied to the body.

In my textile company, we design in fashion technology and the first bit of design and second bit of research because normally it is the opposite of research and development. Because I based on this how-to process aesthetically and approached its usability point of view more the design criteria. And then research needed on different levels, sometimes usability research and then fashion research. Fashion technology is an umbrella for both the three fields that I just expressed new materials, wearable technology, and the production process. That is the way I think it describes myself. Sometimes, it should be shorter, so it is a fashion technologist. I have a few terminologies there. I have a few terminologies there. Fashion tech was used to be mainly about the product in the past. Since then, it has evolved more into retail tech. Since terminology is kidnapped into different fields. It did not make too much easy for me, but we still make it also back. I think in fashion we can wear if they are being innovated on how you gave more sells, and make it cheaper a lot of economical innovations, but not on the product itself not on the material itself peace could have been exactly the same for ages.

We are working on a book, and again we are using fashion tech. For the development of our designs, we are working with fashion designers, product designers, electrical engineers, computer engineers, and textile engineers. My core is in fashion, textile engineering, and industrial design.

Berrak Kirbas Akyurek: Can you tell me about your current projects as such aim / your role of/ in your company, mission, and goals?

I am creating more sustainable, supportive fashion system. I think that can mean so much than what we currently do. I try to do that with the help of technical innovations. So that stuff can take care of us, helping us and make people healthier in a longer period of time without the enormous impact now the products have been produced today on a global scale. That is my goal. Also, I know that it is a huge goal. How I approach is just project base on at the time. I collaborated with Philips; for example, they do a lot in the medical field there. I learn how to embed this kind of electronic systems like technologies treating your diseases, gives you light therapy when you have back pain, and that kind of high tech. It was great to work with them as such a huge knowledge base.

But in the end, I want to have an impact on daily life. For example, you and I, we are in the same environment, maybe different request on climate with different needs and also dynamic needs. Why this whole building need climate control while we only need this part (our wearing) to be more comfortable, nothing more. There is a lot of energy. And as a compliment to the architects and building engineers, they always continued to think about thermal comfort, automated windows, and any similar innovation. I think in fashion we left at our side towards those problems. Textile industry is one of the motivations of the industrial revolution, and a lot of innovations went on. Textiles still breathable but could resist rain. Those kinds of things returned to only economical way, not the content way. It is a pity. We also have to bring these kinds of functionalities like architects are trying to do.

Berrak Kirbas Akyurek: What is the main intention and motivation behind the development of the project?

Actually, it was kind of frustrating when I studied fashion design that fashion pretends to be so much in front of innovation. So new, so cool. You have to buy new clothes. But nothing was really changing, maybe a different color, skirt line, but nothing changing. Next to that, I was born here in the East of the Netherlands, where people are still interesting super high-tech textile industry. So maybe they are doing super protective clothes for the US army etc. I thought of why this is happening and why fashion is doing that. It should be merged so becomes more relevant again. So garments become less and less quality, less and less value, and we have to change that kind of thinking.

Berrak Kirbas Akyurek: Could you describe the ‘novelty’ of your project?

I am aiming for everyday use, advances, but you do not necessarily be seen. In an aesthetical way, how we perceive fashion, I think it will not change. As we still have those bodies, we will need the same kind of suiting. The clothes will look the same. My ambition is for technology to be integrated. Maybe I do not see anything of your climate control inside your body because it is so personal for you but not for my purpose to know and experience it. So, for example, this is quite boring that a black t-shirt could be any color, but on the inside, we put electronics in which measure your heart beat and respiration together with your movement. Those three data set you can say something about your well-being.

Berrak Kirbas Akyurek: Does this example only measure your health data or provide any solution as well?

In this case, it is only sensing. That is not only sensing, and We do a lot of sensing, Fit bits, smartwatch can also sense the data. I think we are good at sensing over the thirty years making sensors better. But also we want something more, treatment and direct feedback. I think this is the second ambition that I have. Because the skin is covering some much skin, you can also do a lot for the body. In this case, we thought the feedback also should be integrated. This example is another one with tiny vibrations. It gives you a relaxing massage, or if you are a bit lazy, it wakes you up.

In another example, we are able to measure all these data sets from the back. As female way look more exactly the same with a man from the back. On the front side, this opened up the field of measuring the female body, which was a bit neglected before. Because we have those monthly rhythms, body fat, etc., are more complex than man.

Berrak Kirbas Akyurek: Nowadays, these innovations are described with a variety of terms such as; sustainability, natural, organic, smart, bio, etc.: Which terminology do you prefer referring to your designs?

For terminology, you have to figure it out yourself. As I mentioned, I started with fashion technology terminology, but it was being kidnapped from more marketing site. There are a lot of books with terminologies in wearable technology, e-textile, and many more. Whatever they name it, techno-fashion also bit care. I do not care, but over the years, I see the meaningless changes have been done. Wearable tech was also used to be quite suitable, but now if you google it, you could only find smartwatches and fit bits. I do not often use wearable tech, but I have to relate it to other people to understand my work.

Berrak Kirbas Akyurek: Is there any study that has been done to evaluate the user's experience?

For example, in this example, it looks like a normal black t-shirt. And we found out that it is too much integrated to start a discussion. The other one is very visual, with some examples in the middle. That is also a balancing act we are learning.

We especially tested how the user wants to have it, and also we tested it in a closed-loop system, so people had to lease it and bring it back. The results are totally different around Europe. We also tested the lifecycle of the product with the lifecycle of the used performance. Moreover, we asked do you need it is relevant, do you want to know, and how you want to know your information back. We conducted extremely comprehensive research, and online information is very limited. Please let me know if you have specific questions.

Berrak Kirbas Akyurek: What about washability?

It is totally washable. We tested 25 times. In fashion, the maximum number of a test is 30. So after 25 times, it was still working. We also tested that you applied them, you wash them, you remove the technology, and reapply them. We manage to them over five times. The life cycle of the garment is way shorter than the technology.

Berrak Kirbas Akyurek: Can you tell me about the user's experience by carrying a technological product on their body every day?

Surprisingly ok. This is a super important way of how we should test. If you see it, you have an opinion. People could say I do not like this color, and I do not want an open back, and etc. Everyone had a direct opinion on a garment when they looked at them. What we also did this. We made all the garments white, selected the target group on sizes and preferences. We had some criteria. It was a specific target group. We asked them to fit all sixty pieces and try them all, and share your feedback.

We conducted questioners with very specific questions. Most of the time, users told us they do not feel the technology. The idea of being measured is very scary, have electronics on your body is a bit scary when you think about it. For me, People's answers were surprisingly positive. Firstly, people want to take better care of themselves. That was the specific request they expressed over and over. But how can we do that? They were really open for that. 2/3 of the users told me that they could see the benefits, but it is not for them. It is for people in need such with disabilities, health problems, elderly and etc. But my ambition is to do less in the medical field and be more supportive, like giving you feedback saying you did it nice and something like a treat.

Berrak Kirbas Akyurek: What are the expected results of the design of this product?

The number of tech acceptance by a female was high. I did not expect this in the beginning. We also put a lot of emphasis on making it as feminine as possible. It was so well perceived and super nice. Here in the Netherlands, the leasing systems are not so accepted. But for example, in us, a lot of people lease their cars and

equipment. Here is not common, but we need to look at more circular business models. In the rest of Europe, it is also accepted. Then more the common things the people say it is pretty, but for people with diseases, I expected this answer but more than I got it. So for me, with these researches, my hypothesis was more negative than the outcome. But I still could not manage to bring that into the industry.

Berrak Kirbas Akyurek: Do you think do you need more time to develop this technology further?

The facts are so clear. I would like to say come on people! Open up for feminine tech, innovations in garments. It is a business model, something going on there. Why do you not see it? I am not sure it is the only time; it is all approach and understanding. But it is a positive thing that data sites amazon and google they also innovative garments. They have research departments. Slowly fashion labels field is kind of fair one. But about the fair, it is not a good reason. I think the reason should be that you want to make and produce the best products. But it does not look realistic.

In fashion industry, they all do the same. If you want to survive, you should do something different, whatever is different.

Berrak Kirbas Akyurek: Could you tell me the potential impact(s) of these products?

Every project has it is own application area. I think garments can support your life a little bit better in your daily activities, in your physical behavior, getting you out of your phone. Of course, the impact of garments on society is huge. For example, you come in like that I have an opinion on, you communicate with your garments. I can be wrong, but communication with garments is already huge. I think this can be more emphasized by technology. So that is more the usability side.

But the other one is a huge problem with garment production. We made so far away from polluting materials, not sustainable, linear process on throwing away when they are ruined. I think on the backside, those makers are also consumers

again. So there is also a huge impact to be made. And then you also have advances in a healthier environment and a better place to live. Of course, this sounds like super huge, super ambitious. I do only it like tiny things, but research says how this can do this. Every time I am trying to achieve more %1 percent, every time I am doing it better. In design, of course, you should be specific, but also, you should think and do something bigger. You can also approach to fashion industry a little more holistic comparing to working on small superficial changes like color, style, marketing, etc. I think that is super important for gaining success.

Berrak Kirbas Akyurek: Do you think it is possible to see any impacts on building design?

Maybe in 30 years from now, our demographics will change, maybe we will be wealthy, we may like to expand our homes, workspaces. I can imagine that the dynamics of living together also change the most important thing is to synchronize the u-cycle and also the life cycle of the pieces. So maybe they should be designed as rebuildable, demolishable with the same materials. If the cycle changes, everything could be changed.

Berrak Kirbas Akyurek: Could you tell me the challenges that you faced in the design of the project?

The biggest challenge is to bring it forward within fashion labels, garment manufacturers to convince them they have to innovate. Of course, they are challenges in the development of technology. There are challenges in material quality and the production process, convincing consumers. But for me, it seems easier than one bridge between the customers and production processors. There are labels and brands, and they are so stuck. They are considering not only the money but their reputation and branding, and it seems reasonable, but they are not so taking care of the customers. So frustrating to see they are saving their reputation by making more bad quality products. How long do you think they are going to accept that?

The big firms surprisingly stuck into their systems; they have strict timing, offices. I am working with a few big firms on many pilot projects. They have their systems

they have to produce somewhere, and that somewhere is at the other side of the globe while we know we can produce better 30 kilometers away in one week. But it is not an option because of their financial systems. I do not know they have a hundred reasons since they stuck into the system. Moreover, when we are making these pieces, we started to have with big manufacturers, tech firms. And they asked as these can be licensed in a certain amount. So you have to think about how you could afford these designs before they are not in the market.

Berrak Kirbas Akyurek: Could you tell me about your expectations for the future and your recommendations for future designers?

The future will not in the way I approached it, and it can always be better. Sometimes also makes it vague works. I want people to be healthy, in good proportion, ease their life, change the product cycle. It is not feasible, yet it makes keep me alive trying to achieve the only %1. It is good enough.

Interview III

Place: Bergen/NL

Date: 19th July 2019

Berrak Kirbas Akyurek: Can you tell me about your background? How do you describe your profession?

When I look back to studying at the university about twenty years ago, I like working as an architect, but I changed my focus to bio-based materials. I was more interested in shapes and spaces than materials when I was at university. Then, as I started to work as an architect in Erick van Egeraat (EEA) associated architects in Rotterdam, he was focused on constructing buildings but also very experimental materials in terms of new opportunities as such a variety of finishes with any specific content. So I learned a lot about the 'next level' in architecture from Erick van Egeraat. He was interested in shapes and spaces as well, but he adds another chapter to what I regard as an architect. Then I started doing my holiday house in Sweden, which we built ourselves. We built it with fifteen friends.

We would go there to the Swedish forest every twice a year. In a few years, a double team would develop. It was the first time I would build my own hands. I realized that the 'last chapter' of architecture is a lot of fun in terms of experimenting and finding out materials, the ways to use them, and see what happens to materials? How are they created? How can you work with them during the building period? What happens afterward? How do they age in time? Do they become more beautiful, ugly, dirty? There are so many levels in that to develop. I think from there.

We are more interested in all the bio-based materials; wood is a very obvious one, natural stone is an easy one to understand. Then, we came across a project in Thailand, and we are asked to work with bamboo. So there was a lot of fun to experiment with that. We did not have any experience, but you can find expertise if you want to. But also bio-based materials like a reed as attached roof, which is

very common for this area (NL) like in old farm-houses, and even in England and North France. They are easy materials by means of accessible and natural. For instance, in the Netherlands, we need to take care of our water balance because we are below sea level. To be able to do that, all the ducts and rivers should be clean. If you do not know anything, as reed grows, and you need to take away reed.

I think, about five hundred years ago, they thought we have all these materials and what we can do with them. And they made the roof. Actually, reed is a super nice material; it is an insulating material, an easily accessible tradition that we can still integrate a kind of modern way into architecture. It is not a high-end development, low-tech with alive materials that we are also interested in. I would say that is the stage that I am in right now. I am still into developing spaces and shapes. But within the past 15-20 years, a lot of experimentation with materials had been added as another level to architecture that we are doing right now.

Berrak Kirbas Akyurek: Can you tell me about your current projects as such aim / your role of/ in your company, mission, and goals?

To describe it simply, we would like to make 'biophilic' architecture. That is also a broad word. If you look it up, it does not really tell you anything. Basically, it means architecture with any relationship with nature. For example, that is a way to be making sure of if the sun comes into your building when you want or vice versa. It could mean you have contact with trees and plants in your surroundings that you use natural materials in your buildings. You could wonder why that is important because we can make a concrete box and put air-conditioning inside. It also works. But I think that is exactly what we did in the past two years. We lost our contact with nature. We thought we could solve everything by developing techniques. We did not only failed to connect to nature and also lost our understanding of nature. That's why basically we are ruining our planet. It is sad for the World and also sad for humankind. Because in the end, we cannot survive. If we go on like this another hundred years, the planet is gone. No, actually, the humans are gone; the planet will be there. We will be gone, and the planet will

recover and find its new balance. But if we want to stay here, we have to find a balance with seven billion people on the planet. We have to find a decent balance to live with nature, and these rhythms of nature like the seasons how circular methods that nature gives us. You know tree grows, and a certain moment that becomes fully grown, and then it dies. If there is a storm, it throws over the tree. The tree starts rotting, and little animals eat the tree. And from that, another tree starts growing. These kinds of cycles have been demolished over the years. A few weeks ago, I got a picture from an architect's friend who lives in Japan. He went back from a trip back to Japan to Tokyo. He sent me a picture of Tokyo, and he was so happy to be home. When I saw the picture of the city, I only saw concrete. There was not one tree visible. How can we imagine nature's function if a whole city is all concrete? There is no natural cycle there. If it rains, it comes down, and you need to make sewage for rainwater. But we forget that if you take away rainwater, we take away the lives that come with rain as well. There is no sustainable thinking there anymore. Our ambition is to make people understand that there is a balance in nature. That does not mean that if it is 20°C outside that, we have to sweat or freeze when it is -10°. There is a gentle balance, and we should try to use it.

Berrak Kirbas Akyurek: Can you tell the main intention and motivation behind the attempt to use bio-based materials?

There is a misunderstanding that the environment needs humans. The earth will survive. Our will to destroy our planet will not happen, we can kill animals, plants, ourselves, yet the planet will survive. So if we want to have a decent way of living for our children, we have to find a balance with nature. It is really about saving human kinds instead of saving the earth.

Berrak Kirbas Akyurek: Nowadays, these innovations are described with a variety of terms such as; 'sustainability,' 'natural,' 'organic,' 'smart,' 'bio,' etc. Which terminology do you prefer to refer to your designs?

Terminology is one of the tricky parts I think from this stage at the moment. Let's take the easiest one. Sustainability does not say anything about what you are

doing. Because it is so broad that everybody can claim their projects are sustainable. For example, suppose I have a Ferrari, which is bad for the environment, then I changed with Volkswagen, which is less terrible. So I could argue that I am sustainable. So if somebody claims they are sustainable, it does not mean anything to me. There are all these labels like Breams and Leeds for architects to focus on. If you can put your Leeds certificate on your building, you can claim it is sustainable. As you look into the building, the building itself could be questionable in terms of not taking account of the sun, fresh air, and many more. The only thing that you put an efficient, sustainable machine-like solar panels. So I try to stay away from those kinds of issues and start to appreciate the effort of people. Suppose somebody changes its worse car with the good one. If somebody plants a tree in their garden, apply insulation to the buildings. Everything we try to create a balance between nature and us is valuable. Let's not make it into a game. It is not a competition. That is all fine. That's my issue with putting labels on it like biomimicry, biophilic architecture. They are all meaningless, and it is a starting point for discussion. That's why I use biophilic architecture as a starting point, which helps to clear out the main goal of making balance with nature. Moreover, biomimicry is about understanding the smartness of nature in your designs.

Sustainability does not mean anything anymore. Maybe, in the beginning, it pointed out something. I think if you ask a hundred architects in the Netherlands if they think they build sustainable buildings. They will say yes. Maybe they are, or they have been trying. Again I am happy with the participation of people, but this does not mean anything. Let's step back and be honest about what we want to do and look at the results to see if things made an impact in the end after we build something. It is a building, and it is not a smart machine with a label. Do all these labels have any contribution to nature? Is it a selling trick? For me, it does not mean that everybody has to build organically shaped buildings or use only woods or anything; there are so many things to discover. Be true to what you are saying.

Berrak Kirbas Akyurek: Could you tell me the potential impact(s) of these products?

Again, that is super complicated to take out one little part of it. Let me give me an example; a private house for a client. First of all, the entire building has been constructed with wood, which is the main building material with a CO₂ positive balance. All the other materials, concrete, steels, and any other materials, have a negative balance. Let's start with that. There is a lot of wood available in the World. One little sidestep in this story, if I do a lecture anywhere talking about wood constructed buildings. The first question is always the same if you want to build with wood; you have to cut trees, which is terrible for the environment. And then I have to explain to people. It is a non-sense remark that makes clear that you do not understand how nature works. Trees can start growing. The trees that we have here are different from the other places like in Africa and Brazil. They become fully grown about 70 years, and they become old and weak and tumble over and start rotting. So a forest is not a permanent thing; it is a circular thing. Trees begin to grow, then they become fully grown, and they fall over, and this process starts again. If we can sustain a forest in this kind of rhythm, let's say we take out the tree for 15 years. If we leave all the branches left, they start rotting and add to the cycle, and a little tree will grow at the stop. The cycle is still imbalanced. The only thing we capture CO₂ data at the moment because we worry about that, but we do not ruin the circle. That's the main importance for CO₂ balance. With that, the nice thing is there is also something called economy, and there is a human being with the need for food and shelter. If they have a little forest, they can have a sustainable living for themselves. So, let me give an example. Imagine there is a small wood farmer in Brazil. He has a little piece of land, and he has own this land with two hundred trees. On this land, he has a wife and children who are hungry every day. Now, I go to Brazil and this little farmer, and say, can you please give one of your trees with good money that you can live for a year? I will make a house from that tree, and when I come back next year, if you will plant another tree, then I will buy another tree. So, he has an incentive to plant the tree and maintain the other trees that he has because he knows I will

come back the next year. With that, my farmer and I make a sustainable method. Trees keep on growing, and I can keep my architecture business; everybody is happy. Now, there are some people who will say to you that you cannot go to Brazil and buy a tree because you have to sustain our tropical forests. So, we cannot chop down a tree. What happens then? I do not have a tree, and a little farmer needs to feed his children. Then a huge American guy comes down to him, and hey little farmer, if you chop down all your trees and put some cows in there, and I will come and buy a cow for my meat in America. So, the little farmer thinks, let's chop down all trees and put some cows, so then I have food on the table for my family. Then, we lost our trees instead of one, and what we gained CO₂ produced cows instead of CO₂ absorbing trees. The farmer is still OK because he can feed his family. But, the world gets less happy. That's really one of the issues I would like to make, all the choices that we do, we have to choose to create in-balance with nature. Or do we fight with nature? I am a strong believer that we have to find a balance to be able to survive for the next generations.

It is also too naïve to think that you can just leave trees. For example, in Europe, we all chopped down all the big forests. That's why we have a lot of space to live in, and we can build out our cities. Then we tell poor people in Brazil that they cannot chop down their trees. They have to live in poverty when we are happy, wealthy people with no forest. Therefore they are producing oxygen they have to starve. It is a rather unfriendly way of looking into nature.

Berrak Kirbas Akyurek: Could you describe the novelty of your projects with bio-based materials?

It is very much in detail. First of all, what we try to do is building with the surroundings, so make sure you understand inside and outside, do not design projects that are completely at themselves, but interacting with the surroundings. So my main goal for the next ten years is to try to make an industry out of bio-based materials. In the Netherlands, we have a big building industry in concrete. Everything we do is concrete, sometimes we add a bit of steel in the concrete, but the concrete industry is big in the Netherlands. My ambition is to move that

towards bio-based materials. Wood is a classical building material, of course, lots of traditions, let's say in Scandinavian countries for many centuries. Here, we have hardly anything, but we look at wood as a building material from the past. We used to be dumb, and the only thing that we could do is to cut down the trees and put them on top of each other and called a house. The interesting thing at the moment in the last 5-10 years, especially wood, turns out to be a fascinating industrial material. So we had these CO₂ products, glued large panels of wood, and they are really easy to prefabricate. So we can easily come to the building site and just mount the whole building together with these panels. They are a lot lighter. In concrete, a lot easier to deal with since they are better insulated, they are not CO₂ producing. But we did not do this because we did not really have machines for it. For instance, CNT machines, the automatic cutters, I just make a drawing in AutoCAD, I send it to the wood producer, he sends this to his computer. Then, the machines start cutting out exactly the stuff we did in the position of the millimeters. The funny thing I learned over the past ten years on working with woods that if you do it like this with the help of this machine, that is only from the past ten years. If I had done it thirty years ago, you would pre-cut wood pieces that would never fit. Now, if they come to the building site, everything fits. We are building a theatre in Paris at the moment. They just started mounting all things together three days ago, and everything fits so far. So they have two big boats filled with wood panels, they are all numbered. They come to the building site with a big crane, and all things were mounted together. Within a few weeks, the whole theater will be up and closed. It is a completely different way of working on a building site for one year or two years. All the poor guys are working there under the rain and cold and being unhappy. We can all do that in a factory. We can do that easily with wood. It turns out, nobody is noticing except for a few pioneers. But this is going to change through this building method. If you just step back in history a little bit and look at 100 years ago, how did we make buildings, and how did we make cars? We made buildings roughly as we did at the moment. We did about the same with cars. Somebody was welding steel, put the engine, and combine all by hands. Now about a hundred years, cars are made by robots,

people working in car factories supervising robots and computers. But if you look at the building side, still the same non-sense, a guy is putting all these bricks under the rain. This dumb method shows we did not involve at all. I really think we are at the edge of the next developments at making buildings much more mass produces thought of and made by computers than hand. I think wood is really helping with that we are at the point of starting the contract of De Warren project in Amsterdam, which is also a big part out of wood. But, we cannot find a contractor that has any experience who are building wood projects on a sort of big scale. They can build a house, but not an apartment building or anything. We found one contractor, he says OK, I also do not know how to do it, but I want to learn. Because in ten years everybody will be doing this, if you want to be ready for ten years, we have to start learning it now. So let's do the project together. I have to invest a little bit because I understand I have to learn to build with this wood, but you can guide me a little bit. You know wood companies that can do it. So together we can make a product. I think that the point we are at the moment, there is one bigger apartment building, a six-story building, has been built in Amsterdam two years ago. They are now doing a seventy meters high apartment building in Amsterdam that they just started constructing on. Three more are starting up among them one of ours. You see, everybody, all architects, suddenly talking about this wood. I think it is really catching on. I was at a conference in Copenhagen, Denmark, two weeks ago, the main topic was building with wood. There is great competition in the World. Where will the tallest wooden tower be built? It is a completely non-sense competition. It is not really important who has the tallest, but it shows interest. A hundred years ago, you had the same competition for general high-rises. The competition was who can build the highest, not because it is important to have the highest but to be able to discover what a high building can do. Here is the same thing for woods; it is not important if the building is 50 meters or 150 meters anymore. The thing is that we are apparently able to make skyscrapers with pieces of trees. That is the innovation that's going on, and it is very exciting for me.

Berrak Kirbas Akyurek: Could you tell me the differences in the building design process?

The big difference is; preparation and building time. Doing a building out of wood requires a lot of engineering. We do together with the wood companies, the whole building in 3D that goes under the level screws that we have to mount. The factory drills wholes where future screws should be. So, it really becomes a sort of IKEA package on a large scale. This means that the designers and also the factory, we spend a lot of time developing to make the 3D of their building very detailed. From there, it goes to CNS cutters, and they all cut it themselves. Then in the building site, you could have done it in two months instead of a year; let's say as a comparison. So, you invest two more months in preparation, and you save eight months in building time just because it is so important that you do. If you do this with concrete, you do not really have to think. You just bring the base concrete floor and put all the ductwork. You do twenty centimeters concrete over it, and nobody needs to think about it. Because the concrete does itself, we maintain a sort of 'damn' method. Since it does not matter, you can improvise. I am also fighting technical people who install electricity and ductwork. Because they also have to start pre-thinking because we want to include it on our wooden floor.

We want the wood factory to make holes where they have to put into ducts, and we want them to put their ducts in the factory on the floor and the walls instead of the building site where everybody is freezing in the rain. There is a lot of time of unhappiness in the building sites. The nice thing is that the contractor for De Warren also has a sort of prefabrication part in which the whole interior finish is already completed in a factory. Normally, if you do a housing block, everything; you make the floors, walls, sort of the façade, then, in the end, you do the bathrooms. Now with them doing in the factory, pre-fab things organized, women suddenly become able to do the tiles. Because it is inside with a decent climate, women said that they want to work there; they do not want to work in rain and cold. If it is inside, it is a pleasant climate. So also, in the economy, you see things could change if we do not do such stupid things anymore as trying to build everything on site. We can really do a lot more preparation. I think that's our

biggest challenge for the next ten to twenty years to be able to pre-produce buildings and part of building in factories much more. Similar to what they do for the production of the cars, we can do this in architecture instead of trying to do it on building sites.

Berrak Kirbas Akyurek: You told the story of designing and constructing a building with bio-based materials from the start; what if you want to use bio-materials in an existing building?

I would say the same thing applies. With the existing buildings, it is always difficult to get measurements rights. If you have a hundred years old building, you have some drawings that are never correct anymore. Because people have changed things, they were not that accurate a hundred years ago. So you start measuring. It is entirely different from drawings. So, you could put your wall panel on the interior and cut it wherever the wall stops. You could also say, OK, let's first start where we need to start. So, we have this existing space; let's make good fitting drawings. By measuring the area carefully, we know exactly what we want, and then we can go to the factory, then we have mass-produced by the computer. We know, in the end, it will be fit because we did our mission right.

I would say existing buildings can still get a new life. One of the biggest tasks for using the existing buildings is related to how do we get them up to date for the current installation values. Because we make really well-installed new buildings, they require little energy. To use old buildings is always a big issue. That's really the biggest challenge how can we deal with it. We are again using bio-based materials. They are super easy installations. So if we would say we have this space and if we put a new interior. Basically, we make our whole space installed without putting additional installation in there. Not a plastic ceiling or anything else. It is not just about health or about how it looks. It is about that if it is practical to use it.

Berrak Kirbas Akyurek: Is there any study that has been done to evaluate the user's experience in the existing buildings in which biomaterials used?

That is an interesting question for a researcher. I think, in general, architects are not good at learning from their mistakes. Frank Lloyd Wright once said if a doctor messes up with his work and the patient dies, the patient buried under the floor, and nobody sees anymore. If an architect messes up, the only thing that you can advise clients is to live with it. I think, in general, as architects, we are not too good at learning from our mistakes. So, in general, I cannot tell you in a sort of organized way that if we always come back after years with a set of questions. I just know that a lot of people that I have worked for still among my friends and contacts. They are happy, satisfied.

Berrak Kirbas Akyurek: Any insights or observations that you could tell me?

For instance, what is really intriguing to me, we use a lot of wood products on the outside of the buildings. Wood is a natural product so that reacts to the outside. It turns into gray; sometimes, it turns green. It could become something really nice or bad. How is that controllable? So what are the influences from the climate on our building material? So we asked two trainees in our office to do two weeks of holiday research in the Netherlands by going to the building covered in woods from the outside. All buildings between 3-10 years old. They tried to do a map of how they aged? What happens as trees surround them? So, we were able to learn a little from what it has to do with which kind of woods are used. There are two hundred pieces of wood. It is crucial for proper ventilation behind the wood. All these kinds of issues that we can learn from the future because this is one of the worries for people to use bio-based materials. How does it react in the future? How long does it last? Also, visually I can promise hardwood; it will last for at least fifty years. That's one of the things that we want to find out and also show to our future clients. This is how wood reacts to certain influences. That is one of the main things that we try to learn from it.

Berrak Kirbas Akyurek: Could you tell me the challenges that you faced in the design of the project?

So many. I think it is one of them I already told you about the clients. One of the other funny experiences is that when it is all out of wood, municipalities do not

have rules to check it. Because, in general, we build with concrete or steel. In an apartment building out of wood, there are no regulations. So they need to go back to general regulations. For example, it needs to have fire-proofing for thirty minutes for this building. But how does wood reacts to fire? So yes, wood can burn. Maybe once in your life, you tried to make a little fire in outdoors or a fireplace. Do you try that with a big piece of wood or little pieces of dried wood with some newspapers, and you try to light it? It is impossible that you cannot make a fire only from a big piece of wood. So if you use CLT walls that are thirty centimeters thick, they can't burn. It is super-efficient material and much better than, for instance, steel. Because if steel heats up, it gets really weak. It does not get fire, but it gets fragile and comes down. Wood is actually a pretty good one if you use this in the right way. These are all the challenges that we need to concur with municipalities because they do not have regulations to test wood. There are a lot of questions marks also from them. If you want to make escape stairs from wood, it really sounds strange. I understand that it sounds strange. It is a natural material; it is probably possible that it will burn. Then we have to prove that these big pieces of wood do not really burn. They work fine.

Berrak Kirbas Akyurek: Which one do you think is the hardest? Technical challenges or convincing people; clients, contractors, etc.?

I think it is the first mentality thing. I was at a conference two weeks ago. An English architect who also built a high-rise building, seven story-building, from wood told a big fight between municipality in London, UK, about the construction. In the end, they showed all these proofs. In the end, the municipality was convinced that wood could not burn, and they said OK. You can do it, but you cannot show that it is wood. You have to cover it outside with stone. Because otherwise, people would be frightened. You asked about the technical challenges or convincing people. Technical challenges we can handle. It is really about getting used to this. You could say it is a new material, but it is not. It is just done in a new way. You have to get reassured. I do understand it as well. Only if we start using it and building it, people can say. You can do it with the wood.

Berrak Kirbas Akyurek: Regarding what we discussed here, Could you tell me about your expectations for the future?

I think the only answer to the future; if we do not do that, we will not only poison our planet by making plastics and others. It is a non-sustainable way because we forget to balance with nature. If we do not understand to sustain balance with nature, we ruin our planet anyway. That's, I think, is the main issue. We are at the cross points in building buildings, and every country takes it seriously. So I have good hopes that we understand what we are doing. There are still some people and presidents who think differently, but we have good chances that we are getting there.

Berrak Kirbas Akyurek: Do you have any recommendations for future designers, in particular to the architects?

I am also teaching at TU/Delft for a year, and I tell my students we have these design tasks to do. But if you want to learn something from me, it is designing wood. Because I know a lot about wood, I also know a lot about steel and concrete. I can help you with that as well. But I have wood knowledge. I am not telling you that for the rest of your life, you need to use woods but try and find out. All the twenty students made a design out of the woods. Even my co-teacher said in the end that I learned so much about, not only about wood but all these possibilities. I think that is my message to architects and especially of the future: Try it, because it has really a lot of potentials. It has good possibilities. It is not the bad potentials that we had and proved they are wrong in so many ways in terms of environment, building technique developments. There is really a lot of good things to contribute to our surrounding areas by trying to use sensible materials that they grow themselves. You only need to help them, maintain them.

Interview IV

Place: Delft/NL

Date: 24th July 2019

Berrak Kirbas Akyurek: Can you tell me about your background? How do you describe yourself professionally?

Very briefly, my background is in computer sciences. I studied in my bachelor and graduate program. I moved to the Netherlands about fifteen years ago to study human-computer interaction (HCI). I profile myself who is interested in the development of innovations in technologies but with a user-centered focus. So instead of looking for further technologies to develop, I am interested in what humans actually needed and how technology can make an impact on people themselves.

Two specific areas are trying to understand this impact of the involvement of users in technology; ‘sustainability’ and ‘healthcare.’ So I’m working in these two areas.

My main motivation has evolved through the years by talking about technology in general, very specific about data’s technological aspects. So you know, with all the new technologies, we gather data from everything from sensors, and social networks, and many more. I am trying to understand how these technologies are data-based and how they can basically empower people to have more time-agency on their decisions and what they do. And also to understand the impact of these decisions on either sustainability or healthcare. I work more for developing methods than developing solutions. Though when I talk about solutions, I basically give more agency to decisions in daily life. I think it is. In sustainability, I am mostly working in the areas of housing and the use of buildings in general, such as office environments, home environments, schools. In healthcare, I am mostly working on e-health, which is a field in that technology should help people to be more responsible for their health conditions or to use medical facilities less.

Berrak Kirbas Akyurek: Can you tell me about your current projects with your aim and role?

Most of my projects are very applied, so I worked within the context. I am always trying to see what is the role of technology in enabling people to have more awareness and more actions on their behaviors. For example, at this moment, I am working on two new projects. One is for schools, as European projects, we are working with six other countries and twelve schools at this moment, two in each country. These are secondary school students between twelve and eighteen years old. And we want to understand the meaning of data for them to make decisions on energy consumption. New trends are saying that these people should have a voice. They want to say something about sustainability. They feel the government should do more because it is their future. Yet, it is not clear what are they doing themselves? What sort of actions and possibilities do they take on themselves? We see that there become more interested when they have more power to convince others because they are just kids. So, we want to understand in these particular contexts what data can bring them. They need knowledge, arguments to convince others, knowledge to make their own decisions, and things regarding the impact on sustainability. So we want to understand what kind of information do they actually want to use, to play with, to experiment with, in order to have more agency and more active roles. So, particularly what I do is to develop these technologies and the platform that can help them to experiment with. It could be large as a room where sensors are attached, where they can also send videos or things they feel necessary to share. And with that, we understand. OK, well, can we do anything about what we see? What if we do a campaign for the next two weeks and we try out something? And we report what we see, what the outcome is, what the income has. So those sorts of things what we are doing there.

Berrak Kirbas Akyurek: So, your motivation is to gather the data and use it? Can you tell me more about the main intention and motivation behind the development of the project?

My motivation is to get the data and give it to them and making useful for them. There are two types of researchers in my department here. The ones who gather data to design new ways for convincing people to change their behavior to nudge them, to engage them in new behaviors. The ones who are gathering knowledge and giving back to people in ways that it is meaningful for them so that they can make changes. I mean more sustainable changes. I am working in the second group. In the group of what we can give people back. So there are tools for them to use and a variety of choices. I use technology for that. I feel that technology has an important role there. But in the other group, technology has the main role. So technology is designing for you. I know you and collect data from you and understand who you are; this what you should do. Well, in my view, in the way we work in my group is technology means to give you what you need to understand what is happening and see what the next step for you is.

Berrak Kirbas Akyurek: Are you working together or working separately?

These two groups are working separately. Yet, I work together with a group of people. It is not that very clearly defined. Like, we always talk about is ‘assistive technologies’ or ‘supportive technologies.’ Assistive technologies have the primary role. Supportive technologies have a secondary role. That is how we define these directions. In the area of healthcare is the same. I am now interested to understand food behaviors, and then the whole project is about how we can understand so far. Most technologies are now talking about what people eat, so we know what we can change that behavior. But nowadays, even dieticians are saying they want to understand why people eat more than what they need to eat. So the question is not ‘what’; it is the ‘why.’ This information can not be captured anywhere. All the apps and technologies that have now been developed until now. They are trying to take a picture of what the nutrition’s are and what are their calories. But nobody does not talk about why. So the project working on again; we are trying to see I can collect? Can I gather data for this context? What is the context we are actually looking for? So we are working together with different people like clients and dieticians to understand how do you explain these. What are things influencing what you eat? And how could you express that? How would you make

them that visible for yourselves and for others to help you with? Again it is data, and it is context and see what technology can do to help them—gathering this information to making use of it.

Berrak Kirbas Akyurek: So the asking the why the question is the novelty of your projects?

Exactly, So in one word. I generate contextual knowledge. One is expert knowledge. This is what we mostly do when we want to understand how energy works and to understand how behavior works. But we do not understand in many of these projects, talking about data is the ‘why.’ Why are these things happening? Why are we choosing these or those options, not the others? And it is complex data because it is very subjective. It is volatile. Even we do not also know why did I do this? What I ate two days ago? By then, we had a bad mood, sick, and even we were not aware of it. But there is a lot of chance to say we need to understand this mostly personalize knowledge for making things more and more effective. That is the innovative part that I can answer this why question.

For design, it is very important to answer this why question. Design is working for the casualty. Suppose these happen, and how can I change. I mean, that is the whole point. But the data now we have is available to address this casualty that we do not know what is causing. So you know this is happening, what is it coming.

Berrak Kirbas Akyurek: Nowadays, these innovations are described with a variety of terms such as; ‘sustainability,’ ‘natural,’ ‘organic,’ ‘smart,’ ‘bio,’ etc. Which terminology do you prefer to refer to your designs?

It is a very tricky question, I think, of course. I have seen using these words, depending on my audience, who I communicate with. I often chose the one there is making more impact on the context. So I am talking about contextual knowledge, the technology that can contextualize and contextual data. And these are the terms that I am using. It works well because my work is very applied, and I am working in the context of well beings, whether the smart part is. As I said, the discussions always engaged as ‘assistive’ or ‘supportive.’ This is one of the things that I talked about technology. And I am more into a supportive aspect than

assistive. I am more towards the technology that can play a mediator role than the leading role.

Berrak Kirbas Akyurek: So is it like to express your ideas you use 'bio,' 'smart,' etc.. depending on the context?

Yes, for me, it does not really matter. It is more like what I can. I resonate with my audience. What I always try to communicate in the context part, whatever I am using or doing, is to gather and to generate context.

Berrak Kirbas Akyurek: Can I say you do struggle with terminology?

In everything... big data, small data, IT... Everyone has a different definition. Even things like concepts, motivation, and autonomy... These are the words that I used a lot. Even those you need to spend time defining what do you mean on it. I feel that the moment you said the impact that you want to do, then the definition will come. It is more important to define the impact. I think we are all struggling with terminology. In design, we like to change the terminology almost every two years, meaning exactly the same.

Berrak Kirbas Akyurek: What would you like to achieve with the application/spread of these products?

Really really long term expected outcome is to activate us; I mean humans. I approach from more the philosophical view, is that we are getting a more passive way of living as technologies taking the central role in everything we do. And in case it is necessary. I mean, in healthcare, we also work with chronic diseases, and in those things, I do understand technology should have a major role. But if anything, I want to have more active involvement of people in their decision making through what technology could give them. That would be the ultimate goal. We are looking at what is the real role of technology and the real role of people, and how you can add something. And the why of this is, to me, is the only way to achieve any long-term behavior change or impact. In my view, any other approach cannot work today. The moment is gone; the effect is gone. That's why we have to give tools to people, not waste doing things indicating what to do.

Because the indication is not there, and they do not know anymore. So that is my long term view is about activating them, then long term effects can be accepted. Otherwise, they will just be more dependent on whatever has been given to them.

Berrak Kirbas Akyurek: I know you are not working on building design specifically, but do you foresee any consequences of the integration of these products into the buildings?

I am not explicitly designing knowledge for architects. But I am currently working with a Ph.D. student on social interactions in buildings, particularly office buildings, and she is focusing on open spaces and flexible desks. And how they positively and negatively affect social interactions in the work environment. This is not really related to my research, as you can see, but I do see in that, and the work I do because of these 'activation' facilities would have to be adapted into a new way of doing things.

One of the things I think could have an impact on this idea is people are having more agency in what they do and the effect of their actions. They should affect building the environment by providing more flexibility or allowing them to occur this agency to be able to use it. But for specific things, I need to think about it.

Maybe fewer facilities will be needed, but I am not sure. The responsiveness of a building has to move forward with what response to the other things we are working with. We should be more aware because I want to bring more awareness to people through their active involvement. If they become more aware, they request more responsiveness.

Berrak Kirbas Akyurek: Could you tell me the potential impact(s) of these products?

As I said, we are looking at awareness, healthcare, active involvement that may affect building design and bring societal changes. In the Ph.D. that I talked about in particular, we are looking at those. Like, what if we could make people more aware of their interactions and more agency to get back on why they were doing these things. So, what are the insights? For example, we have known many people

who are behaving very unsocial, talking really loud in open spaces. And it bothers everybody else, yet I feel no right or means to stop that because I may not see him next tomorrow. It is not the colleague you see every single day, so why I have to make this effort now? Why I have to do it for someone else? It is kicked me back many times. We are observing very unacceptable social behaviors like leaving the desk dirty. They say yeah, the environment does not allow us to build any rules or even to request anything different from people because we are not a community anymore—those kinds of things that I am trying to discover.

Berrak Kirbas Akyurek: Do you have any studies on the user's experience? Can you tell me about the feedbacks of the users?

For example, the project about food that I am working on right now. The main question I had that I needed to get in touch with people experiencing obesity and these kinds of things. How do they experience the whole relationship with an assistive tool they used to understand their behavior? Through in-depth interviews, contextual interviews or focus groups, and co-design sessions, I just give them pros to be active. And it was very interesting to see that although they do talk a lot of things that I expected to hear, such as lack of information, we have to understand everything about ourselves, etc. One of the things that came back every single time, in many different ways, is the constant feeling of the user as being judged by using these technologies. If you look at the reviews of these technologies, they are always good or bad, right or wrong.

Everything it is talking about you is either you are doing well, or you are eating healthy, moving enough. There are no grey spaces, but also it is vital for me. I want to give them knowledge. And to provide them the knowledge, I need them to tell me things, but the more they tell, the more judge they feel, so they stop telling or start lying. So they get at least something positive. So what I began to understand now what if I reward them just telling me whatever they tell me. Even if it is negative or positive. Technology will reward them for telling me something useful to me. It is very interesting because it was not about what exactly they wanted to know or the fact that they interact with any of these tools they feel

judge. Of course, this is an expansion to their social lives. People feel judged by their neighbors by their old dieticians, friends, family. They constantly feel judgment, but particularly the technology is not focusing on engaging, tell me more so I can learn from them. It is just saying what is good or bad. And the technology does not know why, so in some cases, that was not bad. Actually, it was good if you look through the context. So now, I am working on this, how I could build this without judgment. Of course, one moment, you still want to say this is good; the other is not, but we are missing that just rewarding them for using the technology and actively interacting with it. That is what I am trying to understand that if it could make a difference or any impact. So, in turn, I am trying to unlock them. The same also happens, for example, in the case of asthma patients. It is not a judgment as they feel, but they say technology always reminds them they are sick and do want to think that in every moment. They just want to forget. Because technology wants to make sure they are taking their medicine and their conditions are stable. The way technology works right now only reminds them of being sick. There is a design opportunity here.

I think technology has a very large focus on the long term impacts. I want to make people healthier. I want sustainability in the ecology of science. But on a daily basis, there should also be positive impacts and benefits. On a daily basis, people want to make sure they will be able to walk their dog walk outside, find a comfortable place to be. There is a significant connection between that long-term thing and all way we want to get there in the short term. So we need to understand the contextual moment. We need something different, so we need to act differently. We usually just think that that is why they need it, but it does not give the entire picture. Sustainability and healthcare are both important topics, yet people on a daily basis do not want to be bothered with them. They have other pressure things to work with. It has to merge with their lives, so it should give them positive outcomes. And design can do it, can provide pleasant interactions with appealing aesthetics.

Berrak Kirbas Akyurek: Could you tell me the challenges that you faced in the design of the project?

One of the biggest challenges in my field is that I am fighting against other pressing needs and issues people have. I am trying to reach sustainability or health as the long term outcomes. But I turn those challenges into opportunities, so now I am looking at what design can do to satisfy these pressing needs and see how they connect to the long terms outcomes.

The other challenge I think technology you have to use in my research. My technology should be stable enough to survive daily life context. I do more work with hybrid methods of something lack-oriented. I bring people here to explore something, and then I understand. But actual work that I love to do is put a thing out there and see what happens and how their knowledge is generated. Those are very practical challenges. I think, as I said, trying to build a community more active rather than passive, and seeing that everything else is trying to be the opposite is another challenge. I wonder I would ever reach that point or I would have to go for assistive technologies.

Berrak Kirbas Akyurek: Regarding what we discussed here, Could you tell me about your expectations for the future?

I do expect them to have a very conscious understanding of the role of technology. I see the ambition in the technologies that are supporting people more in the background by helping you. You should not talk about accepting technologies, adapting technologies, things are necessary steps, but the final step is the appropriation of technology what technology really has. Find a role in your life, and it works both ways; technology changes life, and technology itself changes because of the thing happening in people. It is the ultimate dynamic I want to reach that people allow to appropriate technology instead of accepting them or adopting them or passive involvement. That is the vision I see. We talked about personalization and making it unique for you. These things are extremely important to keep looking at individuals in their social context rather than one design to fit everyone.

Berrak Kirbas Akyurek: Do you have any recommendations for future designers and architects in particular?

For the idea of appropriation, we need to have a dynamic relationship between two; designers and architects. We (both for any design field and also architects) should be able to design products that are capable of changing. Designs need to be flexible but also engage people to tell more about them. That is how I see the future. We are talking about artificial intelligence, deep learning, and many more. Still, these technologies are now saying something like, 'let me know,' 'capture everything,' and 'will understand what is good for you.' That is not what I mean by technology that addresses me, ask me things, and learn from me, not only from my vital signals. It is also important how do I feel. The problem is that they are based on objective data. It does help but does not solve the puzzle and will not going to get further. Because people would be annoyed, like saying you ate a lot today even though you exercise a lot still you ate too much. Technology should say you have never done that exercise that much you deserve to have a treat. I recommend I should look for new designs making these technologies that can be adapt to things and more responsive. Of course, there are challenges, and everybody has different needs and ways to address them.

Interview V

Place: By phone

Date: 25th July 2019

Berrak Kirbas Akyurek: Can you tell me about your background? How do you describe your profession?

Next to a designer, I am creating a bridge between a laboratory and daily life. All the great research is going on at the laboratory but just only finished in a publication. I am bringing towards the World to help them to develop it quickly. I really believe that I can make it acceptable for the general public that you can push the development of technology further by making it quicker to integrate into the global system.

Berrak Kirbas Akyurek: Can you tell me about your current projects as such aim / your role of/ in your company, mission, and goals?

I think, as a designer, I can kind of challenge to work with the scientists. Because in the lab, everything is in a certain condition where you can make everything. But when you take it out of the lab, a new challenge begins. So I see my role as a kind of bridge between those two Worlds. I really believe, if you show people something new, it will going to make their eyes open, and maybe they will look at the World differently. That's how our daily habits and the whole system could be changed.

Berrak Kirbas Akyurek: What is the main intention and motivation behind the development of the project?

The biggest motivation is climate change. I think the motivation started when I was young because I have been grown up in a big garden at my house with my treehouse where my parents were taken care of everything around me. I think this motivated me to do something really good for the World. And I am also seeing that we are the only organisms in this whole World that using linear systems

instead of circular systems. I really do not like it. Actually, it is so crazy, and I really wanted to change that habit. For example, if you look towards our domestic waste systems, we just wish everything down to the drain because we do neither want to get dirty nor in touch with it. But If we do research what all possible with this accrual, you can achieve many possibilities from there. I see my motivation to change that habit to see everything like nutrition as an ecosystem does. You have to start something small; in the end, you can make something big that can make a significant impact. It also takes time to change people's behavior. So, you have to start something small, because people are never going to accept it when something is too big in one step.

Berrak Kirbas Akyurek: Could you describe the 'novelty' of your project?

I think humans to be in touch with nature again is the 'novelty.' In the end, we designed a lamp, but that lamp has a significant function to reconnect humans and nature and make a kind of new partnership. If you do not take of this plant, it will not serve to light you back. The product itself requests this kind of behavior instead of literally saying to people that you should take better care of nature. I think you can only change behavior by experience, not like telling you should do differently. People should want to do it themselves. So with this product, if anybody wants to see the light coming from the plant, s/he needs to make an effort to that. This product is a combination of science, design, and nature that can be placed on your desk.

Berrak Kirbas Akyurek: Nowadays, these innovations are described with a variety of terms such as; 'sustainability,' 'natural,' 'organic,' 'smart,' 'bio,' etc. Which terminology do you prefer to refer to your designs?

I do not always use just one terminology. I usually try to explain like I got my inspiration from biologists the way how they look into natural systems and their works and how we can integrate this. I can combine them. Please let me know if you find the proper terminology.

Berrak Kirbas Akyurek: What would you like to achieve with the application/spread of these products?

Actually, we are now integrating into the landscape. In Rotterdam, we are combining our technology into a park, which is the first power plant park (Living Light – Park, *Het Morgen Rotterdam*, NL). It was opened in November 2019 and open to the public. It is a project in 75 m² that we used for harvesting energy, and light will follow you when you walk through the light. That will also be a very magical effect. This is the first step in scaling up.

Berrak Kirbas Akyurek: Do you foresee any consequences of the integration of these products into the buildings?

I really hope that it will become more prominent in architecture and building design. You can integrate it in this way. I hope, in the future, a conductive platform plant will collect the energy and transfer it into your house. The new future buildings could be changed in a way that we can harvest energy from different sources for homes. And I really hope that buildings will become living organisms, so you need to take care of them.

Berrak Kirbas Akyurek: Is there any study that has been done to evaluate the user's experience on the Living Light project and Living Light park?

We have faced some bugs, which is logical because it is innovation and helps us develop it even better. Overall the visitors and early adopters are very excited and positive. Berrak Kirbas Akyurek: Could you tell me the potential impact(s) of these products?

I think the impact will be huge. Green around us can be an energy source. Technology is not just applicable to plants, and also to the other streams that are full of organic compounds like organic waste, domestic wastewater, and many more. All these waste sources can turn into energy sources. And in that sense, they will not weaken the ecosystem. Actually, they will be an ongoing green energy source that you need to take care of first. Now we are too from the beginning. Now we can harvest electricity from the plants, and we also know that we can harvest a lot more of it. We need to research how to do it and make it more confident. I think, for example, when we are a bit further, The Amazon forest could become a giant power plant. So, I really see what we are trying is just the very beginning of

something very big. And also, in architecture, we can do it differently by making it completely green. For example, the shell of a building can be an energy source itself.

Berrak Kirbas Akyurek: Do you think the design itself will be affected?

We, as designers, have such a great responsibility for the behavior of people. What we make affects what people buy, what people behave, and so on. If we are keeping designing more beautiful stuff just for appealing aesthetics, people will buy things they do not actually need it. This makes a more significant waste stream. Indeed it is triggered me to change something in the design, something to change within the current system and products to make it more sustainable. Because we need to do it, and we have to change it now. I really hope that how we design will be changed. Because I think what we do is not harming the bigger system.

Berrak Kirbas Akyurek: Could you tell me the challenges that you faced in the design of the project?

That's why it is so difficult to make because working with nature is not constant. It is too broad, and everybody expects a consistent product with high quality. Nature makes unpredictable consequences. It can be a little microbe in the soil that can change the light. That is the biggest challenge to create a product that is working well enough for people that they want to pay for it. Nobody wants a lampworking only ten percent of efficiency.

Berrak Kirbas Akyurek: You talked about the technical challenges. Can you tell me about the people's reactions to the project?

Actually, we got so many positive reactions from people. We opened a pre-order, and now we have two thousand pre-order for the living light lamp. We were also surprised that people really want them to use it. But the biggest challenge is making it consumer-friendly. Being an entrepreneur is also very challenging because my educational background is to be a designer, but as an entrepreneur,

you have to deal with business problems. Also, working with scientists is challenging because of the different language and motivation.

Berrak Kirbas Akyurek: Could you tell me about your expectations for the future and your recommendations for future designers?

I really hope that for future generations, this usage of plant energy is just taken for granted as something normal. This spare fuel is already waiting for us; why wouldn't we use it? Look at what is around it. Waste streams are not just waste put into the bins. But for example, striking your hand next to the stair rail can be an energy source because of the static energy. I see everything as an energy source. Energy is just one thing, and we also need to work on clean water and air. More like to discover the power that we already provide.

Interview VI

Place: Delft/NL.

Date: 30th July 2019

Berrak Kirbas Akyurek: Can you tell me about your background? How do you describe your profession?

I still consider myself a biologist. I studied biology and specialized in marine biology. Then I specialized further, join my Ph.D. in marine microbiology. By working with microbes in the marine environment, I did fundamental studies during my Ph.D. Later on, from marine microbiology, I worked for another seven years on the role of microbes in the environment in particularly what bacteria do in terms of producing and consuming greenhouse gasses in the Max Plank Institute in Germany. So I work on the role of microbiology in global climate change. That was actually my previous specialization before I came to TU/Delft, where I switched in my view to very fundamental applied research; civil engineering.

Because in 2006, I was working with my colleagues on developing self-healing materials, specifically self-healing concrete, using bacteria. Previously, I studied to produce limestone in specific circumstances, which can make concrete more durable. Since 2006, I am a lecturer, but also a researcher. But my expertise in biology, so I am working in the civil engineering faculty being specialized in biology. I am lecturing on sustainability, sustainable materials, bio-based materials, materials that have a very low environmental impact, But, on the other hand, they have very high practical performance in their applications. So the bacteria/bio-based self-healing concrete is partly based on active living bacteria. Bacteria provide the material characteristics that make self-healing, and more durable, so long-lasting. This is a bio-based technique. We can now make concrete that requires less maintenance, less repair, and also extended service life. So both results in much lower environmental impacts, and as a sustainable product, we have a better economic model that we can save money. That was the last reason.

We also started a company based on TU/Delft, which is commercializing three products of these materials worldwide. This is now slowly taking off, and we hope to see it in the future.

Another example is the growth of bacteria on concrete. You know concrete is the most used building material. It is relatively cheap, so that reassign we use it everywhere, but it has negative environmental effects. The production of cement results in a lot of CO₂ emissions and also heat the environment; the urban heat island effect. Because of solar radiation, heats of the material and concrete absorb all the heat and slowly radiates, so solar radiation is converted into heat. So that heat heats the environment. For example, in the last week, we had a lot of hot days, and typically in cities, we know the temperature can be 5-10 C° degrees more in the surrounding areas. This is generally because of concrete and asphalt since they act as the heaters in these cities. One of the other research lines is on how we can mitigate the urban heat island effect by growing vegetation on concrete. We tried to make a living facade in that sense, so we added a layer of living material on concrete. So, we can do with plants vegetation, but then you have to plan them yourself, maintain them, and have to use a lot of tricks (e.g., to cultivate and nursery the plants). But we can also do it autonomously by growing certain mosses on concrete, which mosses do that by themselves. They like to grow on hard materials of the seven hundred different species in the Netherlands. At least twenty of them like to grow on concrete, so this something we would like to stimulate. So, they can slowly convert grey buildings into green ones that have lovely moss layers on the outsides. Besides the aesthetics, the mosses are very good at cleaning the air. They can reduce NO_x and dust concentration in the air. We do not know exactly how much. Maybe, it has a limited effect, but at least they can do that. They can also retain water. So after heavy rain showers, we have a problem in the built cities, because of the hard materials, the rainwater runs off very fast and is collected in the streets. Sewer systems cannot deal with this amount of water, and we get flooding temporarily. One way to avoid this is that also to have green buildings. The vegetation retains the water for some time, slowly releasing it and prevent maximum water flows on the roads. So the flow

would spread over in time, the sewer systems have more time to deal with the water. And also, about the temperature effect that I mentioned, the mosses shield the concrete from heating up because they also evaporate water moisture and provide a cool environment. They are different benefits.

Berrak Kirbas Akyurek: Can you tell me about your role in your current projects and at TU/Delft?

So one of your questions is on maybe be focusing on real and functional applications in the built environment, how biology can really help to solve some practical issues that we see in the cities. Aesthetics is one functionality, but we have other functionalities like increasing the durability of materials, thermal comfort, etc. Although I am working for more than ten years in the civil engineering faculty, I still consider myself a biologist. I am also nicely recognized by my colleagues as an expert in biology. Because if they have some issues with microorganisms or other biological species like some negative effects on building materials, they consult me.

Berrak Kirbas Akyurek: What is the main intention and motivation behind the development of the project?

My first motivation is not much on aesthetics; it is on improving functional performance and lowering environmental impacts. So environmental concern at the same time showing that we can use nature/biology with ecosystem surfaces, also to enhance material and building properties. It is typically a win-win situation. Previously in civil engineering, biology/ nature was something decreasing their possibilities to build because of all kinds of laws and regulations that you have to take care of nature—so biology was considered as something hampering and something lowering the effectivity. By doing the opposite by showing biology is indeed effective in improving properties, and they start to believe that biology something positive. Because it is not only that you have to take care of, but actually make benefit of it. So, if you can read that second stage that civil engineering actively using biology in their designs and materials, it brings positive aspects.

Berrak Kirbas Akyurek: Could you describe the ‘novelty’ of your projects?

It is very novel in that sense, and we started in 2006 with self-healing material, which was very normal in the sense of using biology. It is not only doing bio magnetics because self-healing is known by biology. If organisms get a certain amount of damage, then to a certain extent, it can self-repair. This is not known in man-made materials. That’s why we started a large program developing self-healing materials, partly based on bio-based materials. So also by using other mechanisms besides biology to make material self-healing. But in our case, we use nature by means of biology to make concrete self-healing. That was very novel in 2006, and we became very worldwide known in this field. And at the same time, a larger program started called ‘building with nature,’ so they are a lot of other fields and science. Civil engineers also started recognizing that they should change their mindsets. Previously, for civil engineers, structures are needed to be built against nature because nature was something aggressive, you know, with flooding, storms, organisms trying to degrade your ‘nice’ constructions. So in civil engineering, nature was their enemy. Now, after fifteen years, they recognize they may use biological systems to enhance and improve the materials. They can get benefits by building cities with a way to construct coastal protections by using biology. Then, we call it ‘ecological engineering’ within civil engineering that you can make use of biology to improve certain properties in the built environment. And at the same time to lower the (harmful) environmental effects of our buildings.

Berrak Kirbas Akyurek: Nowadays, these innovations are described with a variety of terms such as; ‘sustainability,’ ‘natural,’ ‘organic,’ ‘smart,’ ‘bio,’ etc. Which terminology do you prefer to refer to your designs?

I would say smart. Smart means something is clever. This is what I just mentioned. We want to use biology to lower the (harmful) environmental effects and also to improve the buildings structurally and all the performance properties of the building industry. Sustainability still has a political meaning. Let’s say something negative in the sense that they see it as something left-wing in politics that you

have to be careful about it. The right-wing of politics says the economy comes first. This is wrong because the economy and nature should be integrated. It should not be saying that if the economy goes well, we will have some additional money to do something for nature. If the economy is based on environmental protection, then you save a lot of money for society. Otherwise, you inflict costs which you expense to someone else, so societal costs usually become very high. Therefore it would be much more clever, also economically speaking, to include nature in our society because we also get an economic benefit.

Berrak Kirbas Akyurek: What do you mean about ‘smart’? Could you explain a bit more?

I believe smart sounds much more positive than sustainable because people also get tired of the notion of sustainability. Because everything is sustainable, and a lot of greenwashing is going on by claiming that everything is sustainable. Ordinary people cannot understand the real meaning. We, as in civil engineering, collaborate with the architects a lot. But we usually say civil engineers are quantitative by trying to find how much does the building cost. But architects are usually very conceptual. So they say we apply green, so it is sustainable. And we civil engineers go one step further, and speak to what extent, sustainable, how much sustainability is there? It is because you need the quantification to understand how helpful.

On the other hand, when we say smart, it describes superior. If you make a bio-based product, it can be quantitative. Because it has different functional performances, and you figure out how well it performs. For each of them, you have to find out how it performs because it can also have reduced performance. In terms of products, you have to consider which performance property do I have and to what extent does my bio-based technology affects all of these properties. Otherwise, all we do is greenwash when improving a property and neglect all the others. So the quantification in our study is always essential.

Berrak Kirbas Akyurek: What would you like to achieve with the application/spread of these products?

To show that it is possible to apply this to the existing buildings in the form of repair products. We have two different types of products. One is mortar for structural repairs for more significant defects. We also have a spray, as a liquid, on construction, which has small cracks/defects. The water cannot penetrate deep more into the construction because of limestone, so it increases durability.

Berrak Kirbas Akyurek: By means of increasing durability, is it anything related to earthquakes?

The earthquakes are not an issue, you have to adapt your design, and it depends on the strength of the earthquake. Typically an earthquake results in damage due to overloading. So you have to design your construction to carry a certain amount of load. The question is how serious this damage. If it is only small cracks, then self-healing will help, but self-healing will not increase the strength of the construction. In the Netherlands, we have small earthquakes, and we can repair the small cracks with spray. The typical problem of the earthquake is with construction problems. This is not what we do with self-healing. We want to make it waterproofing and also preventing the steel bars from corroding because we have a protective layer on the steel. We can also build lighter buildings by reducing the amount of material.

Berrak Kirbas Akyurek: In which part of the building design process do you think this project could be applied?

The self-healing concrete decision would provide better results at the start of the design process. Because when you are allowed to change the design and that time, you have the ability to change the design. Otherwise, it is only added by means of an extra precaution against the crack formation. So then, you do not change the design. You put the same amount of steel, reinforcement and have an ordinary risk of leakage. Then, you apply self-healing to repair cracks. You can go one step further on the design process to reduce the amount of steel and thickness. Also, you can use it for energy efficiency and heat advantages.

Berrak Kirbas Akyurek: Is it possible to see the difference between regular concrete and self-healing concrete with bacteria?

There are several options for making different types of self-healing that depend on the aesthetical appeals of the architects. It also depends on self-healing agents.

Berrak Kirbas Akyurek: Is there any study that has been done to evaluate the user's experience?

We used some feedbacks. Actually, we are working with several contractors because they have to build, and they face all problems of concrete. They see the benefits of innovation, and they always have to take risks. We have already done five different projects with them, and they are very happy because they see the benefits. What we would like to achieve, the owners prescribe self-healing concrete. Moreover, the architects become more convinced to use it in different design options.

Berrak Kirbas Akyurek: Could you tell me the potential impact(s) of these products?

The most practical example is self-healing concrete, in which we added bacteria in formal spores together with the nutrition that adds to the price by making it more expensive. But when you do a lifetime cost calculation, you find out that you can easily earn it back because of leakage problems, which happen a lot in concrete constructions. Maybe for your understanding, if you build a concrete, you should put steel reinforcement in one hand to make sure it is strong enough. But a lot of steel added to concrete to avoid large cracks occurring because the concrete always shrinks. If it reacts, it hardens and gets smaller. Most constructions cannot just shrink. Because shrink is retained since concrete is attached to other walls. It tries to shrink but cannot, and then you have crack formations. A lot of pieces of steel are put in concretes to make sure concrete cracks smaller. So steel should provide strength against cracks.

However, with steel, you have a lot of problems, especially in underground constructions, which are exposed to groundwater pressure and leakage problems because of very small cracks. A lot of buildings are needed for repair already in the construction phase. After pouring the concrete, they have to send a team to find leaking points for injections. This is what we target with self-healing concrete.

They do not have to repair it manually because the bacteria come in, and they start to produce limestone autonomously and seal the cracks. That is our first aim. This works very well, and now you can do an economic model by finding out which typical constructions you can save money on and decrease the need for manual repair at the cost of the self-healing agent that you have to put in in the building stage. Now we found out on the next step that we can also reduce the amount of steel that is typically put in concrete. Since we can allow larger cracks to occur in the concrete, self-healing concrete leads to saving money by reducing the amount of steel. Now we are trying to save money by adding the self-healing agent. At the same time, this also lowers the environmental impact of steel again. So, now two ways of benefits are available, 'economic' and 'environmental.'

Berrak Kirbas Akyurek: Do you think it is possible to see any impacts on building design?

In the design, we have a nice example. There is a small construction in Breda, NL. An architect (Frank Marcus) wanted to design a roof from concrete, which must be very thin, about six cm skin. It is very difficult to build in concrete because of shrinkage; you usually get a lot of cracks, and you cannot make it waterproof. So initially, the architect came to us and asked for self-healing concrete if it allows him to design the roof differently. We said yes, we could try, but the owner said no. They did not want to take any risk. They did not see the actual risk of this project. After they build it, indeed immediately it became very leaky. Then the owner called us, asking if it is still possible to apply self-healing at that point. Then we had a bare product, but we could apply, and fortunately worked very well. We convinced the owner that the next time, he should be more open to innovations. For the architect, he is now looking for other possibilities for entirely different designs by using the potential of self-healing concrete. Cracking is always a significant problem in concrete constructions, while steel corrosion is another. So you need a specific cover for steel.

All in all, you need at least fifteen cm thick. Most of the concrete constructions are always at least 15 cm because of the steel inside. If we can reduce the amount of

steel cover, we can decrease the thickness of the concrete layer; therefore, it brings more flexibility to building design.

Berrak Kirbas Akyurek: Could you tell me the challenges that you faced in the design of the project?

The difficulty in the building sector is that there are so many players. You have to deal with the architect, contractor, owner, subcontractors, and material suppliers. They are all involved in the end, and they are responsible for the end-product, the building. So, one of them wants to apply for innovation; the others are always a bit concerned. Because, for the end-product, they also tend to blame each other. That makes it very difficult to make innovations in the building industry because they first point out the innovation. If you have just one party, which is responsible for everything, this one party can find how to organize internally and see how innovations can bring profits and risks. This is the biggest challenge.

Owners we talk for the largest infrastructure, the ministry responsible for infrastructures, want no risks. Those projects never want to apply any innovation because they want no risk, and why should they? We usually talk to owners about the risk analysis and the benefit analysis of what we can actually bring and how it works.

We have started the company and trying to commercialize it. Self-healing concrete is very popular in Europe for new constructions and to repair materials. Also, for Asia, the middle east, self-healing is essential. This is interesting because, apparently, there are different mindsets in Asia compared to western Europe. Because they do more benefit assessments, and westerns do more risk assessments. If we follow the same standards, everything should be fine. In the middle east and Asia, they are more into recognition by saying that if you do that with steel, you can expect the same problems. So I can say that they are much more innovation-oriented. We (Western Europeans) are very conservative in terms of construction. In China, when they find innovation, the government is willing to build it even for the high-risk constructions.

10. Regarding what we discussed here, Could you tell me about your expectations for the future and your recommendations for future designers and particularly to the architects?

It is always challenging to look in the future, so you do not know the aesthetic appeals or any other requirements. We are still challenging ourselves to make constructions to become adaptable by architects and designers. We approach buildings in forms of different layers, and each layer has a specific technical service life. The foundation and construction part should have at least a hundred years. This means a building should be there for about a hundred years. Other layers like insulations and facades have a shorter lifetime technically, so they should become adaptable. They should be able to make a completely different building by changing minor parts of the construction process.

Berrak Kirbas Akyurek: Do you also see any social impact of the daily human life of the application of these innovations?

Yes, we see that mainly green constructions. We know that nature gives us ecosystem surfaces. So nature gives us building materials, food and provides a clean environment. So this needs to be replaced with very hard technology if you exclude nature from the city. The city becomes polluted, very hot, aesthetically unattractive. People who want to make a picnic, they need to travel far away. So this is what we would like to achieve, inclusive nature in a building. For example, a person should only need to go to the rooftop, because there is a lovely garden or pool over there. You can make your picnic there, and do not need to travel far. It is scientifically known that people exposed to greener spaces feel less stressed. A nature inclusive building, not only economically, but socially bring several benefits.

What we would like to achieve, we developed a concept in our department. We call it 'triple green,' three layers of sustainability. The first one is related to the long service life of construction, so there is hardly a need to build new constructions. Constructions also should be adaptable. The second layer is to use material with a very low environmental impact. The third is that the construction

should provide something extra for the environment, such as it cleans the air, or purifies water, or give a good feeling for people aesthetically and psychologically. We want to have added functionality, so people always want that building in their backyard even if it does not belong to them; they can still benefit from it. It can do something extra through the implementation of biology. Normally nature supports our living, and we need air, fruit, food, cleaner. This is what nature provides. So it is essential to have to nature inclusive cities. We have environmental and social issues in our cities, and nature can solve them all.

Most of the bacteria are very positive. We make cheese, medication, wine, and beer, etc. We are clear to people that our bacteria is safe to use. The other thing that I always say in my lectures that convincing people to use nature in a building is a good idea. Some of them have some fear, such as dirty rats and venomous spiders will appear, but it is not the case. However, sometimes it is difficult to change their minds.

Interview VII

Place: Eindhoven/NL.

Date: 31st July 2019

Berrak Kirbas Akyurek: Can you tell me about your background? How do you describe your profession?

I work for two different companies. One is on mental healthcare, an innovation program everything related to remote and online treatments such as e-health and virtual reality. I also work in the electrical installation sector, which is about more living at home independently. It is more into technologies to provide remote care at people's homes.

In the mental healthcare company, they call me 'innovations scout.' I am the person who scouts for new technologies that could be potentially interesting for mental healthcare. Scouting is not only about possible technologies, but it is also scouting research groups that might have an interest in them to make connections with what kind of research is happening. It could be somehow coupling both of them. I know their topics and problems. To deal with people working in that area and I am connecting the right people at the right moment. I also follow what government funds. For example, they have a lot of subsidy programs. I support all these programs and what kind of topics are really important and make these connections and build on starting their projects.

Practically, the same thing applies also for the installation company only then a different topic; home technologies and what kind of home technologies could be implemented to assisted living at home independently.

Berrak Kirbas Akyurek: What is the main intention and motivation behind the attempt of integration of the technologies?

Because I am working in healthcare, the most important thing in healthcare is the huge shortage of people at health; carers and curers. People provide treatments but also need to take care of the others, and this is going to be a huge shortage of

that. Also, going to be an increase in the number of people that will need some form of care. So, there are two strategies that the government can do to find solutions to these problems. First, try to make people more aware of their responsibility for their own health. So, they will embrace a healthy lifestyle. The other strategy is to provide care with fewer people to let technology take part in that care. People will be as much as possible in their own home environments. In practice, if they need to do exercises or do things, let them do things themselves, assisted by technologies. Only a few people will be provided with professional care if it is necessary.

Berrak Kirbas Akyurek: Could you describe the ‘novelty’ of the technology that you are trying to implement?

Novelty is using as technology, not necessarily apply as a replacement, but as an additional something that you can add to your care system to bring them your personnel and cost. For example, that is a really good looking academic environment (TU/e Vertigo building). A lot of things may seem very natural, commonly known, and you may think, why are we still talking about this? But if you go inside these care organizations. The people there feel the gap between what is possible and what is actually being used is huge. That gap is very, very difficult to close.

Berrak Kirbas Akyurek: So, as you contribute to the implementation of the technologies, the gap is getting closer?

Very very slowly, very, very difficult. For example, everybody uses skype, but when do you skype with your doctor?

Berrak Kirbas Akyurek: Never

Why not? Much more comfortable if you could consult with your doctor. But you have to go there. It is such a simple technology. Each doctor uses these technologies in their daily life, but nobody considers it normal to skype with their doctor. There are a lot of things in people’s heads. We are now dedicated to a team in Eindhoven. And we are told them they are the first online team. They only use

online technology, only when it is absolutely needed; you see people face to face. We selected people who really wanted to do this. They have better results, and treatments are faster. They do not see their patients physically, but they have more contact because they have shorter but frequent meetings via skype. In the meanwhile, they use e-mails; they have a platform that provides feedback. It is much more interactive. In the past, you would see your physiologist every two weeks.

You go and see them only for one hour, and you close the door and go, continue your daily life. And you just forget about everything that has been said in one hour in those settings. The patients say that I close the skype meeting, and it is still my problem. But usually, I would go to a physiologist. And when I closed the door, my problem remains there in that room and go away. It is in their own environment, and it is really inviting people and stimulating people to start to work on their own problem, not put their problem in their physiologist office and leave and go. And that is what we are trying to explain to other physiologists, but only a few people are trying. Because most of them saying, their patients want to see them or not capable of using Skype.

Berrak Kirbas Akyurek: Is it like doctors refuse more to skype more than patients? Absolutely.

Berrak Kirbas Akyurek: Nowadays, these innovations are described with a variety of terms such as; ‘sustainability,’ ‘natural,’ ‘organic,’ ‘smart,’ ‘bio,’ etc.: Which terminology do you prefer to refer to your designs?

For me, smart and e-health. I also use many different terminologies. It does not matter so much. Usually, I use smart if it is more connected to some kind of remote and digital part.

Berrak Kirbas Akyurek: What would you like to achieve with the implementation of these products?

I think I want to have the technology to be integrated into the daily processes of the healthcare providing system. In the end, it should lead to a solution, which is

a simpler problem that, as a society, we will not be able to provide healthcare in the way that we have provided it in few years. Healthcare is becoming too expansive, and there is a huge shortage of people. So at some point in time, if you do not make the transition, you will not be able to provide healthcare in the right way to people anymore. So this is needed. The final goal is to make healthcare still possible but shorter and faster. Companies are trying to make this transition to bring into our home environment.

Berrak Kirbas Akyurek: What is the case with the installation company?

If I am looking into installation companies, that is a different kind of story. I am still confused that a lot of these technologies are now used for independent living like indeed video calling, alarm systems, lifestyle monitoring, and many more. Those kinds of technologies are not implemented yet on a larger scale, always plots, with a lot of subsidies, with a lot of short term goals. They could not sustainably be implemented into a care system. If you want to be sustainably implemented into a care system, you need to consider that care companies and care providers are not technology providers. So they do not offer a technology service. That's why I think these engineering companies with people who are always around houses. Like installation companies such as gas installation, electricity, water supply, you just call, and they came to you on the same day. They are close to the living environment, and they have 7/24 cars. They are accessible and come when they are called. They are the actual people who come inside your houses. Other services do not come into your home. For example, if there is a problem in your attic, these engineers enter into your attic, fixed it, and then go. So, these engineers are the ones that you could teach new technologies. You could teach them what to do, how to make a network, put the sensors. Small companies maybe do not have ICT (Information and communication technology) integration knowledge, but a lot of large installation companies know how to integrate. So, why do not they (big companies) provide a service to small installation companies that get you from a to b business model? For example, large companies could even offer a package to the smaller ones to install and connect some kind of sensorial spots for the care providers. And care providers can provide

their care through that system. It could be an integral part of your home technology like your lighting could be your caregiving system.

Berrak Kirbas Akyurek: I was going to ask that do you foresee any consequences of the integration of these products into the buildings? But you told me a bit like that your lighting system could be your caregiving system.

Yes, why not? Many lighting systems have led lighting nowadays. You can make one connect point, maybe a center—a lot of integrated light and centering technologies. For example, led lighting can be used to communicate by using frequency patterns. So you can give high-frequency signals that one could communicate. So they could also transmit essential data like alarming unusual situations.

Berrak Kirbas Akyurek: Do you foresee any outcomes if these technologies implemented at the beginning of the design process?

I think integrating into the building is the most simple thing. I mean, with current centering and led technology, you could put a camera, sensor, camera even be a sensor. That is easy. I think it is the trend to be more prefabricated elements so you could make these elements in advance. You could put sensors. That is easy to put them into the system, and architects also know this. The difficulty is to implement them into the working process of the other parties. For example, we have this building with all sensors, and how do you connect to your care provider. Then you can have multiple care providers, or you want to change it, or you need additional care.

How do you connect to all these different working processes? How will you do this? So, they might even be required central space that all data should be connected where some form of intelligent space you know how to put it to the other care providers; they also do not know what to do. A lot of different questions will follow. I have experienced that. Some care providers told me that they do not want to know all this health data. Because knowing means I have to do something, but there is no time and organization. That is a tricky thing. I think why they worry about it that they need to have stuff. Suppose you have all these houses with

sensors giving data, what they should do. The cost, number of stuff, the working process are all difficult, and it makes many years to do organization. That doctor does not use skype is simple, but this is very complex.

A lot of different kinds of processes that we were talking about. Now we have an online team, and I am very happy that we are one the pioneers with online treatment. We are already seen how it works, and now we are talking about how we could not make the team really takes all these houses under supervision. But you need an all-new type of care person. People working in care organizations are not used to these technologies. Even young people have not heard anything in their whole education. We see people coming from schools, and they have no clue because their teachers do not know it, and students do not know it.

Berrak Kirbas Akyurek: Any prejudices?

Prejudgments are everywhere all around the care system. People are refusing to work with technology, saying that they want to work with people, not technology. If you ask about technologies who experienced them, you will get positive ideas. But if you ask people what they think you will get much more negative opinions which are very strong. Healthcare is a traditional sector all about people making physical contact with each other.

Berrak Kirbas Akyurek: Is it one of your challenge?

This is really important and the biggest challenge. Because I think technology is there and it is not difficult. And I think we can organize all these kinds of around the technology which can be integrated. For example, we have smart people who can design it, and you can design a house full of sensors even for a low cost. I believe we have everything; all the technological components. I think the real problem is in the working processes and the judgment of the people. I think more people than the processes that make it difficult.

Berrak Kirbas Akyurek: You mean it is possible to fill the knowledge gap between professionals like architects who can learn how to integrate technologies, but it is hard to fill the knowledge gap of people who are the caregivers?

I think, as an architect, there might be some kind of idea to integrate the technology. But I do not think about how to integrate into the care system, so the process around that. Then at the beginning, with some of the innovations, I said Skype, and you also need more than skype because it is not a secure platform, which is something close. So, in the beginning, we started with a security monitor in somebody's house that could talk with the care provider. We came into one woman's home; she has one monitor from our company, one monitor from the other, and also another one for her husband. Now we have apps and so on, but it shows how difficult it can be. Technologies should be open. For example, smart doors are opening to the caregiver. Before that, there is a box with a code in it, but it was not secure. And we were getting a lot of complaints. Also, you need to change if you change your care-provider. Technology should be flexible; you should not have to change the whole system.

Berrak Kirbas Akyurek: Could you tell me more about the user's feedback on these technologies?

There is a lot not known how people experience different types of technologies. So a lot of work and so many pilot studies have been going on. One vital feedback is on the worries about data. The systems create data that comes to the organization, and the question is what we do with it? For example, many monitoring systems might be like big brother is watching you. So I know all these things are giving feedback. And then the funny thing is that, with many sessions that we had with our clients. They told us that as long as the data is used to give personal feedback that they can do something, they do not mind. Of course, data should not be sold or given away, but we see that people find it very acceptable to have technology in their home environment as long as the outcomes are used for their own benefit.

In general, we got positive feedbacks, some saying I had trouble getting used to seeing people on a monitor. But interestingly, people talk more openly than face-to-face. Somehow technology makes people more open. For instance, there was an elderly lady with dementia and already in a clinical setting for a few years, and

nobody could communicate with her because she did not talk. Then, they put a bicycle with a screen that you can cycle with sightseen for an experiment. Then, she saw something and said that she knew that place since she used to live there. And she started to talk about her life with everybody around her. Let me give you another example as well about the man with autism with social anxiety. He did not speak nor leave the room. We have a small robot and placed it in his room. The robot talks via a man typing something, and the man knows that, but he started giving a response to the robot.

Berrak Kirbas Akyurek: Could you tell me the potential impact(s) of the implementation of these products?

I think I already mentioned it. I think the impact is on the healthcare system in terms of society being provided by a high level of care. We are on the verge that our care system is collapsing. You see, huge waiting lists in care, you see elderly people are alone without any social network, and alone at home because they cannot be admitted into care provider. So I think we are letting people down already, and that problem becomes already bigger. As a bigger picture, I think we should be able to do more.

Berrak Kirbas Akyurek: Regarding what we discussed here, Could you tell me about your expectations for the future?

My expectations from the near future are to solve the problem in the caregiving system by bringing solutions through the implementation of technologies.

Berrak Kirbas Akyurek: Do you have any recommendations for future designers, particularly for the architects?

Interoperability is a key thing. I think you can combine these kinds of technology all into one. But you have to make sure that it is accessible by different systems. A system could be expanded over time. In the infrastructure, you should always put additional parts that are interpretable. That is the technical challenge for the designer, basic infrastructure that you can develop further. Another challenge is to take caregivers as manifold, not just people living there. The informal caregivers

are also there, different organizations, different people. Even proper care can be provided by a company that does not initially supply care providers. So they could become complete business models somehow these what you put in a building has to be so flexible. I think the biggest challenge is that we are now technology is developing more like exponent, so what you know today could be so different in five years later. When you built something, it is for 35-40 years, and services should be in the design.

Interview VIII

Place: Arnhem/NL.

Date: 5th August 2019

Berrak Kirbas Akyurek: Can you tell me about your background? How do you describe your profession?

I am still a product designer, in essence. It has not changed and will not change in the future. I do think that any designer these days cannot only design a product anymore. A lot of designers will or should be involved in value chains how did the products are being produced. So, concerning raw materials, production manufacturing techniques, consumer behaviors, etc. I think that the designers of the future and are now interested in them very much. There are too many things that have been changing these days with new materials such as mycelium and biopolymers, etc. Especially these materials have a lot of unknowns. As a designer of the old times, let's say you wait for the other material specifications to be ready. Then, you can select them based on the product you are supposed to design. Those days are gone, basically. It was a beautiful era with unlimited possibilities of polymers with unlimited plastics, also metals, and amazing manufactural techniques. None of those are viable to new material preferences. So, for the designer, there is no option to be only a material designer, to be a contextual designer, social designer, and of course, a developer designer. Because at the end of the day, it is still about what type of product you produce; that is the core. How we do, that is a complication. That's why I still see myself as a product designer because I believe that is where the relationships between the user, material functionality, and spiritualism happen within the design and use of a product.

Berrak Kirbas Akyurek: Can you tell me about your current projects, as such your role in your company, mission, and goals?

So typically, I have been working with my studio as an entrepreneur for almost twenty years from now. Nowadays, I have multiple companies because many of

the projects that I have done in the past were self-initiated. So there is no commission, no client. When these projects have appeared to be viable, as well as in the design field also economics, then a separate company becomes with has its own entity and management structure. So I have three companies next to my studio, and that how I actually corporate. Because besides product designer, I think it is important to not only design things, but also to make sure the implementation of the design, because a more substantial part of my profession is proving best practice examples. That's why I basically design best practice products, and I have to initiate everything along the line in order to prove myself and to the stakeholders and general consumer. This is an actual viable design. Therefore, I had to start companies, so I have formed three different companies to make sure. So my main work these days is management, sadly. It is also part of the job. I am mapping out the value chain, used stakeholders, strategies for approaching them. I am telling the stakeholders that why it is important for them to step out of the existing value chain and to consider something new like mycelium and algae. I am explaining why they should see as the opportunity, not see them as a burden. So partner selection is a part of my daily profession, and then 5-10% of design; the rest is partner selection and management.

Berrak Kirbas Akyurek: What is the main intention and motivation behind the development of the project?

Motivation is many things, of course. So algae fabric was typically a project that arrived in 2014 from two things. One of which is the concept of what is in your backyard. I am amazed by how much we miss, even though the things are right beside us. And it is OK that we miss things besides us that it is understandable. Because either we proceed as things as that has been used in the past; historical. But then our job is to reinvent systems of the past. Because within current respective technology, we should revise these things, clearly have worked for us people on holistic levels. Secondly, what motivates me is this, of course, the inspiration. The fact that day of doom is upon us. This is how many people see this. Yet try and see this as giving of something pretty amazing. So that brings the back-casting process we use quite a lot. So back-casting, you might know, is trying

to envision quite radical in the far future. You optimize your goal and task as a researcher or designer to finding your way back to now.

Through systems, materials, people, and many opportunities, back-casting seems possible to find your way back to now. And you also might consider that reverse process as a road map to get that's quite algae fabric. Algae fabric is a good way to maximize the LCA (Life cycle assessment) of the textile. What would be the best textile that we could intent? How would it look like with algae fabric? Clearly, we resolved this in the back-casting process. Because of doing it now, there is no reason to make algae fabric. It does work but does not work in the whole economic system. It will be step by step; that's why we do back-casting. It is proven in a different thing, but we have done this research in six months just in order to do make a possible roadmap of the back-casting process. You have to check a lot of things, viability studies, but also opportunities in legislation all these things. So that motivates me as well.

The methodology and the technology behind the awareness of the opportunity; these two things are crucial to motivate others as well to create a new value chain like mycelium is also so important. It is not a good product, but it does not really matter much. We need to design towards the systems, and not necessarily the other way around. Just trying to apply things to the system that we have now does not work. So we have to find another way.

Berrak Kirbas Akyurek: Could you describe the 'novelty' of your project?

By the people around me, I would be seen as an 'eco-warrior.' I myself do not see as this is necessary at all. For me, it is about mapping opportunities. Nature is, for sure, an 'inspiration' and also the 'ignorance.' We, as humans, have these approaches in our system. Outside nature provides, so few of our things work despite the opportunities. Within this current time, with so many innovations started to move, temporary connections, and the systems taking apart and rebuilding again, we are on the brain part of that change. It is obvious. It is more about seizing at all opportunities. Then again, not ruining the World in this process. It is more of the design parameters. Instead of just novelty or special

request should be part of the design parameter to start with, you cannot attempt to create a full circular model. In my opinion, it is not possible at this stage. But it does matter when should be a design parameter. Even though there is an urge to good design, good solutions for a good cost, this is not the daily push in my studio. It is more about finding more opportunities and proven to people that it works.

Berrak Kirbas Akyurek: Nowadays, these innovations are described with a variety of terms such as; ‘sustainability,’ ‘natural,’ ‘organic,’ ‘smart,’ ‘bio,’ etc.: Which terminology do you prefer to refer to your designs?

I am very explicit in the terminology we use. So you will not hear me saying ‘bio-based.’ Because bio-based is a basic concept to find something from nature and to organize it, and propose in such a way to fit existing synthetic technology. That’s how bio-based polymers in this stage are implemented.

Not so much of creating a biodegradable product, but something to match to a synthetic system. Of course, there are bio-based products that can be compostable, but often they are only compostable or generable in a controlled environment in the industrialized process. Also, there is a big difference. Everything compostable does not necessarily mean it could break down into its elements. You might be able to compose what you left. What are the components that can actually be used? So the terminology is crucial. That is where a lot of users, consumers are lost in the translation. They have no clue what it means. Mixing up systems at this stage, so they do not like the synthetic anymore. Why? These are incredible materials. You can regenerate multiple times. It does not make sense if you get material like corn and glued with synthetic elements. That material now is just wasted; it cannot be regenerated, cannot be recycled. So this is a wrong concept you should get away from it as soon as possible.

Using bio-based materials is something that has a different matter. It might be a good idea. You can have a bio-based elastomer. There is no glue involved. It is used for shoe production, and it is quite radical. You can never glue shoes any more into the production process. Adidas is doing it now. They said at this stage there is no bio glue strong enough to make sure that shoe to be worn in one year.

So we can only do this with high chemicals to provide consumer satisfaction. It is complex. We can recycle any polymers right now. We can regenerate any polymers, but economically viable? No, it is not. But the technology is there.

These complications are very difficult for the consumer right now. For example, in veganism, I won a vegan award on palm leather. I have been working on palm leather for about ten years. When I started, veganism was not an issue. It did not even exist. And I now become a vegan hero? Why? The consumer is trying to define all new holistic things with organisms.

So yes, the terminology is complicated. It will take a lot of time to make it happen. Actually, greenwashing is significant in bringing that knowledge.

Berrak Kirbas Akyurek: Do you think greenwashing is something good?

What greenwashing does, it creates a vocabulary. You have to see it as a chance, like a commercial. It is up to the consumer to define whether the greenwashing campaign has viability for them. Greenwashing is an essential part of going to this translation. It cannot be accepted entirely, but it creates a consciousness effect.

Berrak Kirbas Akyurek: So we should see the potential of greenwashing in that sense?

The market needs to sell stuff. Otherwise, the whole system does not work. That is my point.

Berrak Kirbas Akyurek: What would you like to achieve with the application/spread of your products?

So my job as a designer is developing best practice examples. Obviously, my designs will not change the world. They will contribute to the transition, like many other designs. So I am trying to make sure that our projects are reliable. We bring them to market in the system where new value change is. That is my main goal as a professional. It is quite limited, but you should imagine that my oldest company is running for ten years, the others are six and three. So these are long-term projects that create principles along the way. Research is, of course, is the goal to make more good examples.

Berrak Kirbas Akyurek: Is it like a step to transferring the knowledge?

It is always a step in transferring knowledge. I think of the products, in a way, from a studio perspective. Let's say; my products are not chairs; it is the process of making the chair, obviously. So I am not selling the chair. I am selling the process. That's the reason we have done a study to optimize the collection of stakeholders who should combine forces within these value and supply change. Who is where? What purpose they have? Who is taking of certain responsibilities within that value change and not defined yet? It is very interesting and quite complex. So we use a lot of mapping. Map out where our opportunities are, where we need people with a new profession. For instance, the concept of drying mycelium is the biggest challenge in that value change. Because even though how lean it is to grow mycelium, drying was struggling.

Berrak Kirbas Akyurek: I know you are a product designer, but do you foresee any consequences of the integration of these products into the buildings?

I work with architects quite a lot. It is about understanding each other's professions. So people have no clue what I do because I do different things. So for the bio-laminate company, bio-laminate has no doc, no organic compounds. Put it on the surface; in fifteen years, re-process. There is no negative material compound. It is quite novel and special. So we worked with architects because, in my opinion, we need them to understand most likely, we are not building a building anymore. For a moment of fifteen years, most buildings we build in a cycle, for many different reasons with the fact that as consumers, we have different demands comparing to fifteen years. Buildings simply are not suitable anymore what we thought of them fifteen years ago. Therefore, when you are an architect or real estate developer, your responsibility will cost soon that you have to take away the building. So implementing a lot of these technologies now will be cost-efficient in the future. So, it is a big thing. These are such crucial things, but so complicated. But sadly, I am not working with architects enough.

Berrak Kirbas Akyurek: Is there any study that has been done to evaluate the user's experience?

Yes, a lot of studies have been done. We do focus groups. We need those. Imagine a product that has not been around, like palm leather. People have no clue what this material is. They do not have to respond to it. Suppose they are not prepared for this. You cannot sell your products. So, for instance, palm leather sandals. They are fully compostable, and you can compost them. After six months, they are gone. When they see a two-year-old product, they start studying the object because they do not know the material. This is horrible because it is a two-year product. It is not meant to be. Because people are not used to the material, they basically pick it up and start criticizing. Like saying nobody will use it, too big, something like that. We need to bridge the gap, and often compromise. Then, we have algae fabrics. We managed to mix conventional cellulose in order to replicate the perception of cotton. So those examples are our tricks. To find the value chain and match it with the customer is something I am trying to do. That's why we need focus groups because people appreciate the innovations, but they are too critical.

Berrak Kirbas Akyurek: Could you tell me the potential impact(s) of these products?

I think it is all about LCA, life cycle assessment. Even though these technologies are not finalized, their life cycle assessments, mapping out full energy use, nutrient use, potential impacts what we need to embrace, we need to rely on data. There are so many innovations going on, and they are not sustainable. They are just proceeding in a holistic urge to the production of organic materials. For example, the so-called 'eco dyes' sounds brilliant. But the addition of color is not really that big problem in the material industry. It is a big problem but not the biggest. I hope one day we can do financing or value change based on LCA, whether it is not causing harm or beneficial.

Berrak Kirbas Akyurek: Will that also affect designing itself?

Absolutely, it has a profound effect on design. Unfortunately, it means that you cannot do a lot of things until so many innovations have fully crystallized. For example, a lot of researchers are going on about enzymes like how to extract, take

apart components, a natural system like your mouth digesting some food. These systems are not perfect, and we cannot digest the products. It could mean we can never ever design a product like today when LCA is our design parameter. For the finish of our bio-laminates, a lot of our clients want polyurethane. We are suggesting them to consider wax—the only thing you have to do that rubbing it with wax every half-year. But there is no harm. Why you want polyurethane? Because they are lazy. Perhaps that product with polyurethane should not be design anymore. So LCA as a design perimeter, a lot of our current designs will not be workable. That's why we are designers, and we should be able to design something new. This is probably my bio-based economy. We engineer polymers from corn that mimic polyurethane, and then we design a Coca-Cola bottle. At this point, we do not have to design anything different about that bottle. But pollutes the bio-based polymer in such a way that behaves exactly the same. So what are we doing? We are not changing because we cannot reclaim that polymer. We have to burn it, and we have to take an extremely long cycle. Then it is renewable. We should get rid of these technologies. Especially there is so much going on like bio-based plastics saying that they can be recycled. There is a flow of chemicals there to make them flawless, colorful, stabilized. And they are ending up as harmful components.

Berrak Kirbas Akyurek: So your point is like not to design exactly the same thing differently, but create something new but works like old technologies?

Exactly. We have to completely re-map the value chain, re-educate users, re-design functionality like in electric cars.

Berrak Kirbas Akyurek: Could you tell me the challenges that you faced in the design of the project?

Of course, there are so many challenges, but let's see, we can highlight a few. So the transition is no fun. You have something you used to it, and then you have to change. The whole process of change is insecure, with unreliable data. For the consumer, the worst thing is that if you cannot do good, everything you do good, everything becomes bad. We have to lean in the awareness that many bad things

are going on, and next week can be worse. The big challenge is how do consumers get their brains around coping with sustainability with the endlessness of materials. Then again, we have, on the other side, raw material issues. It is about the unfair division of wealth. We are not handling our global nutrient system properly. That is a big challenge, as well—a lot of design philosophies being re-occurred. So mycelium became very local, algae fabric could be very local. Consequently, global knowledge, local manufacturing is something we need to work on these as much as possible. If we do not look at manufacturing in the middle, the raw material on one side is about handling the materials, making sure the proper cycle is going on instead of the end of the cycle. On the other side, the biggest challenge is how to get consumers on board by accepting and mediating with the function of the products.

Berrak Kirbas Akyurek: Regarding what we discussed here, Could you tell me about your expectations for the future?

I am very positive. I think it is easy to accomplish with the potentials that we have. So, I am a believer in the new generation. I do not have any negative perspective. I think this is all very, very manageable.

Lack of holistic spiritualism, that is, I guess, something I worry about a lot. I work a lot in China now. I feel contributing the holistic spiritualism that China had for a thousand years, lost in recent decades. That I was fascinated to work on, and I am stunned to see how much this has been lost in the past generations, like awareness of historical value and quality of the materials. I am also amazed at how relatively easy to bring those things back again. I am designing it is called 'flooding of infinity,' it is a balloon it will fly forever. It is a kind of wish. My goal was to create an ultimate ying&yang. I am using gold, and if you can make a balloon of gold, you could capture hydrogen forever. So you could make the heaviest element, gold, and make that balloon be there forever. This an art project, obviously, but it addresses a few core things. It addresses the value of gold other than financial; it all about the specific quality of gold has. Besides, it supports

thriving the eternity that the Chinese community always has. This project just points out what we have been missing.

Berrak Kirbas Akyurek: Do you have any recommendations for future designers and particularly the architects?

For me, my goal is, of course, when I do lectures and teaching, it is about designing a value chain, not only a product. I think, for many designers, they should try a few times. Designing the system instead of a product is good learning; it brings you holistic inputs, context, technical challenges. It shows the conflict of use versus production. I think in schools design something beautiful is crucial, but also to design a system is beautiful, even to discover what is possible to create a circular system.

Interview IX

Place: Odijk/NL.

Date: 8th August 2019

Berrak Kirbas Akyurek: Can you tell me about your background? How do you describe your profession?

My background is, my whole life I am in sales. Five years ago, I thought I have to change what I do. I was the managing director of a car dealership. I have a very big hobby as a gardener, so I like green a lot. And I always thought I should do what I good at, and that's doing advice on sales on the green part. And then there was a job opening here, and I applied, started five years ago. I thought I knew a lot about green as it is my hobby, but it turns out I was not. I learned so unbelievably much from our gardeners. We have two gardeners here who do the glasshouses with a few more people, but they are responsible, they drain the plants. They know exactly what kind of plants grows where, why, and what is needed? How much is required? That's my background.

It is a bit different than what we see in green come. All the gardeners follow green studies, but I did not. I did research, but it was really back in the days for two years on construction knowledge of how the building is built. So it is a nice combination; I get sales what I like, and advise what I want to have experience in the building. And now the knowledge of the green.

Berrak Kirbas Akyurek: Can you tell me about your current projects as such aim / your role of/ in your company, mission, and goals?

My business card says I am a 'green wall specialist.' What's what my business card says. I think that's the right name. I know technique and construction. I know in green itself, everything about green. A green wall specialist is what it is. What I do is, of course, I reply to the requests we have. Today I received requests from six different countries for the green walls, and some questions are only on what is the green wall really from the beginning, and some are like this is the green wall

we would like to have it, what are the costs could you advise. I travel around Europe, yesterday and the day before I was in Berlin, I had eight appointments there. The appointments with construction companies, architects, landscape architects. One company that does vertical climbing. Sometimes the buildings are so high, and we cannot use any electrical lift that they have to climb like climbers of the mountain to cut the plants.

We have the vision of making the World a bit greener every day. And what we do, we believe very strongly in pre-cultivation. So, we can grow something. If you see a green roof, then you can throw something green on the roof and wait for a year, then hope that it is green. But we have a nursery here, and we have a hundred and fifty hectares of land where we grow. Pre-cultivation is very important because the plant must be get used for this vertical situation. When we bring it to vertical green, we grow little plants in the flexible panels already vertical. So, the plant knows from very young, it knows, OK, I am growing to the front not up. We would like to make the World greener every day, but with pre-cultivated materials.

Berrak Kirbas Akyurek: What is the main intention and motivation behind the development of the project?

The motivation is absolutely making the world better. When we set a thousand square meters of a green roof in France, then we see the benefit of a big truck driving benefit to our client. We see the biodiversity is getting better at that place where it is installed. And we know the carbon footprint will be better. That's really in the DNA of this company. Again, it is because we are almost all of us are growers, people who went to a green school where really have everything in nature.

Berrak Kirbas Akyurek: Could you describe the 'novelty' of your project?

Our pre-cultivation is our novelty, what else... Irrigation is in the second part. That is more related to the vertical part. Together with an irrigation specialist, we designed our own irrigation system. Because most of the systems can bring water by the minute, which is too much. We would like to be able to bring the water on the second. We have sensors on the wall, which measure the humidity of the wall.

We have an app and a computer program so that we can check everything. We can change the walls in Hong Kong too. We do have internet/online maintenance, so we can change the walls. When we see the moisture is not enough, we are able to change it. So roofing and vertical walls are the ones that we do most.

Berrak Kirbas Akyurek: I would say it sounds fun.

To be honest, a lot of people say that it is fun. We are a very young company. Our owner is only forty years old. He started when he was fifteen years old at his father's garden center where everybody could buy little plants. I began with five hectares of land. Now here in the Netherlands, we have a hundred and fifty hectares. There are nurseries in Poland, New Zealand, Spain, and China. We grew a little bit. Also, the company is young and vibrant, and then everybody wants to make the world green.

Berrak Kirbas Akyurek: Nowadays, these innovations are described with a variety of terms such as; 'sustainability,' 'natural,' 'organic,' 'smart,' 'bio,' etc. Which terminology do you prefer to refer to your designs?

We see here a lot, indeed, what you have just said. It must be living. What I always say, we do there is nothing greener than what we do. There is nothing greener than a plant. Of course, one of the benefits of green, it observes CO₂, brings O₂ back in the air, we are simulating biodiversity, we catch rainwater. So there are a lot of reasons to use green because it is really about green. What you hear a lot now, we have a green building. But they mean we have a heat pump, and solar shelves, Leed certificates. Here we aim to make houses, buildings 'real green'.

Berrak Kirbas Akyurek: What would you like to achieve with the application/spread of these products?

We would like to achieve that in twenty years, a city I could say. We have so much grown in our cities, and we can lower the temperature by 2% to 3%. We would like to hear from the city that people see the birds again. Because if you go to a big city, and look for a bird, there are hardly any birds because there is no food. There are no insects as well because we have taken away the green and plants.

We have built a big flat, a big apartment complex. Where is green now? We can bring them back. It would be really nice to see/hear that over twenty years from now that we achieve that kind of benefits with our green walls, and 100% we will. There are several studies, not ours, that showing what green is really doing well. I am amused by a study in Germany, University of Darmstadt. They can show exactly what temperature is doing with a green environment, and they can show how much heat from the sun is kept away from the building because the sun exposes less. So we need more nature, less air-conditioning and less electricity. That is a really nice test showing what green is doing.

Berrak Kirbas Akyurek: Do you foresee any consequences of the integration of these products into the buildings?

The thing is there is not much to change on the building when you would like to have a green wall or not. The only thing is the plumber has to bring more water to the building, that is the biggest difference. The other one is, if we bring a green wall, you do not need a fancy wall or whatever behind the green wall. That could be just concrete because you will not see it. Yesterday, I was with an architect, and he planned a facade from a green wall, and he designed some façade parts with a very expensive natural stone. I have asked him what the price of the stone is, and the cost of the green wall was a bit expensive than the stone, but a just bit. And I said to him. I gave him the benefits in costs of taking away the natural stone and putting just green and then telling him what the green, of course, is doing in terms of ecological reasons. Then, he said why I should use the natural stone. Then he did completely green, and we could lower temperature by bringing more biodiversity, greener. In that case, you can see the changes also trigger a change in the architects. What we also see that the architects are still a bit afraid of using green walls because there are a lot of green wall examples that do not work properly, or they do not know the water pumps go around the building, and they do not know what is needed. I am advising all the time to the architects, the construction companies, and building owners. They always think it is hard to make a green wall. I always say OK, let me present what we do, and I will ask one more time. Everybody says at the end of the presentation: Is it really that simple? Yes,

it is. Because you only have to listen to the plant, that's what we do. We have a nursery, and we have to give the plant what it needs. Construction on the building with 45kg/sqm is easy to do. Sometimes, they are really relieved that they can create the project they have in their mind.

Berrak Kirbas Akyurek: What about maintenance?

Very important. You have to cut twice a year for the outer of the building, in the wall six times a year, because the inner parts are warm, so they grow quicker. It is also important to know from the beginning if we can reach the wall to maintain. Because installation on the skeleton is always possible, we have to come back twice a year to cut the plants and can be reached, or we need to build a skeleton again. It is just a garden but vertical, so you have to cut and maintain it. It is important. Without any maintenance, plants will not be as old as we need to cut them.

Berrak Kirbas Akyurek: In which part of the building design process do you think this project could be applied?

Many times, I often receive an architectural drawing, and they say we have this in our mind. Can we do this only stripe of green? That's the part I enter. So the architects already have the idea. They should initiate and come and ask us. They see more and more, of course. I did in the past. I visited a lot of architects just to show what we have, and a lot of architects that were not interested in at that time, they are interested in now. You have to wake an exciting part of their minds. Nowadays, it goes on so quickly, and they all know how it works. The stage where we step in is there is already a green idea. Then we discuss how we do that. Then you see when the project started to live. For most of the projects we do, we have three to four years before ending the project. That is very important because we need to bring the water pipes and the drainage and reserve a place for the irrigation system. Architects also need to convince the client. We also sometimes contact building owners or the energy company.

Berrak Kirbas Akyurek: Is there any study that has been done to evaluate the user's experience? Can you tell me about the user's feedback?

Users are pleased with it. Like I said yesterday, I was in Berlin. I was at a green wall we did one and a half year ago. I called the owner; he claims that he cannot guess how many people have taken pictures of the wall. He says it is really unbelievable. He had one apartment with six apartments, five sold, and one not. He says the people who bought the 6th one they bought because they loved the green image of the apartment, which was only 45 sqm. The apartment, of course, was fine, but the green wall was an extra step to let them buy it.

Berrak Kirbas Akyurek: Do you see the differences between a building with a green wall and a regular building in terms of interior comforts, such as air conditioning?

Officially on the green walls, we cannot tell how much isolation we bring. We have a gap of three cm for the ventilation. In the summertime, when the sun is burning, the façade is regularly heated. But the plants reflect the sunlight for %70. So no heat from the sun gets through the panel. Thus, the building is 2C° to 3C° degrees cooler than a building without a green wall. That's the same for the roof. If you have a green roof, if you have a black roof, just a typical black roof can be heated up to 70C° degrees in the summertime. If you put a green roof instead, the roof cannot be hotter than 37C° degrees around. You cannot exactly say this is the exact amount of the isolation we bring with our walls, because of another reason that the panels we use, we water them every hour for a few seconds. So when the plants are watered, heat can change. So, we cannot say this is the exact amount of isolation before the project. But we do isolate 100%.

Berrak Kirbas Akyurek: Could you tell me the potential impact(s) of these products?

I always say, what happens if you take a bunch of flowers for your wife at home. They all say she feels happy; she smiles. That's exactly the same with green walls. People feel well at green walls. But we also see many times have the same question on vandalism. Does somebody steal plants out of the wall? Nobody takes plants out of the wall. It could be a normal idea to think if somebody drinks too much, s/he can pull over plants. I will say it never happens. But also vandalism does not work. It makes people happy. They say the productivity of people who work in the

building is higher when they are surrounded by green. I can understand. The oxygen is better, and the smell is better, the amount of fine particles is less. We just did a test with one company that measured everything (NOx, temperature, and so on).

In Amsterdam, there was a real estate fair. They made three conference rooms. 1th with one table with six chairs, 2th with one table with six chairs, and they made green with paper on the wall, and the 3rd one was the chair table and our green wall. They said OK, you could use it for 15 minutes and pick a room. Everybody walked to the room where the green wall was. That was the first thing. The second is that room was 2C° degrees was cooler than the others. There was %25 less dust in that room, and there was %6 less toxic dust in that room because of the green wall. That all helps people to feel better and then work better. It is psychological. But it is also real nature. When you walk in green, you feel better. When it is a warm day, walking under a few trees, you feel that the temperature is 2-3C° degrees less.

Berrak Kirbas Akyurek: Could you tell me the challenges that you faced in the design of the project?

I think the challenge is the height of the building. How high is the building? How high can we install? How can we do that? I think the problem is to make sure that architects or the owner are comfortable using it. It is not a challenge. It is just telling them that it is possible and show them it is possible. And show them winter pictures and wintergreen. The challenges are also related to the technical parts of water pipes that we need for a building. When you have a bigger wall, then maybe we need 5,6,7, or 16 water pipes, and plumber says no, architects say no. Where is my space to bring these pipes? That could be a challenge, but there is always a solution.

Berrak Kirbas Akyurek: I believe transferring this knowledge to architects is very important because the architecture field is tough to talk about this topic. Also, in practice, everything is all about money, and also, they want something stable, durable (nothing will going to last), but you know the idea.

I ask a lot of architects and owners that how long should it look like as it looks. What we see is the most buildings are renovated after twenty-five years. So, a lot of architects ask how old will this wall be. It will last for fourteen years for sure because our oldest wall is fourteen years old. The materials we use last for thirty years and plus. So, we think of their life as thirty years. And I am turning the green walls more into construction materials, same as steel, isolation, aluminum just like construction part. It is OK to live aluminum for twenty-five years because everybody knows that they need to change it. That's the knowledge I bring to the architects too. We think it will remain twenty-five to thirty years. In the meantime, you will renovate the building, and maybe you use it on your new design because we are circular. We can be re-used. That is, I tell architects that this green wall is a construction material.

Berrak Kirbas Akyurek: Could you tell me also your experiences on using this green wall in the interiors?

We do more outdoor than indoor. People think that outdoor is more complicated than indoors, but as long as you measure everything, it is not. As long as you have a winter program, it is not. So, % 70 of our works are for outdoor, maybe %80 outdoor to %20 indoor. Because indoor is a bit easier, it is always 20C° degrees, we complete the same amount of water and fertilizer, but for outdoor, we may need to change every time.

As long as the plumber brings the water pipes or we have a solution to a water tank, you have to fill the water tank yourself every six weeks around depend on how big the wall is. Then we only need to have electricity points.

Berrak Kirbas Akyurek: Regarding what we discussed here, could you tell me about your expectations for the future?

How I see in the future, in green, growing, growing everywhere.

We will keep on developing. For instance, we are working on a quality certificate which says you bring that the original or recycle it. I believe it is important to do. I think green walls will grow in Europe by about %20 for a year. It grows so fast.

We do eighty to a hundred walls in a year. We have doubled it in three years. There is a possibility of it. We need more people like you who have the interest to bring them into the future architecture. I was in a meeting this morning through Skype with two Belgian guys from Zurich University from Switzerland. They are developing an irrigation system that was for vegetables. They may think it is beneficial for green walls. That is not the case, but their idea in their mind is what they have is exciting and triggered me a lot. That's why I invited them just to tell a lot more.

Berrak Kirbas Akyurek: Do you have any recommendations for architects?

One important recommendation for architects is that they have to keep their eyes open. For a company, it is the same for us too. Maybe some times in life, there are coming towards that you need to pick. Maybe some new ideas. You can always work on the same thing, but nothing changes. We have a really very good green wall system, and we need to develop them for sure. There is always a better version. They should invite new ideas. A lot of architects use green walls, then the client asks. I think they should use a green wall as construction material, not as a feature, not as your specialty. You should use nature in your building as a standard. At the moment, they still think about it, how. In Amsterdam, if you want to build a new building, then they say you can have a permit, but you have to make it this amount green. You have to catch rainwater, or some percent green, etc. Otherwise, you cannot get a permit. That also has already been in the minds of an architect who designs buildings. But the idea I have to include nature in it. Not only the green roof. It is not enough. These ideas must be their standard.

Interview X

Place: Eindhoven/NL.

Date: 15th August 2019

Berrak Kirbas Akyurek: Can you tell me about your background? How do you describe your profession?

I am Jordy, and I work at the Mind mansion as a developer like programming, and also a designer. I also work on concepts and creative thinking. We were started with Mind mansion about three and a half years ago.

I am Melle. I was working in the Mind mansion since it began. Basically, my role in the company is in the business and finance of the company. In the company, Lisa (Slegers) specialized in marketing and communication. Mike (De Greef) is also a game developer. And Kars (Van Den Eijnde) also works on programming.

Berrak Kirbas Akyurek: Can you tell me about your current projects as such aim / your role of/ in your company, mission, and goals?

J: With Mind Mansion, we are combining three different technologies to improve the healthcare system of main fear and anxiety. We are using virtual reality to simulate the environment that induces fear and panic. For example, for claustrophobia (fear of being in a small space) or acrophobia (fear of heights), next that, we use gamification to motivate clients to face their fears to those exposure therapies. The last thing is biofeedback, which is why you are here, to show the client and therapist how the client is reacting on different occasions.

M: In this way, we are giving more objective feedback towards both of them instead of a therapist asking people how they are feeling and giving an opinion from one and ten. Because we have heard that a lot of times, clients could also lie since they do not do anything or they do afraid too much, the clients can say six or maybe it could be ten or perhaps the opposite.

J: So, at this moment, we add another layer to the therapist to be more objective about the treatment and how the client is feeling. We thought about also implementing automated biofeedback, and the environment changes through biofeedback. But we stop doing that because it was really risky. Because if the biofeedback does not work %100. It does the opposite of what it should do, and it only makes it worse. So we stopped doing the automation on it. We just used it as an objective measure line for the therapist.

Berrak Kirbas Akyurek: What is the main intention and motivation behind the development of the project?

J: In general, we started as a school project. We started with business gamification. That was a minor, and we all joined from different schools. So the main part was to gamification, and we added virtual reality to show that fear could also be induced by using virtual simulation by proving that we added the biofeedback. After we had demonstrated that biofeedback induces fear, we also proved that it could be treated. So that is the reason why we added biofeedback. We finished the project in school, and we were realized this is something we should continue working on it.

Berrak Kirbas Akyurek: Could you describe the ‘novelty’ of your project?

J: Actually, we do not have a lot of competitors using biofeedback. As far as we know, we are the only ones using it, and we only know others in Barcelona, Spain.

M: The combination of all aspects makes us unique comparing the other virtual reality exposed therapies in the Netherlands. Maybe because most of them only use virtual reality. Maybe in combination with gamification or the adaptability in fear simulation. We are combining all that makes our work unique.

Berrak Kirbas Akyurek: Is it like using biofeedback to make your work unique?

J: Triangular combination, creating the relationships; gamification, biofeedback, virtual reality that what makes us unique.

Berrak Kirbas Akyurek: Nowadays, these innovations are described with a variety of terms such as; ‘sustainability,’ ‘natural,’ ‘organic,’ ‘smart,’ ‘bio,’ etc. Which terminology do you prefer to refer to your designs?

M: Maybe we talk about biofeedback as a whole term. Because for the therapist, that is the most known.

J: We kind of make it smart; we do not use raw biofeedback to the therapist. We add a sort of a filter to it and bring it back to one variable. So it is easy for them to read. But we do not call it smart.

Berrak Kirbas Akyurek: You do not want to call it?

J: Smart gives the idea of the automated part.

M: We would have an automated home version. I think smart for me as something extends its own decision.

J: Biofeedback is understandable. That’s why we chose the word.

M: We also have gamification, it is also a hard term, but it is easy to understand. That is also similar to biofeedback.

Berrak Kirbas Akyurek: What would you like to achieve with the application/spread of these products?

J: Mainly faster and targeted treatments. So, the system pinpoints the exact problem and the trigger of the clients way faster than in real life. After that, you can practice it over and over again compared to real-life situations. You can simulate a place like here (a meeting room), an elevator, let’s say, or a plane. You are mainly speeding up the treatment period.

Berrak Kirbas Akyurek: Do you see any advantages in addition to being fast?

M: It might also be better in some sorts. I am not saying anything is wrong technically with the current treatments. But suppose someone being afraid of planes, there is no proper way to fly together with his or her therapist. Aside from watching through the screen, with virtual reality, you can simulate and get into the treatment area.

J: It is like a middle step before real-life therapy. Before you start, you think it is just simulation. But simulation is emerging enough to trigger your fears, so it goes both ways. It motivates people to begin the treatment and good enough to treat in general.

Berrak Kirbas Akyurek: I know you are working in a different field, but still, do you foresee any consequences of the integration of these systems on the buildings?

J: I think there will be more possibilities like we can go to the ER (Emergency room) pretty quickly, and the existing room could be changed into a treatment room.

M: Also, the advancements that we have seen. For example, when we start, technologies had space limited with cables that create constraints. I think the new version will bring new advantages and things will get better.

J: I do not think virtual reality will ever go away. I believe it has already proven itself as a useful and valuable technology.

M: I do think that the placement of virtual reality in the market was unexpected. I think the developers would think that it is a consumer product that is shifted more towards the enterprise. I think twenty years ago, when virtual reality was released, it is expected that a few years later, people would have a set in their homes and used it all day. Maybe in the future, it will happen, but now it has been using for more severe purposes rather than entertainment. I think aside from serious uses, and gaming is still the highest in entertainment.

J: I think virtual reality is boosted in applications more than did in the games.

M: Yeah, virtual reality for gaming seems very high, but not as expected to be.

J: There are getting cheaper, but not seems possible, at least not yet.

Berrak Kirbas Akyurek: It is like smartphones. We could not imagine twenty years ago, they will be a part of our lives or not.

J: It is a very nice example. In the video around 1996, when people asked for using cell phones, they seem they are not impressed. They are asking questions like: Why would I need it?

M: Some people said I have one for my car. If I am at work, they can reach me from the work phone, and if I am home, they can call me.

Berrak Kirbas Akyurek: And now, we cannot literally live without our smartphones. Could you tell me about the user's feedback?

J: Actually, we had a more significant impact on clients at the moment than therapists. Because therapists are really holding tide on the current way of treatment, they are like... I have already got used to applying this treatment for twenty years. Why do I need to change it? However, the clients are actually experiencing it, and they see that it works on their behavior and get benefits from them. For now, we have significant client results. For example, there was a guy with a fear of flying. After two and three treatments of VR, we saw improvements, and he started to believe himself. That was very good to see this quick progress. We also get a lot of feedback from therapists and leading us to change our simulations. That way, we hope to boost the acceptance of our system into the treatment.

Berrak Kirbas Akyurek: Is it like you are challenging with the therapists more like clients?

J: Definitely, mostly because therapists do not believe that VR works even though many studies in the literature proving it is working.

M: Therapists have to take a look at what is financially good for them. They need to consider how much time, how much risk do they have if they use this, and many more.

Berrak Kirbas Akyurek: Could you tell me more about the challenges that you faced in the design of the project?

J: Also, there are a lot of problems with insurance. We do not have specific data that they provide faster treatments. So they do not see a way to earn extra money back. But we cannot get enough data, so they are not willing to try it.

Berrak Kirbas Akyurek: What about the role of biofeedback?

J: The problem is more likely on our side than the client-side. The biofeedback that we used, for now, is just a watch, and clients did not mind. But we had a problem when you move your arm. It does not measure your heart rate precisely. That is a problem because while you are using VR, you are continually moving. Then we tried some neurofeedback, which is a bit of a gray area because everyone has different brain waves. You do not know how to use them correctly in the whole method. Back to biofeedback, we are struggling to find the right hardware for the price because we had to sell it to organizations and therapists.

M: Cheapest way would be ordering samples and typing on people's skin. But that is not user friendly, and it may not work properly. We had a test about a couple of months ago with different biofeedback wearables. There are different opportunities, but they are expensive. You also need to buy a license.

Berrak Kirbas Akyurek: What about the feedback you can get from the therapists?

J: Sometimes, clients tell lies to avoid treatments, get through it, or just stop it. They think that it is valuable to have a back-up. So if you are doubting what the client is saying, you can double-check the data.

M: Also, sometimes, the client does not know the exact triggers for the fear. For example, for flying, clients could say that fear is affected by the closing of the doors. But we see in biofeedback that the fear is triggered while somebody sat near them or someone putting a piece of luggage above their head, sometimes only the landing. You might be scared of something else that you do not know.

J: It also plays a part in helping the therapists to diagnose the actual fear by finding the triggers.

M: For example, you can assume that you are afraid of flying, but you might be afraid of closing the doors. Actually, it is a different phobia. For example, people

with agoraphobia also get claustrophobia because they are inside all the time. But they cannot get out, so people get depressed. That's why we want treatment to be faster because, in the Netherlands, there is a long list to get treatment about twelve weeks, even more up to twenty. For example, it may start with something simple, and if it is not treated, it can begin to affect your daily life in different ways.

Berrak Kirbas Akyurek: You told me the potential for fast treatment and better healthcare. What about the bigger picture? Could you tell me the potential impact(s) of these products?

J: I think there will be a lot more when more people can be treated. Because a lot of people do not even start treatment since it takes too much time and not easily accessible if you can bring it to at home, pretty much all the people with fear and anxiety will be treated for less money. That is also health insurance companies can get benefit from it. So it is also easy to build out to the other countries. There are a few regulations in healthcare to change or keep in mind, but the rest is doable. So I think it is an easy way for more people to get better treatment.

M: If people get better, and will be able to live their lives. That is also something forgotten in healthcare a lot. There is a long waiting list, but there are also a lot of people who do not want to go to treatment because they think they can deal with it. For example, I can imagine fearing height is something manageable in everyday routine. But if you are afraid of driving, your quality of life decreases. It is really inconvenient.

J: So we are not only improving the current system but also adding a new customer group. People who do not go to the treatment do not see any use of it. But if you bring it home, maybe they will try.

M: They can try at home without any inference of people. That is also an interesting fact that it is hard to admit people to be sick when it especially comes to mental care. For example, admitting you are afraid of heights, it may be OK. But let's say it can be hard to accept your social phobia or many different fears.

J: We are faced with strange things like fear of ducks, trash cans, stars, and many more. Suppose you do not admit that even do not speak about that. You will be the only one that knows this fear. In this way, this technology can provide people to get rid of their fear.

M: For example, people still feel the impact of fear, but they do not think they should go to the therapist. They know they have to do something, but they do not feel a treatment is required. So they reach us because they think that it is something in the middle.

Berrak Kirbas Akyurek: When you talked, I also thought maybe I wish I could test myself to define my fears. Does it work like that?

M: Maybe that is something we could do in the future. Make a virtual reality checklist to determine your fears. There are a lot of people with manageable fears and anxieties. But in ten years, that fear might not be manageable anymore. So it is an interesting thing that the mind works sometimes.

J: A diagnostic approach... Sure it can be done.

Berrak Kirbas Akyurek: Regarding what we discussed here, Could you tell me about your expectations for the future?

J: I am convinced it will take off exponentially. First, we have to convince those therapists and organizations because it costs less money to treat them this way. Once that done, it can go in the snowball effect. Every year we see more news about fears and virtual reality, and there is more exposure to people that work that is available and in progress. Once it kicks off, hardware, software, biofeedback will get better.

M: Something you see quite often in healthcare, one organization has a little bit more respect for the others, and the others follow it.

J: It is also the same for health insurance.

M: It has also happened with the computers; they took the place of the checklists. It takes a while to develop technologies in this specific field.

J: What we see the younger therapist, which mainly work children mental care, they are more inclined to use it than the older generations.

M: But, the younger therapist also less leverage within their field comparing the older generations. In healthcare, the experience is quite important, which is something shifting in other fields. In a lot of sectors in the technological field, it seems that younger people are getting more respect.

Berrak Kirbas Akyurek: Do you have any recommendations for future designers, architects in particular?

J: Change your market, but do not change to please everybody. We did in the beginning. As therapist A told us something s/he like that, we assumed that need to change. But when we talked with another therapist, he told another. Then you spend time and money. So to keep your focus, and do what you want to do, and change a bit if you see the benefits for a larger part of the group, not only for someone.

M: I think it is really important to talk about customer issues and their opinions because they will be the one who is going to use it. If you are looking for something innovative, you should stick to your plan because there is a reason that you went for that path with a decision. If they tell you that they do not want to that way, you would have a really good understanding of why not they do not like it. If %90 of a hundred people say do not do it, you do not do it. I think it is crucial to keep in mind: Why are you doing it? How are you doing it? And What is the way to do it?

J: Sometimes things can be different than you expected, but that is the part of the journey, I guess. You should keep your vision until the endpoint. You will get there.

Interview XI

Place: Skype

Date: 16th August 2019

Berrak Kirbas Akyurek: Can you tell me about your background? How do you describe your profession?

I started studying biology. Actually, I quite like it, but I found it quite specific to me. It was a little bit too much into microbiology. And I wanted to create things. So, at that point, I created a portfolio and applied for the Design Academy in Eindhoven. Then, I started to study design from 2010 to 2014. At some point, I began to integrate these two. At first, a little bit playing around. Especially during graduation, it becomes something that I started to believe in more and more about the fact, which I noticed when I was studying biology. There are lots of innovations happening all the time, but in scientific institutes, there is not much to derive; we had designers have to. The results may be published but not translated into something useful, practical, or tangible. Sometimes, but often there is not. Besides, scientists have a different mind, and they work differently than designers. So, it was a specific example that I had in my mind at that point. A professor of mine, working on algae that produce biofuel. It was actually engineering of the algae. But he told me at that time; he still had one kind of problem there, that algae were killed by biofuel while they were producing. So I was super interested if I could manage to solve this problem. I thought you could create a product with the algae in it. So I contacted him, he solved this problem, but there was this issue. As I said, it was an engineered organism that is, of course, dependent on the strict regulations. So if I could make something, it could not leave the laboratory space. For me, that is an example of what I think that I am doing. When I start new research and topic, I try to contact to the scientists to hear their story. Maybe they are working on, which is not yet implemented yet.

(Current projects)

Maybe it will never be implemented like the electroactive bacteria that I am currently working with. There was actually a part of twenty years of research on how we can clean our wastewater streams—at the same time, producing energy with this. So there was a fabulous idea, but it was never found profitable on a larger scale. In this research, there was not so much that has been done at the moment. When I noticed when I speak with the scientists, usually, they are super happy to anything that they do to see it translated into something tangible. The projects are more likely conceptual. My last project was electroactive bacteria. Now I am a working consumer product, so something that people need to take care of it in a way. So that is kind of new for me. Because I also feel that you need to show that all these nice developments that you can translate something useful.

Berrak Kirbas Akyurek: I was going to ask about your current projects, but you told me a little bit. Thank you very much. So my next question is: What is the main intention and motivation behind the development of the project?

I think I already told the most critical part of my motivation. Also, what I consider very important that if you want to tell people a story, everybody perceives it differently. Some people like to read a scientific magazine, but I think it is quite common that as something that is visually interactive and people get curious and get to more about it. So from the topic that may be difficult to understand, it is formed into a straightforward element. It makes people understand a much broader topic. Everybody can dive in as deeper they like. They can read the text or start asking questions, conducting interviews. So there are different kinds of levels that you can get into this research. I think it is also good people take away something in it and do their own thing afterward. For example, for bioluminescence, one can say that you need to patent it. But I do not feel like that, maybe it sparks someone's interest, and something will be achieved.

Berrak Kirbas Akyurek: I see your point; there are lots of innovations happening in the labs. And for us, we have no idea, not even a clue until somebody makes a product.

Yes. What I have done with the ‘Spark of life’ project is quite similar to a reactor that would be in a laboratory. But if you look at that reactor, you would say it is just a pot with liquids and wires. So it is just trying to get the core and the essence of making something people can relate to.

Berrak Kirbas Akyurek: Could you describe the ‘novelty’ of your project?

I think, especially when I graduated in 2014, it was rare to see people using bacteria, in fact, a natural element in general. I think people really in need and a craving to feel we are still surrounded by nature in these kinds of technology-driven World and taking care of nature in some way or another and also appreciating that kind of effort. I think my work is exactly in between the technical and natural Worlds because I harness this natural part within something in our built World. When you push the switch, all the lights are gone. You do not really think about it the whole process, which should take for that energy to get to you. Actually, it is all being supplied for the all-natural process. Then, for my recent lamp design, you have to feed it once a week. And only when you feed it, the light goes on. It is an artificial LED light, but it is powered by microorganisms. When you feed it, you feed every time feel that it becomes brighter, or if not, it goes down. That’s how you start to think also about energy and energy usage; also the interaction with us. So, maybe you appreciate less light and energy usage.

Berrak Kirbas Akyurek: It sounds that you (people) are about to comprehend the importance of light and energy and to understand what is happening around you.

Yes, exactly.

Berrak Kirbas Akyurek: Nowadays, these innovations are described with a variety of terms such as; ‘sustainability,’ ‘natural,’ ‘organic,’ ‘smart,’ ‘bio,’ etc. Which terminology do you prefer to refer to your designs?

I always say that I am a ‘bio-designer,’ maybe it is one thing. I like to use the word innovation and nature. But I am not sure it is always about sustainability... That’s perhaps I realize what it takes to make something that is really sustainable; it is not something my projects interestingly are. Something can be part of sustainable

development. But of course, it is within the umbrella of sustainability, and you have a quite responsibility if you are creating something sustainable. But I do not make mass production because it is not sustainable. Maybe you can remind me of other terms?

Berrak Kirbas Akyurek: What do you think about smart?

I think it applies to me more digital and technical projects. Maybe not smart; it is more tangible, tactile, biological. It is more about less technical, trying to get emotionally evolve. I have to think about it.

Berrak Kirbas Akyurek: What would you like to achieve with the application/spread of these products?

That would be a very new thing if they would be in the market. I think what I want to achieve that people should start thinking in a different mindset. If you start to take care of something, you start to notice energy and light installation when you usually do not have to take care of it before. I hope that people start to think about the broader aspects of the concepts. I think these objects, maybe, for now, they are almost like art. And art has a lot of essential functions to tell about who you are. So, if you come and visit somebody's place and see an art piece and you often ask them what it is. So you can have a conversation about someone's interest. If you have this object, in my case, it does not look like something simple. It always looks like something you relate to it and also different. It could also sparkle a conversation between people, and they could start to talk about the planet, sustainability, and smart becoming natural.

Berrak Kirbas Akyurek: It sounds like a 'triggering' object.

Yes.

Berrak Kirbas Akyurek: I know you are not working in that field, but do you foresee any expected results of the integration of these bioproducts into the buildings?

The technology that I am working with now electromagnetic bacteria is a kind of need for a shield of material in which bacteria could live. Now I am using a

cylinder because it is material saving, practical and useful. I did think that you could implement it into a wall, and you can have your energy wall. I do not know, it could be implemented, but I am more into the object scale. Maybe in the future.

Berrak Kirbas Akyurek: Is there any study that has been done to evaluate the user's experience?

No, not yet.

Berrak Kirbas Akyurek: Maybe you can tell me about your own feedbacks, like people's experiences and observations when they speak on your designs?

People always kind of surprise about what the possibilities are and hopeful in a way. But also just it is fancy and attractive. And speak who immediately wants to change the World, want you to own rights for it to gain money. The main thing people respond is that they are so surprised that I translated it into something visual.

Berrak Kirbas Akyurek: Do they have any concerns like ethics?

Rarely. But it surprises me, but there are people asking ethical questions, which is if you know biology, very funny, but understandable.

I usually work with bacteria. If you have a shower and washing soap, you kill a hundred bacteria. Bacteria is a kind of organism that lives and dies. Their concerns, for instance, for Ambio, I have to refresh the liquid every day. So, liquid from the previous day, maybe keep it light is off. But these bacteria will die with natural causes as well within a day. On the other hand, from a different perspective, I am actually growing them, giving them exactly a place to live. But it does not make sense to think about one cell organism to think about ethically.

Berrak Kirbas Akyurek: I do understand your point. I also have those questions. For bacteria, I do not know, but maybe for plants?

For plants, it is something different, for wood especially. Even if you do not respect the tree as a living organism, a tree is a source of life for so many living organisms. If you cut trees, there is an impact that you need to compensate for it. I do think there is an ethical aspect to it. But then, with bacteria, I am not taking anything

from our environment. Because with bacteria, it exponentially grows. I am also giving the right environment to live in without interfering with the ecosystem.

Berrak Kirbas Akyurek: They will not leave that controlled environment, right?

That is also another thing. I usually work with non-pathogenic bacteria, naturally occurring and not genetically modified. I do work with it because I think we are too afraid of genetically modified bacteria. So people can be concerned, for instance, what happens if you left all things in the toilet. Actually, electroactive bacteria strikes in the ecosystem. It is not the singular organism. They all balance each other. In a formation, they are very much like naturally appearing in a river. If you flush in the toilet, the bacteria will end up only being beneficial. And touching with your hands, it is like walking in your garden, nothing specific. Modified bacteria, of course, something is occurring in our environment. So, in that case, if I would flush into the toilet, I would always put washing soap in it to pure them. Not that it is needed because they are super sensitive; if there is any influence from outside, they will die. It is just a responsible act.

Berrak Kirbas Akyurek: Could you tell me the potential impact(s) of these products?

I think my projects maybe will not mass produce. I do not see that path, and it will not be that kind of big impact. Perhaps in this way, it will become normal to use bacteria as a source of energy. Then, it can be more like aesthetics. Maybe there is a point to it will become normal to use nature and biology. Then you can be free to make things that are powered in this way.

Berrak Kirbas Akyurek: Is it like mass production is not the only way to get attention to these products?

Yes. Maybe it is also a part, education or something. Perhaps it is helping others also to find a way to do it. Why not?

Berrak Kirbas Akyurek: Could you tell me the challenges that you faced in the design of the project?

So many challenges, I would say. Of course, working with living organisms bring so many challenges because you are doing something that probably has not been done that you are probably doing it. People still want to exhibit, for instance. Now I have an installation in New York, US, and they are taking care of it there. I have not been there, and they had to do all these works themselves. I think things can go wrong right now. We decided to refresh a bit liquid, and it is not working right now, although it was working before. I cannot do anything from here. I can only advise them to do it. It is tricky because it is just living organisms, and you can never know what is happening. You need to restart with a new bacteria or strain, or sample. So that is challenging.

It is also challenging as a studio that sometimes you are making things not possible to sell them. People want to buy something from you for the income model, but it is often not possible. So you have to think of another business model like a project base, which is also really like.

Working with the university is also challenging for some people. It is also difficult to find people within the scientific field.

Berrak Kirbas Akyurek: Regarding what we discussed here, Could you tell me about your expectations for the future?

I think it would be really interesting if the products that I made would be more common for people to have something like this which is alive and you need to take care of them. It would be exciting if other people would adopt that mindset to create things that are hosting nature in a way. Like our plants at home, nobody finds it interesting if you have plants in your home. But when you have something bacteria, it is interesting. Man-made problems on our planet can still be solved by using bacteria like clearing oil spills or even nuclear waste. I think you can start to realize the future is hard for us because we do not see bacteria. It is like hygiene; if you cannot see it, you can clean it and also hide it. But we realize that we are living together with these organisms. I think it is about %60 of the biomass of our planet is bacteria; we have to live together with them. Now it is a very unconscious way, and a way that I am making it may become conscious.

Berrak Kirbas Akyurek: Do you have any recommendations for future designers, architects anyone interested in merging living and manufactured elements in their designs?

It would be to realize whatever you create. You create it together with nature, not on it with it. Respect for the planet is also important.

Berrak Kirbas Akyurek: Are you are implying back in history, it was more likely to design against nature, and now it is becoming design together?

Yes, definitely, it was also not realizing that we are nature. It was essential to develop to go through. But the times are changing, and we need to embrace that and do that more. I think designers can create a super significant impact, either positive or negative. The thing is, people are not always responsible. You cannot hold a person who is buying a plastic bag responsible for plastic soups in the oceans. Maybe nobody is completely responsible. But when you look at the products that are made, they are intentionally made to break within twenty years. Otherwise, there is no business model. That is a big responsibility that as a designer for our environment. You make things to last, and they have lasted. In the end, giving them another function such as reuse and recycle and so on is very important.

Interview XII

Place: Amsterdam/NL

Date: 26th August 2019

Berrak Kirbas Akyurek: I read your book, and I see that you have gathered several examples that also represent in-between technologies. Why do you prefer to call them biodesign? Why did you not prefer to say bioarchitecture or biobuilding?

Language-wise, biodesign is a very useful term because it is like an umbrella under which all these ways of design making. Biodesign term covers work of design it is for or with biology. That is a kind of helpful distinction that I found based on the intent I had.

Berrak Kirbas Akyurek: Is there any specific reason that you do not prefer to use any other terminology like bioarchitecture?

I think for reasons of simple occasion and consistency, I like the use of more general terms rather than try to define them. Other than using something like 'bio approach to fashion,' 'bio approach to architecture.' Biodesign is an overall approach that can be applied to all the different subcategories. For me, it is also consistent with the idea that is critical stands for. Biodesign is a land in which you can judge all design in a way it is biodesign. For example, (you see this glass) It just sand heated to very high temperature for molding. But it does really affect biological systems. The fuel that was burned to make the sand. That was biology at one point. So in a way, this (glass) is an example of biodesign, but just a poor biodesign. It impacts, changes biological systems, but in a small way and not for the better, I would argue. I think everything, in a way it is biodesign. It is just that plants are much better in some ways. It is acting as a kind of resource support for the things growing inside.

Berrak Kirbas Akyurek: I did not expect that there is a hidden logic inside of the term.

That is not in the book what I just described. That came to me later by way of conversations with academics and other people. Is biodesign need to be a field now, or define a question? Maybe it does. I think it does. I would go that way. It may be similar to that. At one point, there was no landscape architecture. It was like there were architects and gardeners. Architects were like the specialist when gardeners were designing a park. Eventually, a merge, a collaboration, was happened between those people. And eventually, a field was born. Let's design a curriculum for this; people need to learn these exercises, read those books. This is about this, and this is about this. And it was like a start. Maybe there is another field that could be born through answering how design could merge with biology. I say it is a kind of verbal trick encompassing to help to describe all the works that are already happening. Bio designers are just like speculations or critics that we design right now.

Berrak Kirbas Akyurek: What do you think about the terms of smart or sustainable?

I tend not to use those terms. I think smart is overused and often stacked to the products to help some people. Sustainability is also overused in so many contexts. Its actual meaning of it has been attenuated, reduced to little meaning. Also, the term of sustain becomes a tricky term because there are so many systems existing now perpetuating, destroying things that are good and necessary for us to maintain. We are sustaining mono-capitalism, power structure, how we do Ph.D. We are supporting something like absolutely changed radically.

I prefer terms or phrases that are more specific, like something that is ecologically effective or combinations of words like that. OK, we are talking about ecology and effectiveness, meaning there are some assumptions here ecologically effecting building supporting, and helping to be sustainable.

Berrak Kirbas Akyurek: Could I ask the main intention and motivation behind gathering all these examples of biodesign?

I was inspired by other people, writers, and curators like Matilda McQuaid, Paola Antonelli, and the others whose work gives a platform and visibility to, especially

young designers daring to creative stuff. To put them into the exhibition would speed the innovation and advance the field. I want to do that.

Berrak Kirbas Akyurek: Could you tell me the potential impact(s) of these biodesign examples?

Fortunately, in the last couple of years, we have seen real uptake interest in experiential design approaches. You may understand that in many things. The major exhibitions come to my mind like; The structure of the art show at Pompidou Center in Paris, France, Tree in alley in Milan, Italy. I think recognizing showing to the World that this has become really important.

Berrak Kirbas Akyurek: Could you also tell me the potential impacts on building design? Do you think something will change through biodesign?

Designing with knowledge of what's happening around us is important. I hope that some of the technologies that we have now might be replaced by utilizing biology better.

Berrak Kirbas Akyurek: Could you describe the 'novelty' of these biodesign examples?

In a few ways, but maybe the main one is that, to some extents, that can be accepted as 'anti-modernism.' There is so much of modernism and aesthetics around it and controlling sanitizing spaces and objects.

Berrak Kirbas Akyurek: Do you mean hygiene phobia?

Yeah, the white cube is a kind of ultimate expression of cleanness, and it is so much modernism. We need to step away from it by embracing the uncertainty with the inclusion of elements that we cannot control in biology. Actually, you do not need to understand how they work thoroughly. That was, for me, the main, special thing to be interested in this kind of design examples. We have an outside environment; we have lots of stuff like plants, biology, the biosphere is happening. Let's work together and create a friendship not to be odd to each other. Still, it is the case in architecture, especially in traditional approaches, let's control the nature, biology, environment, everything...

Berrak Kirbas Akyurek: Could you tell me the challenges that you faced in the design of the project?

Sure, in the beginning, everything is always hard; it is getting easier but never gets super easy working with over time. It is a very challenging process, but I was fortunate in the sense that people cooperatively wanted me to introduce myself to their works. That has happened in bio-books, exhibitions, and sessions.

Of course, there are always challenges like finding the platform, funding, etc. Maybe there are also challenges about understanding too. Perhaps it is easy to talk with you because you are interested in the field. I imagined we would have another conversation with people outside of the field. People have other desires, and they are often confused by the design of biomimicry or some other things vaguely bio-related. They must be thinking that biodesign is design in it and something related to inspiration or something. So I kept having to explain it. I came up with better and better, memorable, more condensed what it is and why it is important.

Berrak Kirbas Akyurek: Regarding what we discussed here, Could you tell me about your expectations for the future?

As I said before, I do have to be optimistic, although they're a lot of reasons to be pessimistic. There is evidence out there. If things are continuing this way, the world will be in trouble.

Berrak Kirbas Akyurek: Do you have any recommendations for future designers, particularly architects?

I really think that they need to be vocal advocates of policy changes, things like evaluations of building energy. And be OK with certain things becoming much more expensive to do. In the future, we have to pay the prices of the impacts of false choices. So if we do not have that those systems in marketing, in buildings, we should compromise.

That's is something I like about this book (Biodesign). There are a lot of examples in the prototype phase. Because they are not economically feasible, but they are

an attempt to change the way how the system works, who makes subsidies for the design. People are looking at this book and seeing how we can do this.

Interview XIII

Place: Eindhoven/NL

Date: 27th August 2019

Berrak Kirbas Akyurek: Can you tell me about your background? How do you describe your profession?

I studied industrial design engineering in Delft and never thought I would be a researcher when I studied. Apparently, I also liked a few courses related to research. Then somehow ended up in a research group within Delft. And I thought I really liked these people in the way they approach design. So I decided to do a Ph.D., which is what we now call 'research through design.' Actually, through the act of designing, you generate knowledge. I thought this is nice because then, at least I can use my competencies as a designer to do research instead of becoming lab people or an image that I thought about researching. I think my project at that point was 'quiet.' Other people call it 'canonical,' an example of the research through design. So designing something like an alarm clock with the buzz words of these days, 'active computing.' The way you set it could actually generate and detect a personal emotion. So this was the thing that I implemented into the experiment. But the nice thing was something that I was realized. At that point, one of the people on my committee was like, why do you not turn it into a product? At that point, I thought like a researcher by saying this was not commercial. This was a research point. He explained like you are at the gates of heaven, then you turn around. I realized, Ok. Commercial products are like heaven, which frames innovation is coming out of research that could go out on the market. Then, I supervised Ph.D. students after me going through a similar approach to designing a lamp that tells with aesthetics and ethics in the way it has interacted. It changes its interaction according to the values of a person. Then I was like, maybe I should take into account to turn into a commercial product, and think about what it would mean if it turns into a commercial product. So after his Ph.D., he started a

company to develop this further. He managed to bring out 700 lamps on the market. Then, during those times, some problems, and the product being too expensive company failed. But they used IP to do other things as well. Then I think we also realized that for four years, just researching design is not enough for the next step. And taking the next step only after finishing the Ph.D. seems not right. Why not try to do that step as a part of the Ph.D.? If we study the consequences of technology in society, why do we not study the consequences of technology in a society already doing a Ph.D. instead of staying within a lab and/or in a design studio?

So for the smart textile projects, because funding from Dutch creative industries, a wicked approach that company should be small-medium enterprises, we avoided working with Philips and TNL. I think eleven concepts had been created through several iterations, and some of them closer to the market. This is what we called a growth plan where the first step is incubation, which happens in the design studio with a few people in a very protected environment to explore what we can do with these technologies, which were at this point in smart textiles. Then, out of that collection of ideas, we invited different stakeholders, which could be people as service providers. This could be people at elderly care, for the case of smart textiles. We invited a technology company that made electronics. When we invited them to look at these things, they commented on them. Then, we realized that some of these ideas had more potential because they got more interest from these companies.

Then we proceeded through the second phase, what we call; nursery. That still occurs in a protected environment, but looking at the implications which we were starting to scale these things up. So, instead of researching one prototype, we looked into make ten. What does it mean to make ten? What does it mean instead of one m² smart textile if you make 10 m²? If we have ten square meters, we allow designers and technologists to see what they can do with this material. We also had a small investment that could help with people's rehabilitation in elderly care. It had sensors and electronics, and yarns. It was connected to iPad applications so people could play music as elderlies lift their arms. In this way, people are

motivated to move their arms, which is very important because if they raise their arms, it is easy to put/change clothes on them. It actually saves time. In that example, we also realized that it worked from a technological point of view, but people said it is not fitting, it is hideous, and they do not want to wear this. So, social acceptance also needs something else. So, we also invited people that could actually make it more comfortable and better looking. We invited a fashion designer, and she turned it into a nice knitted cardigan actually looking good, in different colors to understand what does it mean to people. That is the approach we are now trying to take. If you want to study technology in the societal context, not keep in the lab, in the studio, try to bring out society by considering the consequences of whether people are accepted or how they critique it. It is essential to understand how other people see value in it.

Berrak Kirbas Akyurek: I was going to ask about your role in your research, but I think you explained a bit?

Yes, I was the initiator of the project as a big project leader, especially looking at a more long-term strategy. And I also help organize these meetings, invite them, and look at how people are approaching. It is very important. For example, if you put a (regular, common) building to architects, they will be critical. If you provide them with new materials, they will be like it is very interesting. How? Who? So you get them triggered, and interested in furtherly thinking about it. The way you present and how you present are really important to create an attraction to different people. I think we realized that by working with different people.

Berrak Kirbas Akyurek: What is the main intention and motivation behind the development of these projects?

I think two things. One is curiosity. I am curious about the next step. If we were able to design it, then I am curious about what it does with the uses. What if multiple people have these things. The other important motivation is responsibility. As a designer, an engineer, we should have an interest in what the next step is. What other people are going to do with my technology instead of I only design this technology, and it is the other people's responsibility to do things

with it. I felt like we should be aware of what the consequences could be. Next step to put into the market for (mass) production. Something we should take into account when we take the first step. Not necessarily take the second step, but at least be aware of what is the next step—in that sense, also interested and responsible for the next step.

Berrak Kirbas Akyurek: Could you describe the ‘novelty’ of your project?

One is demonstrating the opportunities of these new materials, smart textiles, in the sense of demonstrating a new class of products, more embodied wearable service systems. For example, the cardigan itself is a product, but it can collect data, and it can be a part of a service with an iPad. If it gathers data, it can be part of a system. So if you collect data by rehabilitation, we can compare data across service providers between patients.

Suddenly it becomes a large system. That is my interest in how we can move product design to service design and system design. That was one of the knowledge contributions. I think the growth plan on how to approach is one of the knowledge contributions. As a side effect, it is not just going from product to service to the system but also the collaboration aspect. How to exchange knowledge between different partners; textile persons compared to technology person, service providers, rehabilitation experts within the elderly care home. How do they relate to the projects? Make it tangible, visible, demonstrate it.

Berrak Kirbas Akyurek: Nowadays, these innovations are described with a variety of terms such as; ‘sustainability,’ ‘natural,’ ‘organic,’ ‘smart,’ ‘bio,’ etc. Which terminology do you prefer to refer to your designs?

We are doing a lot of projects and a lot of smart textiles, service systems. Smart was a buzzword and also a nice addition to service systems. We came from electronics for interaction design. Certain electronics can be softened and could be integrated into textiles. Here, we thought it is a very nice opportunity for industrial design, interaction design, and combine it with very nice material aesthetic qualities of textiles. This is a very nice, sustainable opportunity. At that point, it was about smart textiles. We know that smartness is not integrated into

the textile anymore, also because it has huge sustainability issues. But actually, smartness is in production, so the software is used to design completely new materials. It is not so much, but bio-based materials and its combining 3D printing and textile it providing a dramatic result in architecture, not so much in industrial design. More parametric design using 3D printing can be related to people. There are some examples of shoes. You can measure people's feet and use them as input, and then you can specify parameters for particular designs and characteristics. So smartness is more in the design process but less in the final product. It used to be that technology, as such, was in the product itself, but now it is more in the production process towards technology than again in the service. If we can collect data about people, we can use the data across different products and also make it within circular thinking. That's again, a combination of designing with data, and data becomes a material. Data becomes material for designers just like for me it used to be metal, plastics, and wood.

In a broader sense, we term these emerging technologies as fashion technology, wearables, parametric design, and smart textiles. When I was doing my Ph.D., it was a part of the funding for Delft on intelligent products with Philips. We had endless discussions on what is intelligent, what is intelligent products, what are the characteristics? So we came up with the characteristics. Then, one of the examples of people saying this is an intelligent product was Furby. It did not fit any of the characteristics. Then we stop doing the definitions. So for me, this is also a bit anti-scientific, anti-academic. Instead of first define the phenomenon before we start researching it. We do not know what is smart textiles are. We do not know the definition yet. But if we want to realize it, we need people that understand textiles, technology, and service. Let's combine those, put a design in the middle, and push the project and see what we can end up with. If we start with smart products, let's first define what is smart. That is typical engineering with requirements, and in the end, we would see if it fits with the requirements. Now we are like, let's start and see what we will end up with.

Berrak Kirbas Akyurek: What would you like to achieve with the application/spread of these products?

Did you see the Ph.D. project of Kristi Kuusk, *Crafting sustainable smart textile services*? How she went through the entire process is very interesting. At a certain point, she wanted to get some craftsmanship there. I am trained as an industrial designer. So I never believed in craftsmanship because that is artistic and not scalable and not industrialized. I did not see so much value in it. The thing that she pointed out, especially the values that are in crafts and also in sustainability values. Then it is partly economic, social, and environmental sustainability and how they were overlayed in the craft. Within craft, you never used more materials than they were in your environment. It also has social sustainability because many people are involved. They realized craft has even the same economic value because craftsmen needed to be paid or, at least, sustained to keep on crafting. She used that craft perspective and the values coming from it to look at smart textiles. That's how she came up with some criteria for smart textile services to look at these craftsmen's perspectives as well as sustainability aspects.

At certain points, you got commercial interests, and because of other people getting involved in the projects, you also give away some control. The first one was actually embroidering. We used the embroidery machine that we have here. Then the company said that they are not an embroidery company. They are a weaving company. So we can weave this. There were some stories related to Estonian culture. Technology companies involved in image recognition and QR codes asked not to have a story behind it. It should be understandable for people who are not from Estonia. So she needed to go again some control away. Then, commercial partners came in. These went through some iterations when a very big Indian company was interested in making it into commercial by putting it into the market. They actually did in the US and Canada. At that point, so much giving control away resulted in the violation of some craft values in there.

Thus instead of just weaving, also textile quality has changed. People want to touch this material, but it was printed on an inferior material because it was cheap. It lost its qualities. Instead of local stories that she wanted to transfer cultural heritage, companies asked for local versions to have a general Disney like story. At a certain point, the product failed because it did not have the aesthetic qualities.

People, parents, and kids could not relate themselves to the story. Therefore, parents could not tell the story through to carpets to kids, then also parents are not interested in it because they taught that they would let kids play with the iPad. But it was important for parents, family to tell the story. Now she is actually writing a paper about how the interference of companies concluded with projects losing some of these values or ignored some of these values. And the product failed partly also because of ignoring these values. She also has some anecdotes and some data about unsuccessful products because it violates some of these craft in sustainability and qualities that she thought necessary for the product-service system.

Berrak Kirbas Akyurek: Is it like she tried to compensate with the companies, but the product is failed?

Yes. It is always tricky. But then again, if she was on your own, it probably will never be realized. There is still this trade that we can expand it, but by losing some of the original qualities. At a certain point, if you lose a lot of these qualities, the product will never be successful.

Berrak Kirbas Akyurek: Do you foresee any consequences of the integration of these products into the buildings?

I think some of the ideas behind it in smart textiles incorporated in flooring, for example, or walls. I believe there are also several projects on integrating solar cells into blinds. So I do see some inputs in there. Based on the success of these projects that we did, we got in touch with some European partners, Marie Curie Project. The large overall textile thinking to improve quality of life, they looked at four different scales; of and on the body, around the body, and also building wise. So there were architects doing textile thinking. I do not know what the exact things came out of it. What was the knowledge contribution from the different people? But, I thought it was exciting to look at textile thinking on different scales, body, interior, and building. I do see some cross over between, in that sense, smart textile thinking in these different areas.

Berrak Kirbas Akyurek: Is it like rather than gathering the smart textile material itself, adapting the way of thinking?

Yes, I am more interested in that sense in the way of designing than the actual outcome. I think it would be, in a way, translating. For a while, smart textile was very trendy, for wearables is still in trend. But at a certain point, we are over it. The way of thinking and designing is what stays, and then it is used for the next emergent technology and the next buzz word. We get a better and broader understanding of design and material. I found it more interested than the actual outcomes; in that sense, I am a researcher. Knowledge is more interesting and more sustainable.

Berrak Kirbas Akyurek: Could you tell me about your researches on the user's experience and user feedback?

Before designing, it is important to understand the user's interest and then start designing. That is one thing. The other is the design and do user evaluation, but also, the best way is to incorporate the user before and even during the design process. Then, use the evaluation. I think that is the role of the user within the process. Soon after I started to project, I went to Denmark for two years, where I was a part of the research center. They were good at the participatory design, which, of course, was further away than user-centered design. Because it actually starts to dismiss the notion of user. Before designing, it is important to understand the user's interest and then start designing. That is one thing. The other is the design and do user evaluation, but also, the best way is to incorporate the user before and even during the design process. Then, use the evaluation. I think that is the role of the user within the process. Soon after I started to project, I went to Denmark for two years, where I was a part of the research center. They were good at the participatory design, which, of course, was further away than user-centered design. Because it actually starts to dismiss the notion of user. There are participants in the design process, not just the end-user that you designed for. The interesting thing about participatory design in Denmark is so much ingrained into the Nordic culture. That you only realized that it could only work in this culture

where it is so democratic. There is a lot of equality. There is also a fear of technology taking away the jobs of people. If we are going to research technology, we better involve the people whose job is probably going to take. Therefore, who will be influenced? But it also made me realize some of the downsides, and you cannot really expect huge innovations from participatory design. Because it becomes very democratic, and something that is very outspoken and triggers people thinking and it becomes a compromise. I also saw it. In the process, it is a very long process. I guess I do not have the patience for it. That's one thing. I also think it ignores the skills of a designer. The designer becomes more like a facilitator of the democratic process. For me, it should be a healthy mix to be really innovative. Outspoken design is not very user-friendly, and user-friendly is not outspoken.

Berrak Kirbas Akyurek: Could you tell me about the alterations that you made through user feedback?

Let me show some examples. This was the alarm clock that I designed, revealing emotions and allowing freedom of expression in the way you told in that expression. The device could actually recognize a person's emotions. It was a very controlled experiment to demonstrate these relationships. This was then this lamp was being designed. You can see how it reacts differently to the user. So this was trying to inflict social power, so make the feeling person socially powerful—the value of helpfulness. You needed to help to lamb, saying doing well. These examples demonstrate the relationships between ethics and aesthetics. Then also, aesthetics for interaction, because form its own does not change so much. We are here focusing on the aesthetics of interactions, not the aesthetics of visual form.

Berrak Kirbas Akyurek: Could you tell me the potential impact(s) of these products?

I think the bigger impact will show in time, like ten years from now, and also in a way that we cannot really foresee now. If I look at smart textile service, I think none of the things suggested were successful. What it did that it changed a lot of things about how people work and make changes in other ways. For example, the

technology company that was involved realized that we are not just providers of technology where other people tell us what we need to make and what we need to make for them, which is their business model. They realized we could actually build our platforms and put those out on the market instead of just doing service. So in that sense, it made a lot of additional changes that probably have more impact over time than the actual thing itself, like the way we work, the way we behave, and the way we communicate with each other, which we found valuable. I think that is the place where the changes are going to happen. Hopefully, architects do become more user-centered in time or clear separations, which is user-centered or not. But we now only distinctions; instead, we only have one flavor, which is not user-centered. Or architects were listening more carefully to the biologist. I think those cross collaborations are far more interesting than the actual outcomes. I believe there is a real innovation in the methods, the ways of working and crossing over, and the notions. I mean, now we see it is not just product design; it is more service design. It is probably more sustainable.

Maybe in the future, it will be more about designing systems and how systems can grow. Those are the real innovations instead of having IoT devices. Another thing we have now, we try to get away from users because if they involve in the design process as well, they become co-designers. If people start, they can print a copy in their own printer. They soon turn into manufacturers. I think the current notions of design, user, producer, and designer are going to be more ambiguous. That understanding and knowledge are more profound than having a little smart t-shirt. I think that is the real and long-term innovation where designers and engineers start cross collaborate with other disciplines, and understand their way of thinking, and used them as inspiration and information.

Berrak Kirbas Akyurek: Like fading the boundaries between disciplines?

Yes, in that sense creating new disciplines. I mean, we have data designers; someone can design with data by relying on computer scientists and mathematicians. They do not just rely on a designer. It becomes a new hybrid. Then, this new hybrid works together with, let's say, a biomedical engineer, and

then what happens. It's interesting that it blurs the boundaries of disciplines, creating new disciplines, and these new disciplines start working together with other disciplines.

Berrak Kirbas Akyurek: Could you tell me the challenges that you faced in the design of the project?

I think the biggest challenge is the last one. Working across disciplines is hard. It is difficult. It takes a lot of time. It is also really confronting yourself with your limited knowledge, limited scales, and limited attitudes. A lot of those times, designers needed to give away control to somebody else, and that is very hard, I think. It stops with does with those things. I think you give away control, and you are not interested in the project anymore, and then you lose your expertise. Or you give away control, and people are not doing the right things that you have no control over what they are getting. From an outsider's look, product design sounds more related to other disciplines compared to architectural design. It is also risk related. I mean, if you are building a whole building. As an architect, you can develop a feeling of a structure like it is yours. But in a small product, a half year later you can design another product. But the building will be there like at least thirty years more.

Berrak Kirbas Akyurek: Regarding what we discussed here, Could you tell me about your expectations for the future?

I am very hopeful in that sense that I think young people do not have a problem. Because they have not established themselves yet, so they are very open to things to do outside their own idea of who they are. Therefore, they are really inquisitive, very critical. They want to show older people like they are moving on. Young people are very much capable of bridging disciplines and willing to take risks. Because they do not have so many things to lose, they have not gained much. So they are not losing that much if they take this risk. Therefore, they believe that they do need to take these risks. In that sense, I am positive about the future that will be shaped by young people. I think also think that young people should be more concerned about the thing that they put into the World because it's becoming

their world. I was highly motivated, and critical, sometimes very angry. Because the things that we are designing are the things we want and need to have. Therefore, they are responsible for things they are creating, better use that responsibility well. In that sense, I also believe young people for their decisions.

Berrak Kirbas Akyurek: Do you have any recommendations for future designers and architects?

I think two things; one is to be critical, and the other thing is to be open. Be curious and open to new things. Then, this is also a part of my ongoing lecture, not just being critical by saying this is going wrong, do not do this because it is bad in such a way. It actually provides an alternative. It should be critical and also be open and inquisitive for the alternative just being critical. And then, we can discuss the alternative, then we gain more insight and be more productive. That's what the students need to say, what already exists, and then provide an alternative and demonstrate why the alternative is better. That's how I am trying to train the students here as well.

Interview XIV

Place: Eindhoven/NL

Date: 27th August 2019

At the beginning of the interview, the following information was provided by the interviewee on the ongoing Bio ^ mi Project. Then the interview continued with the interviewer's questions.

Bio ^ mi Project

Title: 'Biomimicry and bionanotechnology in education for sustainable development.'

Background: Bio ^ mi, a collaboration between architect Nadia Jellouli-Guachati (XS2N architect.office) and biomimicry architect Lydia Fraaije (FRAAi architecten & BiomimicryNL), feels the urgency to investigate sustainability inter-and multi-disciplinary with various stakeholders involved.

Bio ^ mi wants to research, raise awareness, inspire, and connect. Bio ^ mi wants to introduce various stakeholders, through the technical/functional properties of biological nano-structures, to biomimicry so that they understand that nature is the source of inspiration for the development of sustainable materials.

Bio ^ mi wants to share knowledge about new applications or techniques with existing and new &natural& materials in bionanotechnology. This should lead to more awareness and inspire the development of sustainable materials for the future.

Bio ^ mi believes in the power and importance of connecting the creative sector with the scientific field, business, and education and is now working with various partners from these different fields.

Theme: Various parties are engaged in research into (sustainable) materials. New materials such as bio-based and recycled are emerging, and new technologies such as (bio) nano-technology. How are (new) sustainable materials found and

developed in a world where some materials exert a major impact on the environment, some materials become scarcer, or even disappear? How to increase awareness of the use of (new) sustainable materials and to inspire stakeholders with practical applications? What can biomimicry, bionanotechnology, and ecosystems thinking mean here? How to broadly share and embed acquired knowledge in training, business, etc.?

Content: Sint Lucas, one of the collaborating partners of Bio[^]ami, wants to anchor awareness of sustainability in education because of its impact on design-oriented thinking and sustainable action. Biomimicry and bionanotechnology are used as inspiration in a program and made accessible. In order to be able to anchor it sustainably in the education program, support and knowledge are needed. Furthermore, Sint Lucas wants to contribute with contemporary means to the visualization of bio nano-structures and relevant information about them.

The process to achieve this (How do we do this?) And for which students, it is suitable to offer a 'view of the world' from the chosen perspective is a search with all kinds of challenges.

Berrak Kirbas Akyurek: Thank you very much for the information on Bio[^]mi Project. For starters, can you tell me about your background? How do you describe your profession?

I have been introduced to biomimicry through Lydia Fraaije. She is calling herself a 'biomimicry architect.' I would not say I am because I just met biomimicry through her for a year and get into the material. But as an architect, I am very interested in sustainability and nature. All these kinds of things I saw the aspects also Lydia is interested in. We have been teaching Architecture at the Academy of Architecture and Urbanism in Tilburg, NL. We knew our interest in textiles and materials. We call ourselves material fetishists. We were always talking about our interests. Once there was an open call in Eindhoven Culture, which is a foundation of the municipality. The open call called material for the future. When I saw that, and called Lydia, and asked what do you think we can come up with, Lydia had already some aspects of nano-structures. So we started with Bio[^]mi Project.

Berrak Kirbas Akyurek: What is the main intention and motivation behind the development of the project?

Our start with this project was motivated by the new materials for the future. We all know that the materials are not endless. You cannot get all the materials from nature; the sources are limited. We know we have a sustainability problem with nature, and all this what we are doing. So we thought that can we have something to get back to nature. Eindhoven has a kind of quote, says 'share the vibe' in Eindhoven.' So we thought that it could be a nice idea to turn it into 'share nature's vibe.' Because, here in Eindhoven, they are focused on technical things and design, but not on nature. Even at TU/e, we wanted to research in the nano-lab here. They would not allow our research because it was only for designing chips. The rooms have to be very clean. If you want to come with organic materials, it is not possible. That is very strange. Even in the biomedical and chemical labs of TU/e, there was no place available for us. So our partnership with Saxion University of Applied Sciences on bionanotechnology was the one participating in this.

We are now working with the Saxion University of Applied Sciences, Enschede, NL, and Fontys University, Eindhoven, NL. We work with Saint Lucas, the creative community for the design and graphical industry, and Athos for IT to make a platform. We also had an advisory group that comes from different companies. That can help us also like company, Biomimicry NL, and some designers, also businesses that do something with bios, nano-structures in their products. If you want to know what Bio^{mi} is about. It is about creating awareness, inspiring, exaggerating innovation, and educating because we think different kinds of people are acquainted with biomimicry through the properties of biological nano-structures. Therefore, it is important to understand that nature is a great source of inspiration for the development of sustainable materials.

Why biological nano-structures? They are also new techniques; not everybody knows about them. There is a very clear example of Leonarda Da Vinci looking at birds how to fly. If you get material on that level, you have to know more. Or you can look from new perspectives. It does not matter you see more unless you cannot

get a new perspective. That could be a way of leading us to develop new materials or others. Because of what we do, we try to connect the creative industry, business, and researchers. As architects, we cannot do this researches ourselves. We need biologists, researchers. We need to work together, and if you work multi-disciplinary, you get to learn more about the fields where everybody is working in, so the knowledge is growing. So if you take an urbanist and biologist and let them think about a problem, you get different solutions. Then if the urbanists are working with another architect, you see a different kind of perspective. So that's the main goal to create awareness and multi-disciplinary themes. We have the motivation to prevent climate change and to achieve sustainability. We know we have to do something for a change. So we thought about what can we do as an architect. Because, in the building, you need a lot of materials. The building industry is one of the greatest industry uses so many materials and is also responsible for a lot of CO₂ emissions. What can we contribute in that manner?

You know, I will not call myself a biomimicry architect, because for me, interreligious. I do not think there is only one way to see things. I love nature, respect nature. I believe that we should create materials. I do not want to limit it. But I think it is quite an interesting philosophy. We can inspire by nature; maybe there is innovation to find if you use it in the right way.

What I find very interesting is 'ecosystem thinking.' From design thinking, you go to the system thinking that was I think interesting in looking at nature to look ecosystem thinking. Somebody made the definition I like. Ecosystem thinking is systems design through design thinking with a holistic strategy. I like that because ecosystem thinking is whatever you do, you think about the whole circle. When you start and where it ends, or there is no end or a beginning. Finally, that's a kind of ecosystem thinking.

If you look at nature, the things at the start end, and get back to the loop. That's for me, the exciting part of it. Can you get as close as you can? We need a lot of time in research before we get very interesting things out of it. There are examples, and we show examples to others that like Lotusan (self-cleaning facade paint - Sto

SEA). It has paint that has durable qualities because they have kind of structures that are inspired by the lotus flower. Because waters fall out of the leaves, and the flower stays clean. How does it do that? On the nano level, they (scientists) know how it works now before we could not see these kinds of things. They understand at the level of nano-structure how it works, how waters stay, etc. By using this kind of knowledge, this paint is created; however, we do not know if it is sustainable or chemical. We do not know it yet. If it is chemically done, it is not biology.

Nevertheless, if you paint buildings wise, you need less maintenance, likely more years. And you make little step in the sustainable circular etc. Everything can contribute to a better and more sustainable environment, and it is already a step. Maybe we can get further, but that is a step.

You can show people that there are some examples already using the principles of nature. And they can find it in nature. Do you know the Sharklet project? That has made materials very anti-bacterial because the shark has anti-bacterial skin. But it does more than being anti-bacterial. Everyone looks at what kind of problems they have and find a solution for that. Sharklet has become a dome for materials they used in hospitals, in kitchens where it is needed to be anti-bacterial as most as they can. A spido brand used it for creating swimwear less resistible in water. This is more bio-inspired. It is not biomimicry. Then again, you can see it as one step.

Then working with electrocuting nano-technology, they say that if we are talking about nano-technology, a lot of people do not know what we are talking about or what it is? They needed a way to visualize nano-structures to communicate with and about them. The fact that you can print it and you can see it in your hands. It is also a kind of awareness of structures. They are in these materials, but we do not see with our eyes. But in some kind of microscopy, we can see these things. So, 3D prints are to visualize them. Here I have a sort of sheet that says we are researching natural nano-structures what we did in Eindhoven with the biologists and got some samples just like plants. We researched them, and we had a biologist that are doing some pictures of the nano-structures. With that, we are going to

use 3D printing for making a nano box printing to visualize what the structures are in these materials.

What we really want is to find out the technical and functional aspects of these plants, so to use them in different problems. It is like the lotus that has all these capabilities of hydrophobic, and it gives new ideas. In the 1960s, when they were developing nano-structures and looking into that, a lot of people said that it is unnecessary. Who needs it? But the first glass developed which could be very clean, and you do not need to wash it every time, a bit by bit you see there are applications in design. That shows that nano-structures can bring benefits to the design problems. Because, when you are having any design problems, you can look into different techniques. And nano-structure now, one of the very new upcoming method that a lot of research could be developed through it. With all these, we want to try to make an open-source database so that we can accelerate innovation. Suppose we have this creative industry, business, researchers, uploading downloading nano-structures for knowing more about structures, or doing something. Even you can do art by visualizing things. We hope that accelerates innovations from these aspects.

Berrak Kirbas Akyurek: Are you trying to create a specific knowledge or more general?

It is more general. It is not for architecture; for the creative industry, all the people that are involved in the building design. So it is also for researchers, architects, businesses. If you collaborate, we share more of this research that you can come up with new ideas. So, we think that is our part, and we want to do this to create awareness by inspiring each other.

Also, electrocute nano-technology telling us that they do a lot of research. All this research paper stays in the closet. Nobody sees it. So how can you create something with it? So that's why we want to open up the NOVA company; these researchers work together with more designers and businesses and are collaborated with our problems. We found out that lot of biomimetic materials developed in the medical world. That's a lot about creating skins, robotic things

in our body—the most developed not to the other aspects. So we think OK, in the medicine world, they are doing great, but we could go further. So we collected plants in Eindhoven. If you want to make a platform, you have to identify things, and the identification comes with a lot of knowledge about the aspects of how do you look at the plants and characterizes them. You know, from a very simple shape from nano-structures. So chemists and biologists do this with us. What you can see already, structures in nature are applied in engineering for creating structures that have less material. Looking into these kinds of structures, using fewer materials to make quite good constructions can be done. To explain a nano-meter as we say, making invisible to visible.

Our plans, firstly, to look at with a light microscope how do they look at what kind of patterns they have, their characteristics. Already we as designers think, wow! It sounds exciting. Already the aesthetics are tempting, but they also have functions. What are they? Why is it like that structured? So what can we learn from it?

Berrak Kirbas Akyurek: You explained a bit, but I want to ask one more. Nowadays, these innovations are described with a variety of terms such as; ‘sustainability,’ ‘natural,’ ‘organic,’ ‘smart,’ ‘bio,’ etc. Which terminology do you prefer to refer to your designs?

Of course, the meaning of words is very important to know what you are talking about. But in Germany, they do not talk about bioinspired, and they talked about ‘bionica.’ Because they want to do more with technic and it does not matter how to reach biological things. It is not a holistic strategy in it. You think about nature, and it is also good for nature itself. We can use nature for our benefit without considering how it affects nature. You can think of biomimicry as never-ending, always have to go in a natural way. But that is not true.

I saw there are designers. For example, a designer made sequin (payet) from cellulose, those payets were used to be plastics, and they become something biodegradable. She also looked at coloring from insects. I think that is a very nice project. Bio-based is not always something very well to nature. It can have a part that is biologically done. It is not degradable as fast as everybody thinks. There

are a lot of ways and differences when you talk about it. But I think for me, the most important thing is how we can reach sustainability as much as we can. I do not believe we cannot do it %100 entirely, but you can always do as much as you can because it also has a price; research time. So you cannot say that you have to do it like that. You can get inspiration from and think about how the ecosystem works.

Berrak Kirbas Akyurek: And for you, the novelty of these projects is making a step?

Yes. For terminology, you have to tell what it is, so there will be no mixed up.

It is also nice that you use the word smart, smart technology. And in Eindhoven, everybody is talking it is a smart city. I do not like the word smart much. It is pretending that something superior, different. I think it should be better one be 'wise.' It is more including everyone to think about how to become wiser than smarter? Smart brings a kind of feeling that not everyone feels attached to it. But for a wise city, it can mean a wise place for everyone, benefit all from it. How can we benefit all from it, think about it, and contribute it? Not only smart people, everyone can contribute it.

Berrak Kirbas Akyurek: Everyone can contribute?

How to be wise in getting altogether more sustainable in a sustainable world? How can we change a bit by bit? Thinking about your actions, what can you do? Do I take the bike? Do I take the car? All these kind of changes does matter.

Berrak Kirbas Akyurek: Could you tell me the challenges that you faced in the design of the project?

There is also a lot to find sustainable materials. Technology itself is needed to be developed when it comes to biology. These kinds of developments do not come from architecture. They come from product design and material design. We have now contacted a material scientist in the USA. She also works for architects in Canada that are now trying to develop an acoustic material. She explores the wings of moths because they are very silent. And they are researching the qualifications of these moths wigs try to make a kind of product. These kinds of

processes cost a lot of development and years of research, with many going back and forward. Twenty years ago, somethings that we now have were not normal. That's why creating awareness of these kinds of ideas is the right way. Also to biologists to think about what they can do better with their knowledge. My perspective as a biologist could be mean to create something.

I think knowing each other better and what we do and what we can and how to look at things could be interesting in innovation. Innovation comes from working with different themes in multi-disciplinary.

Berrak Kirbas Akyurek: In the presentation, you mentioned that one of our challenges is storytelling. Can you explain a lit bit? Who are you referring to tell your story?

To our customers, our future customers, if you want to make this platform. Suppose you want to exchange all this knowledge. Our customers are in education, in business, in research, and storytelling is how do you tell the solving. So for people, if it is clear what the vision, the mission is all these kinds of things. I think storytelling is in any project you do. What is it, and what can it mean for them. To find out who our customers really are. As we say, we are making a platform; how do you exchange? Do you want to exchange for your research? One person advised us. I came from Portugal. If you say to people, do it in open data. People spent so much time, why should I share it? It is not for free. That is also an issue. Can you create something that has an open data source where you want to exchange these things? How do you do that? So it is not easy. We think it could be a nice way to accelerate innovation in that manner. Because of the knowledge of biology, you cannot find it very easily. That should be open to up more. Knowledge of biology and nature is not so easy. So you need to convince people how they are so beneficial.

Berrak Kirbas Akyurek: So you need to convince people how they are so beneficial with open data?

Open up the information and the knowledge to a lot of different kinds of people. So they can contribute to nature because it should be benefiting nature itself.

Berrak Kirbas Akyurek: I also wonder how these things will affect architects to design a building?

Well. A kind of awareness on materials I think that mainly the kind of materials you use...

Berrak Kirbas Akyurek: Do you think there will be any consequences in the building design process?

What I think is that you should be aware that every decision in the design you take is not something you just do. That's also environmental consequences.

Berrak Kirbas Akyurek: Is it like every step of the design process with the involvement of material thinking you will think about the environment?

If you look into materials, you should also think about that if I can find them in my own neighborhood. To make it with or not. Is there something that is going to be demolished, and can we use something out of that for new buildings? There are already in the circular economy. There is a lot of business trying to make the passport of these materials where they come from where they go to. I think if you have a kind of awareness, you should also integrate it into your design process. I do not believe you can design whatever you think we did before without consciousness and climate change.

As I said, sustainable materials are one part and environmental thinks. Sustainability has a different kind of levels. What kind of space that you create can also benefit the environment? There are a lot of aspects to designing what you are making. I think if you are aware of these kinds of problems, decisions would be changed. You have to think that I can only make a nice design, but how do we create it. How does it benefit environmental sustainability, etc.?

Berrak Kirbas Akyurek: Regarding what we discussed here, Could you tell me about your expectations for the future?

Well. This morning there was an article in Eindhoven news. It said that Eindhoven is very afraid that there are building productions, and they are very ambitious because of the lack of housing, and the expats are coming. Now through court,

there is a problem for building projects to be built because of the CO₂ emissions. So now a lot of projects are stopped because of that. They are now thinking about what we should do, what the consequences are. I think the future is telling us that already there is no going on like this as we used to do. They have to explain how they contribute to making it less CO₂ or what do they do something else to reduce CO₂. Our industry is asking how do you stop. The reality is the problem already there. What can we do about it? I think that no matter what, we all have to change things in our design process to answer the question of how does it affect the environmental issues we do. So the future is already there in a sense. To be honest, I do not know if humanity all wants to change. I think changing is the most difficult thing, but we have to. We should not think as somebody else will do it.

Berrak Kirbas Akyurek: Do you have any recommendations for future designers, and architects in particular?

You (architects) are responsible and accountable for the decisions you make. What I mean is that even architects, whatever you do, your decisions have consequences. So to be aware of it. You should also be responsible for making these kinds of decisions. Because you have a huge impact on the way building areas, houses look like. You are also responsible for them. You cannot say it is not my problem. I think being more responsible and be aware of what you do and your own actions. I have been thinking about this for as long as I started to work in architectural education. Every decision you make is something that you are responsible for.

As an architect, you should also combine a lot of social issues—even in urbanism, spatially organizing social issues. As an architect, you do a part of that. You should be aware of all these social issues there are. Context with social matters is very important. That's why I think architects are also responsible for these kinds of things. You do not want to be aware of the decisions you made that are having an impact on society is non-sense.

Interview XV

Place: Beneden-Leeuwen/NL

Date: 5th September 2019

In architecture, the main improvements and innovations came either by less cost or construction technology with less effort. Architects find a way to either more solutions in buildings with fewer costs or innovative construction to reducing the cost of typical constructions. For this particular building, *Zelfherstellend Paviljoen*, I have many reasons to use self-healing, as a called bio-concrete. With your questions, I would like to say the reasons behind it.

Berrak Kirbas Akyurek: Can you tell me about your background? How do you describe your profession? I know you are an architect, but I wonder anything changed after the use of bio-concrete?

Too little. I found the mind-blowing new way of designing with concrete. Not only I thought I know I did. It is not the same as the industry will follow up. The departure of the questions is like whether or not if I fill in this innovative technique, design technique. I will explain because we made buildings with six centimeters of concrete thickness, roof, and wall. Typically, it is not enough. Prescriptions are at least twenty-five centimeters, preferably thirty. 1/5 of the total amount is a huge step already. To get there, this is mass construction will get stronger via 30cm. I had to find another way to get there.

By looking back to the older preparations and building techniques, I found the old skeleton technique by making timber and carpet. So it was a lost casting for concrete; it is not normal anymore. Have you ever lost casting in interior design? I talked to people in TU/e, a construction specialist who needed a balloon cast, a bubble. This technique to make double-curved structures. I thought if it is going to be like that, first of all, no gain in material reduction, and also too expensive. So there was a disaster for the project, but as an architect, we found another way to design. So I did this lost cast carping cast. This is not interior, so I asked the

timber to be red. And it was possible. That's why I got a wooden building and concrete on the top. First, the shape was already there, not sufficient for the demand of the building, but it was there. Normally, it should be in concrete to have these beams like that. Before, I had a different building in a different location. In the end, they did not want that, so I made my solution.

Ok, I was going to tell you about my projects, but we are already talking about the project. Let me show you. Here, the project is in the rural area of Breda. The place looks like a tropical area, even someplace like in Australia. There was an existing building I tried to design; re-use of buildings was already a perspective in my head in the planning part. But in the commission, people did not want to do it. I want to decrease the (visual) impact of the building because it is a nice surrounding. I want to make an organic shape with less visual noise as possible. That's what I do this.

Before I studied in academia, I was a contractor designer, designing the inside of a firm over the contractor, so gaining his accusations, portfolio, and buildings. Because I was a builder, I was technically schooled and skilled. I grew up in a family of builders, dad as a contractor architect. I grew up with building structures and started to get more interested in architecture.

Here is my presentation. Why I make a building? Because the place is so beautiful. They need to be in control of the spot. Otherwise, terrible ways of tourism could go on over there. The area is only one and a half kilometers away from the city center of Breda. I gathered the words they used to explain what kind of tourism activities could be held over there; night tourism, drag tourism, gay tourism, and many more. And they needed to be in control. OK, only a few days, the place is above 20C° degrees. So first, I made a tower like the works of Oscar Niemeyer. But they found that costly and funny. I tried to make a building something organic for the place.

Berrak Kirbas Akyurek: Can I ask your role in the use of self-healing concrete?

I make designs on the existing buildings. I was trying to make growing green in the concrete. At home, I designed a building in which I could control the green

growing in the concrete. With high-pressure rinsing I cleaned off, I like to be in control of what grows. So I found several producers and investigators. I found one at TU/e and TU/Delft as well, who was doing a Ph.D. on the green on façades and concrete. In the end, he did not want it. I could care less if it was inside; it would be less remark on my design. He told me you could talk with Henk Jonker's because he is doing green inside as well.

Then I saw the picture of concrete. I got so enthusiastic. He (Henk) told me I just study in the lab. I said I do not care, and I am going to get it. He was looking for more sponsors for more investigation. I said that I could not sponsor you because I have no money. But I could be a kind of create a project for testing. Then, he got very enthusiastic too. We put in a technical commissioner boss from Breda, and he pulled it out. He did not believe it. Then the crisis was there, and we needed to reduce costs. So the building was not executed. Later, after almost two years, suddenly, some contractors started calling me and had some questions about these drawings and the design. They said we have to use these and this concrete.

That's the way the project came back. Henk started to do it, the healing agent concept, not the inside concept. I wish he did the interior concept. I tried it several times for the project, and it is so good. Also, the quality of the concrete is extra fine. We were the fanatic contributors to things to realize because there was no proof, no rule. There was nothing more than investigation and good common sense. This I combined in one page, and the contractor of the builder said I believe it. I will try it.

Berrak Kirbas Akyurek: What is the main intention and motivation behind the use of bio-concrete?

Because it has a significant impact on the CO₂ footprint of concrete, it is specified in this project and also for the whole building industry. Suppose we would be using it more, first of all, less concrete needed. A more specific argument is no need for all these fossil maintenance products for bridges. Every day vans go around, and they glue roads. That's why I see a big gain in architecture, in the building industry, and environmental causes.

Berrak Kirbas Akyurek: Could you describe the ‘novelty’ of your project?

For a very low budget, you can make a shell construction. That’s is unique because you cannot make a shell construction with an average budget. Now it has become possible.

Berrak Kirbas Akyurek: Nowadays, these innovations are described with a variety of terms such as; ‘sustainability,’ ‘natural,’ ‘organic,’ ‘smart,’ ‘bio,’ etc. Which terminology do you prefer to refer to your designs as such this specific building?

Self-healing ‘bioconcrete,’ but I think ‘biosmart,’ is the general word.

Berrak Kirbas Akyurek: Biosmart? As a combination of bio and smart?

Yes. That’s the way I used it.

Berrak Kirbas Akyurek: Don’t you think biosmart can be easily confused with wearable technologies?

I do not care. For me, biosmart makes sense.

Berrak Kirbas Akyurek: What do you think about sustainability to describe this building?

I am using it to make my point. I think CO₂ foodprint production is a big step in the sustainability of the building industry and the concrete industry. I fanatically grow into this commission because I saw the chances of sustainability. Furthermore, the major thing was the reduction of the concrete mass. That is related to the production of CO₂ footprint because of the demand for fossil maintenance applying afterward. The building itself has the smart thing of shape and eye. That’s what I think a way to design, but it is a design technique.

Berrak Kirbas Akyurek: Do you foresee any consequences of the integration of projects like self-healing concrete into the buildings?

I still hope. Some steps were made on different projects, either for maintenance or for new constructions. Every time, I have a chance to make a new point. To be honest, it is not easy. But sometimes, architects really like white concrete-like white skin. In this way, they also have to use extra fabric like titanium oxide. The

advantage of this bioconcrete is that skin is very soft and white. It is good skin. The result of the bacteria gives you whiter skin than the normal, average concrete. Sometimes this is an extra motivation to put in something sustainable as bioconcrete. For aesthetical reasons, it is a fair reason. It is, surprisingly, additional value. We did not know that because there was no project. Several technologists were tried in the building, and they said it is far better than we thought. First, we were against it, very much in opposition to the technique. When we see it, it is doing better than we thought. And the advantage of the skin is nice. Engineers and architects want better skins for their designs.

Berrak Kirbas Akyurek: I wonder about the impacts of using bioconcrete on your building design process. Could you tell me about your design process?

Severally, because I had to change my all idea about how to get a double-curved shell construction, I only need six (6) centimeters to get some iron in. And iron will not corrugate because concrete self-heals itself. So I have to think about how I am going to bear six centimeters of concrete? Via timber, it is not difficult. It is not heavy, of course, it is heavy but not like thirty centimeters. This is the problem solved by using bioconcrete. It gave me new opportunities to turn back to old techniques of skeleton and casting. I felt free. And as an architect, you want to be free. That is a cliché in architecture. You are not free at all, because there is money, material, functions and many more. I investigated several other possibilities because the boss in the commission refused many ideas. He was also scared of double-curved shelf construction. He had another project in the city with Erick van Egeraat, and they had huge problems.

Berrak Kirbas Akyurek: Could you tell me the potential impact(s) of these products?

The reduction of fossil maintenance products, the reduction of volume needed to make a proper concrete construction, furthermore, the nice skin that we discussed. We use additional fabric to gain soft skin so that you may have white skin via this road. Another one is that you are allowed to put any kind of fabric into concrete if it is less than 1%. I found out during the exercise. So I did not have to ask for it.

I could just put it in; nobody cares. Everybody can start using it. It is not prohibited. You still have mass concrete construction, but it reduces fossil maintenance. This is where I won the argument in the second round of trying to make the building built. This constructor started to believe in me via different ways of investigation its own, via my works, via Henk's works. But when we said the concrete plant could not discharge the content because it allows 1% deviation. If the deviation of the one-meter cube, less than %1 is not a problem. It was also convincing the contractor and the supplier of the concrete. We convinced them with this argument, not with a 'bio' argument.

Berrak Kirbas Akyurek: Could you tell me the challenges that you faced in the design of the project? You told me a bit, but I wonder which one is the most difficult.

There is a technical question in applying this technique and getting insulated as well. This building has an advantage because it does not need insulation. The building is only used twenty, twenty-five days in a year. So using this technique, in living standards, in a house, for example, is a big challenge. I am eager to solve it. I believe it can be solved. The next one is that there are all these 3D printers all around the World. People should focus on how to use concrete instead of all these focuses on printing and designing more with it. More functions and more architecture will bring more challenges. To get the industry on this side, you can put the fabric in the concrete.

Berrak Kirbas Akyurek: Putting fabric in concrete does decrease the cost of the building?

It is not a problem. Concrete is the cheapest building material. It is not an issue. There is no other comparative material. There are like other companies like concrete factory 1, concrete factory 2...

To be honest, if you use it for cellar building, foundation, you need thicker self-healing concrete. It has an advantage that it is more durable because it heals itself.

Berrak Kirbas Akyurek: I wonder, do you want to use this material in another project?

A thousand times. If there is another possibility, I will go for it. There is a possibility in Nijmegen, NL. I hope we can do it.

Berrak Kirbas Akyurek: Could you tell me about the user feedback as such comments after the finish of the construction?

A big war is going on in concrete technology. Concrete technologists are divided, refusers and believers. We are so surprised by the refusers' part because the technology was over there 6-7 years. The designing part and architectural journalism part did pick up with our project. It was sent around the globe through German magazine. German tv program Galileo, it has been on Tv. They told me that they are broadcasting in eighty different countries. I have also been published in the biggest architecture magazines.

Berrak Kirbas Akyurek: What about hygiene phobia of society on bacteria?

It is the same as the farmers are landing. By the way, they use in soil nowadays. It cost them points for soils. Because of artificial chemicals and monothematic agriculture, farmers started to think differently. People can think about differently to bacteria. The farmers did not need those poisonous pesticides ten years ago. Why they need it now? For better and better...

Bacteria is everywhere. In standard concrete, there are also bacteria and biochemicals all over. We all integrate just one of the good ones. This bacteria is already in the calcium. Henk told me that if it was not for this bacteria, which he uses as a healing agent intensively, it was not to be existing calcium will not be there anymore. To me, I used it in my presentation and convinced the people.

Berrak Kirbas Akyurek: Regarding what we discussed here, Could you tell me about your expectations for the future?

I do not have too many expectations.

Berrak Kirbas Akyurek: Do you think you will construct any other projects?

I hope. I do not have too many expectations because this question was asked ten years ago. The design is ten years old.

Berrak Kirbas Akyurek: Is it a bit slower than you think?

Far more than slower. We could apply this technology far more often. And we could use it intensively in the projects if everybody is open about receiving the facts of the product. Like you say, people eager to avoid bacteria. Everywhere is covered with bacteria. Every spot in the World contains bacteria.

Berrak Kirbas Akyurek: Do you have any desire to use any other biomaterials in your designs?

Yes, if it is possible. More often, it is more likely a design inspiration like biophilic and learn from nature. But sometimes fabric and material improvement like in bioconcrete. Most of the design improvement can be learned from it. Bioconcrete is hardware. The design technique is architectural software. You have to be a good commissioner or sensible for this argument. For I defended today, I want windows low on the floor to be open up to ten centimeters around the whole building. I have to hold on to the skylights opening electronically. Not via sunlight, CO₂, or shadow inspired just by humans. If we need some air, open it, close it. This is a design technique. It is not fabric, and it is good architecture. For material in fashion, they made some steps, and I feel in the building industry, this will have consequences. You see a little bit.

Berrak Kirbas Akyurek: Do you have any recommendations for future designers and architects, especially for the ones who want to use those biomaterials?

First of all, to look back on how they do before. Not for a richer, competitive economy, before that. How did the medieval Romans build their buildings? How are they standing? Not only by the weight and heavy construction but also by smart thinking, with the ways of wind and sun. Find your way in whatever you call it biophilic, biomimetics, anything bio.

Beside an architect, I am a heritage expert as well. This heritage part is pretty exciting to see how they got things done, either technical or architecturally. Not

scientifically underlying 'bio' studies, look at it, and use it. See and explore across the border of architecture and building techniques.

Interview XVI

Place: Utrecht/NL

Date: 5th September 2019

There is a huge gap between theory and practicality, and no one is bridging the gap. Theorists are talking about theory and potentials. And practical companies are too afraid to try because they can be damaged financially.

Berrak Kirbas Akyurek: Do you think it makes it difficult to understand and express the ideas?

I think in the bases, it comes to the flood dynamics. That's all that matters. We have a system; if you mass with the system, something happens. You produce something in the system; something happens. It is the basis of everything. All the systems that we use in the system of a building, we have to quantify the effect dynamically. And humans prefer dynamic equilibrium like your body always maintains the same temperature even though outside the temperature is changing for better or worse. You have a constant temperature. With our buildings, we give one particle around, and we say this is what you do. That's it. This is absolutely ridiculous. It is like wearing a bikini in winter. Because people responsible for building design do not know what they are doing. Or they do not want to do it.

Berrak Kirbas Akyurek: Are you saying architects sometimes underestimate the role of the products?

I really dislike the word biotechnology. It creates a division between mechanical and biological technology. They both have an impact on the same system. So we should be talking about system technology. Once we could describe the system outside and inside, you can see the doubt about the technology.

Berrak Kirbas Akyurek: Can you tell me about your background? How do you describe your profession?

I studied biology and business economics. So I am the number's guy.

Berrak Kirbas Akyurek: Do you describe yourself professionally as a number's guy?

Pretty much. I think all my colleagues do that either. I am the general manager of the company because I am good at designing technology. Since I was small, I was experimenting with patterns and data. So automatically, I am working on the data process. I am making everything together by describing the systems. I did my thesis on air filtering capacity of plants because I was very frustrated with all these companies saying these plants air filter these amounts of air etc. Biologically, that is not right because if we were talking about CO₂, the average leaves five million milliliters of oxygen every hour. But humans are taking fifty million milliliters of oxygen. You need about a hundred plants even to meet one human. So for CO₂, it is irrelevant. Plants can only filter CO₂, not toxic gasses in the air. This is an interesting phenomenon because we are very susceptible to CO₂, but we ignore the other gases released through building materials like benzene or any aromatic gases. We do not see them, but we are very susceptible when we feel them. For example, when we are talking about sick buildings, people often say the air quality is bad, but it is hard to know what in the air quality is bad. People have a certain opinion about the air, and they can be wrong. In Holland, most of the time, we have low humidity, which is a problem in the winter. People can say that it is a bad air quality, which is not right. It could be very fresh air with low humidity content. Then we perceived it as bad.

Berrak Kirbas Akyurek: Can you tell me about your role in your company?

I started with the idea that I can and want to quantify the air quality because I hate all this non-sense going on about air. After all, there is not any concrete evidence. I started testing experimental conditions. That has been done before, and there is a lot of tests. That seems to be quite a substantial fact on these gases because plants can break them down or absorb them. It is not we know them, but they disappear in the air. But, I did not find out very interesting. I want to make a practical system where we could quantify the benefits of the system that will use plants and reduce cost. That would be interesting.

One we did the first project, we noticed that we need the right sensors. We also noticed that sensors are not there yet. Sensor technology was very bad because there is no checks and balances in this data in the systems. If there is inadequate data, we cannot really talk about the problems. It is a very unhealthy market situation.

Berrak Kirbas Akyurek: Could I ask about your first prototype? Was it also a wall?

We started something else, then immediately it has become a wall because it was not taking so much space in a building which is always a problem. And we could convert plants in the area, and we could control the substrate. Since bacteria and soil is very important for the filter capacity of plants. But when we started, I hired someone as an engineer, and we flew to China. All the tips were there, sensor companies, and everything. So we have gone there, we have started measuring the building. There were a lot of problems in the building, which was caused by the system itself. All these different particles were fighting each other. And instead of focusing on this problem, the proposals were just wasting all this energy. There was no way that plants would ever solve these problems without the help of technology. So we moved the system into a dynamic system that we used the data to produce ourselves feed models to quantify what is up and identify where the problems lay. Before biophilic solutions could mitigate the problems, we could solve the problem. Because saying plants can solve everything is ridiculous. However, you have a substantial matter of plants; the humidifying capacity of plants is quite high. Calculating all these numbers, you see that they have a substantial reducing cost effect.

Right now, our algorithms are so strong that all the companies that produce this system (HVAC) want us to help them compete in the market. So the people maintain this building; if they do not do it well, we can add another layer to the existing system. In that way, we can help to support the strong players in the market. Because of what we have done, we have algorithms, and we have sensors. We calculate all the necessary data, including outside data, which we need to mitigate heating and air solutions. We are looking at all the clusters and

identifying problems on the bent with, and calculating the most cost-efficient way of solving that problem is. Then, basically orchestrating machines to do everything in sequence, just like they protect the systems inside. It sounds very fancy. I think it is very easy what we do we measure, a black box, on and off switch. We can add to any system that is already there. So all these systems are there in the architectural world, most likely speak one system language. What we do we have IoT solutions speaking that language and basically translated it. That allows us to take over any infrastructure. So, we can make buildings smart with minimal effort.

Berrak Kirbas Akyurek: Somebody's mistake a kind of opportunity for you to make a smart building?

Yes. At the point where we switch everything off, we do see where in the building centrally have these problems. At that point, we can switch on biophilic solutions to mitigate the problem.

Berrak Kirbas Akyurek: Why do you do that?

Because they look beautiful, they also had a climate impact on humidity and CO₂ gases or a particular matter, which are a problem in inside conditions.

On the solution side, we have water solutions that are efficient at humidifying. It is passive humidity, not droplets but gas, which does not contain any contaminants. So it is very effective at humidifying spaces. We made them into not so much walls, kind of like furniture as we use as humidifiers. That can be integrated biophilic solutions without any needs.

Berrak Kirbas Akyurek: Could you tell me more about the main intention and motivation behind the development of the project?

I think when I started, I wanted to this what we are doing right now. But it was tough to communicate with people who do not understand. I waited for years for everyone to be in line with what we are doing. Only now, people started to understand what we are doing and trying to do it. I used plant wall systems to give myself time to develop the sensor technology that we needed. Now, plant and water systems will be secondary to data systems. But they are in the market as one

of the companies in Holland. So, they basically produce enough capital for us to innovate. At that point, when we are now, people could start integrating everything into current innovations.

From an architectural perspective, I think it is very important for architects to look at physics more. So if you have a building, we call system one we can get the outside air, which is system two. We constantly have to look at what system two does system one. System one does not have any effect on system two, and only it emits toxic gases.

We are currently working with UN Studio. If you look at their buildings, they are bio-inspired, and they look great. But it is all about facades because they know it is important. And all certifications etc., are so important these days.

Berrak Kirbas Akyurek: How do you see those certificates as a win-win situation for healthy indoor and outdoor environments for people?

Yes, but you also copy the system, a lot of lobbies going around trying to protect the system, which is failing. At this point, instead of going straight to the market, we have built relationships with science faculties. So we have got the support of the scientists, and at this point, the data speaks for itself. Thus, I could just show people how the project is performing, how they are performable. At that point, what we are doing is not switching off the systems, adding more systems. Most of the buildings were designed for overcapacity. So we are saving energy for better climate conditions.

The plant systems are quite expensive, but plants are the solutions for everything. They look nice and influence on stabilizing the system. But the best thing we can do is to create an equilibrium with all the mechanical systems dynamically. From a system perspective, if you think about the products separately, the system will get air and will not look at humidity or temperature. Because that is the problem of another product so another company. This really does not make sense. All the sensor systems do not know about each other. We have parallel systems that are practically bonded to focused on the simple factors.

Berrak Kirbas Akyurek: I was going to ask about the 'novelty' of your project? But I guess you explained a bit.

In brief, it is performability and working quantitatively. You are presenting a new system and also infiltrating it into the existing system.

Berrak Kirbas Akyurek: So your systems are for the existing system?

Yes. The only way to get into the existing system is to change it. That is the problem of disruptive technologies. You have to mitigate the change. Biological life and mechanical life are very different, and I think we should not distinguish differences between living and mechanical. We should describe as 'impact' and 'system.' Anything can create an impact. If the system is stable, we are doing well. If the system is unstable, we can know why it is wrong by looking at the data.

Berrak Kirbas Akyurek: Nowadays, these innovations are described with a variety of terms such as; 'sustainability,' 'natural,' 'organic,' 'smart,' 'bio,' etc. Which terminology do you prefer to refer to your designs?

Then again, it is semantics, is not it? The word does not carry meaning. While we are communicating, people do not understand what we do.

Berrak Kirbas Akyurek: Do you have any preferences?

I think I need to think about it... Because it is hard to find one single word to describe everything.

Berrak Kirbas Akyurek: What would you like to achieve with the spread of these products?

Efficiency. Efficiency is my greatest driver. I just want to know it works better than the existing system, which does not work at all. I do not care about power. I do care more about the impact and progress efficiency.

Berrak Kirbas Akyurek: Can you tell more about the consequences of the integration of these products into the buildings?

The thing we are talking about this until now. I think we are talking about marketing where we are coming. But we are starting right now, and we are

working with architects in order to overlay it. In the green wall system, we put sensors, the humidity parameters in the winter, depending on how much we used to increase by about %10, which is huge. That really mitigates the problem in the safe zone. For CO₂, it is very hard to put any number on it. We were in a medium change.

Berrak Kirbas Akyurek: While you are working with architects, when they involve in this process?

It started to change. We do not talk about data with architects. Now interior architects take our story when they go to the client. So tell the client what is possible, and the client says, I want that. That's where they come in.

But as in the case of the current project, we have. At the beginning of the design process, it is the best way to integrating plants into the system because you have a stable amount of plants that will impact the system. And you can quantify it.

Berrak Kirbas Akyurek: As a biologist, have you ever get ethical questions regarding the use of plants?

I do not see anything wrong with using more plants within architecture. The unethical thing is to cut down the plants. I do not see any ethical perspective on using plants. Often we got ethical questions about spreading soil material. But plants have roots, and they rise from there with the bacteria they want. When you often see because of the reason being scared of bacteria, they use hydroculture plants without any soil. So then you are missing almost half of the plants. They will not grow, so they will not have an impact on humidity and the system. I think it is very unethical in the sense of making a problem which is not existing in the soil and use plants in the wrong way. That is the most unethical thing.

Berrak Kirbas Akyurek: Do you mean hygiene phobia?

Actually, hygiene phobia is causing a lot of health problems right now. The more they protect themselves, the people become weaker. For biologists, it is very straightforward, but for other people, it can be looked strange. The bacteria on the leaves, roots, and soils are important, and they do not have any known impact

on human health. Actually, one of the know contaminating bacteria in a building comes from concrete.

So ethical questions about plants... I like to think evidence base, and there is no evidence that there is unethical ongoing on or there is no evidence of plants being the root cause of any harmful issues. I do not know any source of these questions coming from anything rather than fear.

Berrak Kirbas Akyurek: Do you get any questions regarding their maintenance and guidance?

What we do, we do not do the maintenance, and we do not place the plants themselves. We make the wall and ensure green scaping will be done. They use recommendations for whom they should ask to maintain. Essentially, it is their problem. We work supposed to make systems numerical.

Berrak Kirbas Akyurek: Could you tell me the potential impact(s) of these products?

I think creating efficient systems where you use a system that creates a system rather than product dynamics. Try to create a situation with a system that is an incentive and changes itself. This is very difficult for a small company, but I think we are doing well.

Berrak Kirbas Akyurek: Do you think it is possible to see any impacts on building design?

I think it is relevant in the sense that there is a lot of building over there and needed to be fixed. But as long as we have a simplified way of calculating the data, we can fix any situation without any high-cost. We are thinking of buildings in a less static way.

Berrak Kirbas Akyurek: Could you tell me the challenges that you faced in the design of the project?

So many...

Berrak Kirbas Akyurek: Maybe you can tell me some bullet points?

I think the biggest challenge is finding out how resistant to the old system for change. So you have to force the old model to change. In order to infiltrate the system slowly and not aggressively, we as a start-up company need to find a way slowly. I think proper technology stepping front should be with your system rather than against the system, which is very difficult. You have to be patient. People and companies are always thinking about the short-term benefits of a single product, not the long-term.

The other thing is you have to strong enough to get cynical because you see a lot of activism going on. There is no point in that either. Because if you do not change anything, why all these complaints? Help change the system. People always have opinions without foundations, but they do not really understand how the system works. They are expecting people to change. That's happening all around the world right now.

Berrak Kirbas Akyurek: Is there any study that has been done to evaluate the user's experience of the project?

We do not interact with the end-user much. Because in the buildings, there are feedback loops that can mitigate problems. What we are creating now is to interface. People want to have power in their situation while we give them questions. It is like, are you cold or hot. Because it is subjective, perception can be voiced, and the system can be understood while this is happening. The subjective feedback is very important for perception. You want to create setpoints with this feedback, and now we have our system. So that's why we do not interact with end-user. They are perceived as true, but fundamentally it is different. I did not even want to change the system considering the user feedback.

Berrak Kirbas Akyurek: Regarding what we discussed here, Could you tell me about your expectations for the future?

It is a very dangerous question and conversation. Fundamentally, people tend to move forward in the system. I think in the general sense, we had an industrial revolution with a whole new market born. Then we had tech-boom, which led to a new market movement. And alive-boom, not the general alive, more like the use

of computer models. I think from now on, and humans become irrelevant in the process. All these specialists could be changed. I think everyone should be very afraid. Not so much a dystopian scenario. It is realistic. I am not saying architects will be relevant. Architects should be careful because of all design generating models. No matter how the design looks good, it will be irrelevant. I think people should be way more worried about it. I think we will have a different world in five years, and the world will be a more technogenic place where specialists make their rules based on their specialisms. It is fundamentally correct because who else knows more than specialist about the special topics. But if specialists are unethical, who is going to see what they are doing. We see these with Facebook, and for example, no one is doing what they are doing.

Berrak Kirbas Akyurek: Do you have any recommendations for future designers, small companies like you, or architects in particular?

I think that parametric design is very important, and architects should not underestimate its importance and potential. It is the only way to look forward. I believe it is crucial to break out the current system, and we should start looking at what is relevant in our sector as in now. Because the background you get in your school is probably is on the skill sets, but not on the current development of technology. Since technology is moving so fast, sector leaders should be integrated into it.

Interview XVII

Place: Eindhoven/NL

Date: 6th September 2019

Berrak Kirbas Akyurek: Can you tell me about your background? How do you describe your profession?

So, I am an associate professor, so part research, part teaching, part management. Unfortunately, the research part is always on stress. I am teaching at the Human-Robot Interaction Chair. For research, we usually do perception research and the context of a collision and loss experience on robot research. How people interact with a robot? How should robots interact with people? Those are my domains, what I do here. My background is in physics. I studied applied physics at this university and also did Ph.D. Physics of Man at Utrecht University and more and more physiological domains came. So, my domains are visual perception and later even motor control, even later more locomotive process in the brain. And now, I am looking at how to transfer technology for better behavior for robots. So that is my background. I see the brain is something like a big inspiration, and I want to learn from them and want to model things. Sometimes how the brain solves problems, and then we can also see by putting it to robots for interaction.

Berrak Kirbas Akyurek: Can you tell me about your current projects as such aim / your role in your researches, mission, and goals?

I supervise Ph.D. students and basically make sure that there are courses on the topic. And I supervise a lot of student projects. I also do some research myself, and then research is basically to publish. I do peer review processes, actively participate in conferences, program chairs. I am an associate editor of an International Journal of Social robotics, for example. So in terms of research, you basically have a number of lines of research. A sort of human-robot interaction is very big. We mostly work on approximate so how robots should position themselves with respect to people, at a certain distance. But these distances are

not only determined by physical or environmental constraints, but also by physiological motivations like what kind of activity I do like reading, watching tv or are you, scared or happy, those kinds of things, how robots should behave. So this is one research line. The other is the behavior of the robot, on exercises, the gestures, or try to make eye contact. How can it be used? How can robots give social cues to help people understand the robot better than it works? If the robot understands social cues as well, then we have an interaction. Most recently, I have been thinking about emphasizing more learning aspects, moving more to artificial intelligence. I mean, there are already so many works on reason and decision making. I want to focus on more recent developments. Already initiated Eindhoven Artificial Intelligence Institute, this is going to be a big thing.

Berrak Kirbas Akyurek: What is the main intention and motivation behind the development of your projects?

Originally it was because... Before coming here to work here, I was a post-doc at Nijmegen, Radboud University, NL. I have worked on a European project. There had an expressive goal to measure the qualitative process on the brain using fMRI (Functional magnetic resonance imaging). Normal those processes and then put those capabilities to robots; that's what I actively work on of those things. When I come here, I was appointed as an assistant professor. My main task was to take care education task. I had to take cover a course on visual perception, and I had a good background for it. Then I decided to make human-robot interaction as a research line because it fits very well with the main theme of this group, human-technology interaction, and this like an umbrella where I can put all things I have done in the past. Basically, social robotics is the sole application, and it is a win-win project.

Berrak Kirbas Akyurek: Could you describe the 'novelty' of your project?

I think a different approach than most. One of the main things that I do differently, I am biologically inspired. For sociorobotics, in the Netherlands is still a very small number of groups that work in this domain. What I do differently, I do more modeling And more experimental validation, a little less applied maybe and more

focusing on fundamental issues. That makes it relatively unique in the Netherlands. For example, my quote on the webpage is ‘if robots need to understand people, then people need to understand robots.’ It causes one level deeper. You need to understand them to find out how they understand you. So you get this chain of thinking. It is fairly unique; there are a couple of scientists in Germany, etc., who do this. For model staff, I am trying to make robots smarter and more intelligent. And focus more on social intelligence but not so much on deep learning staff. This requires more recognition, classification, and sometimes function learning. My topics are more in interactions.

Berrak Kirbas Akyurek: Can you talk more about biological inspiration?

When you model how processes in the brain work, then you get an artificial neural network that is completely different from what we commonly use nowadays. For starters, they are neural networks, and they have a particular structure. This is known that the brain uses this structure a lot. So many people believe that that’s probably for a good reason. But then, when you build behavior on robots, artificially network, you get a completely different model than deep learning. So that’s a way in which biological inspiration on a very low level has effects on how we do things in artificial systems like robots.

I am not talking about the body but the mechanisms on the brain.

Berrak Kirbas Akyurek: Nowadays, these innovations are described with a variety of terms such as; ‘sustainability,’ ‘natural,’ ‘organic,’ ‘smart,’ ‘bio,’ etc. Which terminology do you prefer to refer to your designs?

If I want to describe what I do in a short version, I would say robots are socially more intelligent. But there are a lot of terms out there; if you are in the field, it could mean a number of different things. One of the problems is the word of intelligence sometimes used for systems that are not intelligent at all. But they have some feature that makes them able to do things that are considered more difficult such as face recognition or emotional – expressional recognition, is something really belongs to computer – artificial intelligence because of neural network and staff. In that sense, it is intelligent because it has a neural network

in it. The fact that it is like classification, and it is more like a dictionary. In that sense, the dictionary is not intelligent. Because sometimes it goes with the mechanisms that have been used to make it happen. That's why some people talk about general intelligence, and then they mean humans are smart compared to any other organism. So having language, reasoning capabilities, cognitive capabilities, if you could put all these specifications into a machine, we could say a general intelligence. For example, we very much use chat boards like Siri, and Google has a version of Alexa; those are examples of systems that have no general intelligence. They are basically in the detection stage; they basically detect speech and convert it into words. And then they compare it to a vast database of what other people sometimes type and respond to these words. So, you just look up a dictionary that people say the most and then give them back. The system has no reflection, no understanding of what the meaning of these messages is. So, the system is as stupid as it can be, but it shows the way people interact with it. It gives the impression of intelligence. So, if you say give me a definition, then basically, you need to know which context. You can easily test by asking an open question like why is that. If you use expressions, it completely fools the systems.

Berrak Kirbas Akyurek: What would you like to achieve with the application/spread of these products?

My personal goal to have a good understanding of fundamental research questions, so I really want to understand things at a very abstract level, but there is also the responsibility of a scientist. There is always you do something for something in an applied context, at least. Basically, in basic science, you do not do anything, just the goal of acquiring knowledge. So that is my first goal, and then I want to say what socio-robots be like in the future, then you see a lot of things don't work well today. One of the reasons I am interested in socio intelligence is very basic things like, you know, when we are talking, we make frequent eye contact but not all the time. So this behavior, how do you model that, and how can you put this feature to the robot so that the robot can do that too. Because if you put a robot eye stares at all the time, or adjust completely misses you and not looking you, but as soon as you make human behavior, then you get

a totally different feeling about the robot trying to do. If it is communicating non-verbally, it has a very profiled impact and how you experienced it all. This means, in the future, robots will be used for people that do not necessarily know what a robot is, how it works, what limitations and capabilities are. So, in those situations, robots have to help all the people live safely and healthy at home, then in those situations, you need non-verbal communication and verbal communication as well as that work very well. And it should signal the natural way that a person can do with a robot. This is still very bad.

Making eye contact is not too difficult to come up with rules that are OK, but if you buy a robot, none of them have it. Maybe you see it. It is a robot girl, bold, also called Alexa, I think. A chat board is a face with just an upper body. What they do, they give a robot a facial expression that matches the chatting. But the novel work of communication is completely wrong. Even though it received a lot of media attention, it sort of very stupid social intelligence of non-verbal communication. The funny thing is if you do it well, you do not realize it, but when it goes wrong, it breaks the level of communication at very, very basic levels. It is a missed opportunity, and I think that's why every application people work on robots, they should think OK.

Berrak Kirbas Akyurek: Do you think those technologies can be applied to the buildings?

The closest thing I think we have done is how to integrate smarter technology, especially applied in the building. For example, if you put a robot here and say go to a coffee machine, it does require a map to go. It does not know where it is, and it requires sensors usually in the building that tell the robot where it is and what to do. Also, for the health care domain, we did a European project that goals to help elderly people at home. That was monitoring the health of the person, environmental quality of air, and sensors that help to detect where the robot is, and the motor system was automatic, like where automatic door openers, all sorts of things. And that line of thinking goes, all the way the internet of things like the fridge knows what to order, the kitchen can dig all information on recipes and

presents to you, knows what time you need to cook, how much water you have to drink. You see that smart technology also does a lot in a building. Then the question is how to design the space so that everything works perfectly. In my point of view, I care about the robot but do not care where the sensors are, as long as they work. That's where some point architecture meets robotics when robots do not function on their own without their communication equipment in the building. For example, if there is no Wi-Fi, probably a robot can do nothing. They all need information from some source and transmit them via Wi-Fi. If they cannot, it won't work.

Berrak Kirbas Akyurek: Is there any study that has been done to evaluate the user's experience and feedback?

I think a lot of work we do is take user feedback. So most of the time, we do lab experiments, sometimes field studies. This is specifically needed to get information that you need from people interacting with that system. This can be very basic, like whether some people notice things, sometimes IT is very elaborate, but you can quantify certain effects, for example, eye contact. You can measure how many degrees of eye turn you can look away before you can prefer to break eye contact. Then you can have the whole study, and then you can figure out that it is, let's say, 3 to 4 degrees. You can move eyes 3-4 degrees away, and then you still experience eye contact. If you go beyond that, then there is a chance that a gaze direction is looking somewhere else, then you have 10 degrees, not looking at me. The interesting thing is, if you are very far away, it is still 3 to 4 degrees. Geometrically saying, it is very strange but apparently how it looks. I also have quantitative data collection depending on the details, research question. We always have human participants. They have to do some tasks, usually, design such a way that we can hopefully access the information we want to have.

We are using user feedbacks for anything you can imagine. For example, just before some holiday, a group of bachelor students had a project where the robot moved a different way, could move in a zig-zag pattern, could stop and go all the time. Hence, the behavior of the robot was how it moved in space and how fast it

moved. This was manipulated, and according to literature, people can associate a certain emotion with doing that. We have also found out ourselves at earlier studies that we wanted to know which emotion did people see in the robot. But we also want to know which emotion did they experience. Then we basically design an experiment that does exactly that. And we also measured the time and how much distance people did respect the robot so suppose you afraid of it. Then you may be staying a little bit further away than if you are very comfortable with it and like it somewhat. The question that we assess the emotion that people see in the robots, assess emotions to experience, and we use sensor data to measure the distance to the people to respect it. Sometimes it is really difficult. Colleagues of mine wanted to know how aggressive people feel, but how do you measure that? I mean, they spend a lot of time figuring out what it is and how do you measure it and if it is even possible to measure it. A lot of studies say sometimes related to some kind of comfort level. So, for example, we also have a study. We measure the perceived comfort people feel when the robot passes by then, and we use different distances to see that. The perception studies about this comfort layers, we have a light source, how much brightness affects the comfort layer. In the end, it is all about how people feel. You want to access physiological information, but you cannot do that directly. You need to measure something else like the distance, time, or roof of a questionnaire. Sometimes physiological variables do not give expected results, but it is typical for physiological research.

Berrak Kirbas Akyurek: Could you tell me the potential impact(s) of these products?

I think that developments are in industry robots need to perform certain tasks, and if they do that very well, they can automate this task, then that way people can save money, that's why they want it. However, if the robots get intelligence actually to work together with people, then you do not get robots to take over jobs but help people perform better at their jobs. We also have some sort of device just to make people better at their jobs. For example, the butcher has knives. But in the future, we will see very advanced systems at the bakery where robots help to operate a machine, but it is not going to take over jobs over a person. It is going

to help that person with tasks it can do, so make World 'light' for that person. Then the person can do other tasks better because s/he has more time for it. So we see in the future, robots will actively collaborate with people rather than independently doing things, and where the robot is, people should not go. In a car manufactory, there are welding robots, and when they are operational, you are not allowed to come there because it is dangerous. So this distinction between robot doing something, doing it very well, very fast that will still happen. Still, we will also now see a new class of robots that are not necessarily good at everything, but there are more and more assistive tools that make people work better. Also, in healthcare, the doctor determines which medicine you can get, but the robot can help the doctor to administrate them. Because it is at home, that patient has to take some reminders, maybe doing some simple monitoring tasks. The whole organization of medical care can get better.

Berrak Kirbas Akyurek: Could you tell me the challenges that you faced in the design of the project?

Challenges are, robots cannot really do what we want them to do yet. So they do not move fast, are not accurate enough; they have limitations. The part of the problem is that people think that they can do a lot, but it is not really true. So you see all sorts of very nice movie clips, robots doing something, but they are fake. That one is one challenge. The other challenge is the nature of physiological research. Basically, you cannot get measures directly. You need to come up with some kind of a modal and then link physical variables that you can measure with physiological variables. That is a very fundamental one. Now the challenge is general intelligence like we would like to have for artificial systems is really, really difficult—nobody able to do that satisfactorily way. So, despite all advancements in new technologies like deep learning, this problem is not solved at all. It is the same problem that we had in the 1980s and the same problem that we had in the 1950s. The only different thing is the amount of data and processing power.

Berrak Kirbas Akyurek: I was also going to ask about your expectations for the future, but you also told me about your ideas about the healthcare system, Is there anything do you want to add?

I think the point is if you put robots in front of people, they have all sorts of expectations. They want to communicate with it in certain ways. But they cannot because this is not socially intelligent; it can only do its task. This is very dissatisfying. So talking about user feedback, people do not like it. So it is more like if you have a socially skilled robot, you make all sorts of tasks easier. Because people want robots around rather than wanting them to go away, so that's is the big change. Normally people need the robot very severely. Now we are moving into the situation that robots are used in the workplace in all sources of roles. And there are also people working there. So their workspace is the same. Again it is social intelligence that is useful because there are people.

Berrak Kirbas Akyurek: Do you have any recommendations for future designers and architects in particular?

I think for designers. It is just one simple example. If you put your eyes on the robot, people see that the robot thinks since the robot looks in a certain direction. But if you use a flat-screen, you have a certain physiological effect. It looks as if a picture of a face looking straight into the camera. If you see the picture, that picture is looking at you, and that works for any directions. That's strange, and it is very common and useful. If you look at the TV, then the newsreader looks at the camera; it does not matter I am sitting here or over there newsreader is always looking at me. If you compare to this real world, if you look at this direction at me while I am sitting over there, you are no longer looking at me. This is called the Mona Lisa effect. So the picture seems to follow you around. That also works for the robot if they have a screen with a face on it. It is very easy to do, and a lot of designers use it for robots. But if you want to mimic human gazed direction and eye contact, it does not work. It is impossible, so you need a real face. So this is an example of where knowledge about how things work in humans and the human brain affects how things should be designed. There is not that much connection

between these domains. For designers, it is important if they are aware of these things.

Berrak Kirbas Akyurek: So, if they are aware, they can design further?

Yes, nowadays, it is all about aesthetics and functionality. There are so many constraints that designers can only put a shell around it. That looks a bit smoother. Therefore they are not as scary as an open robot without skin. I mean, these technical difficulties will go away. It will be possible to put a lot of hardware and software in a very small space. Therefore, there is not just aesthetics, and there is also functionality in terms of how people experience the robot and how they interact with it.

Interview XVIII

Place: Eindhoven/NL

Date: 18th September 2019

Berrak Kirbas Akyurek: *(A short introduction of my thesis and studies)*

I am slightly philosophical. If I look at what you are doing, it is a very important subject. I feel that we really need to come to flourish in the coming years and decades. For me, it is a part of a new narrative. Technology and nature that is really interesting. If you look at nature, you could say it is a very advanced technology that we do not yet fully understand. That is a wonderful way of looking at it. What we had done as human species, we have this narrative that has been around for a couple of hundred years. That we are separate, we are not part of nature. That's why we want to control nature. Science is very mechanical in their approach, from Da Vinci to Descartes, as they were looking at our bodies that are like machines. That model is not really working anymore. We are sort of in the mid-phase. We have seen that our old models are not working anymore. They are breaking down. They cannot handle the complexity that we are now finding. We are in the position now; everything is emerging. It is not possible to control it. If I look into the future from my vantage point at the moment, that is very naïve for future perspectives. Like all the new technologies are coming, it looks like actually lead we would be God-like. In this sense, we can do everything that we want. That's what it looks like right now. Then again, it is very naïve. But what I see, I have this narrative for a few hundred decades that we are separate. We need to compete with nature instead of collaborating. That is also the system we have created. Therefore, we have created many stuff and impact on life, nature, and protection from nature as well.

Berrak Kirbas Akyurek: You mean like nowadays, we have 'too many' clean environments. That's very interesting that we see a lot of allergies at the moment.

Have you ever head of Microbiol?

Berrak Kirbas Akyurek: No.

Microbiol is all your bacteria in our gut. We have more DNA from gut bacteria than human DNA. So if you look at our nervous system and our brain, we have neurons around the hearth and the gut, about a thousand trillion bacteria. That also shifts the focus of what does it mean to be human. Because bacteria also affect the way we feel.

I used to be a physical therapist. It is quite a holistic way of looking at Western medicine. Again, it is quite mechanical—our bodies like machines. Physical therapy is also trying to see the interrelatedness of all sources of systems. If you look at our body, our body is a cooperation of cells working and coming together to specific organs. But they are also fighting together. But also with these gut bacteria. Now we see if you are too clean, you do not have diverse bacteria in your gut. You have more allergies and more terminal diseases. It is far more than symbiosis and a combination with nature. If that has been a story about how we also built, that would be amazing. At the moment, I love biology. I think biology is the next big thing in technology. That way, we can look at the universe as life instead of matter. Biophilia is a new buzz word for me if we can thoroughly work with nature instead of against it. That is a mindset, and it is a position. Therefore, it is amazing that you are doing this work because nature is an incredible constructor.

I do feel that technology is one part of being able to create the future we want. A big part is a narrative that I tried to explain what we believed as a society (western society). With capitalism, the system was created out of that narrative. It worked for years, but now it goes too far. That's been working, but currently not working and actually harming the ecosystem, so that's why we need to come up with a new story and model that works. If you do not do that, any technology that we actually create will increase the problems that we are at the moment. Because it is the mindset that has been informed by the story that is actually creating issues we see around us. Because we have enough technology, we have enough possibilities to be already completely sustainable.

Berrak Kirbas Akyurek: You talk about the importance of the narrative, so maybe it is a good way to start with a question of terminology. Nowadays, these innovations are described with a variety of terms such as; 'sustainability,' 'natural,' 'organic,' 'smart,' 'bio,' etc.: Which terminology do you prefer to refer to your designs?

Biophilia is a word that I came across just so soon. But it resonates with me because it actually explains what I am thinking about what I am feeling over the last months. Because for me, it is all about life. What is a life we do not know still? Is it not crazy that we still do not know what life is? What makes plants alive? You can say a plant is alive, it communicates, it can react. So what are sentients? What is consciousness? We are coming to this part in our society who does it mean to be alive? What if something inanimate or animated. We are now seeing that planet earth is now at the risk of not being able to support life. We are looking into other planets like Mars and thinking about how to colonize Mars. So if we just make it very, very easy. How can we construct, built, support life in all aspects? Looking at the Netherlands, our cities are more biodiverse than our agricultural lands. It is difficult on the one hand we have an agricultural industry supporting life, but one species: human. That is actually not supporting all the other life forms. How did we decide we worth more than the other species? Which species worth more? Again this comes from the separateness of seeing ourselves outside of nature instead of being part of nature and seeing that we can own land. Can you own land? Mars? I say no. Ownership is something that we, as humans, created out of wanting to solve the problem. The problem was the tragedy of the commons.

Berrak Kirbas Akyurek: Can you explain a bit the tragedy of the commons?

So the tragedy of the commons, as an example, you have a field of grass, and some persons put a sheep in that grass in order to create wool. Then someone else put two sheep and try to extract as much as possible. So, what they come up with is that we can have ownership; someone owns the piece of grassland. It is there, and you can utilize it, and you do not overuse it. It is more about mindset. That's why it is important, and we have all these regulations and rules. Again who is in control

of our systems of the earth? It is a runaway. Nobody has control. I think we need to look at that narrative that we are part of nature instead of being apart from it.

So, yes, technology is essential, but also the mindset of how to apply this technology is important. Otherwise, we get more of the same, but then with more risks. If you look at exponentially growing technologies, now coming out, they seem innocents; how we apply them to what purpose. It is our responsibility.

Berrak Kirbas Akyurek: So you are saying if the mindset does not change, the change in the technology still can be harmful in a way?

As an example, at the moment, we are looking at a building. It has bricks, glass. It is not natural. I mean, not how nature works. Let's put it that way. There is no intelligence in that structure. Nature has intelligence. So I would say that this building does not support life even at a minimum level. I would like to go with biophilia. It is the love of life. What is the point of the universe? Could you say it is a love of life? So what we do is to think about how we can live by supporting life. How could we understand nature more? How does nature work? How could we grow our building?

It is about a new story, a new narrative, a new system. Again, I am also looking at the housing sector in the Netherlands at the moment. It is also crazy, and prices are going up. They said there is too much nitrogen, and they said they are trying to protect nature. But it is not working anymore.

Berrak Kirbas Akyurek: Prices are too high, lots of students are homeless...

You know why? Every person has the right to live, and that means water, shelter, and food. It is a choice that we can make. Then we have to look into it from another point than pure economics. I think if we go into sustainable and nature-based technologies, it just grows. So there is no cost to it, maybe some time.

Berrak Kirbas Akyurek: Actually, the cost is to create a specific environment that makes them grow.

But the circularity can become smaller, faster. Everything, even oil, is circular but very slow circular. Ok, let's go back to your questions.

Berrak Kirbas Akyurek: Can you tell me about your background? How do you describe your profession?

My background is I studied physical therapy. That is a very high-level people and technology, social and technological study. It is also where you come across a complex system. The human body is a complex system trying to understand and help that person to be healthy again. I went into that, and very quickly, I realized that it is not for me. To contribute to society, I became an entrepreneur in 2008. From there, I have just picked up everything I found interesting. I started really learning after school a lot of emerging technologies around us. Social media, and how social media could impact society and organizations to become decentralized and non-hierarchical. How can we work together? But the theme is really technology could impact society to who wants a new way of living. For me, that's really about the new hippie style, the World where we grow old together and live in peace and harmony. I genuinely believe that it is possible. I have worked in smart cities as well. I love the smart city approach from Boyd Cohen. Again a new model of organizing. For me, it is not a technological issue, and the thing is—technology to enable how humans can organize our cities and society. Then again, we have to be very thankful for the system that we have created that's far brought us a long way. It is time to say thank you and goodbye.

The difficulty is not a new system, per se. It is letting go of the old and embracing the new. And it is timing it. Timing it in a way that most people want the future all to be inclusive, sustainable. But timing is tricky. If you do not have the time right now, there will be a lot of people who will suffer. We cannot have a sustainable society by not caring about people who are not able to do that by themselves. What we do is to inform the systems that we create. If we say let's kill half of the human population in order to be fair and inclusive, a good society. It is not a good option.

Berrak Kirbas Akyurek: As you are saying, I think we are doing that by letting people suffer and die.

It is hidden. It is already there. I am a perpetrator as well. So every person living in the West is a perpetrator. It is all the hidden costs. We do not pay for what we receive. It is very difficult for one person to come out and say I will do everything by myself. I think more and more people are doing that. I see myself becoming more aware. If we know how to come together, we can build a new system and multiple systems in the beginning and say goodbye to the old ones. So it is more about a transition issue than a technological issue.

So, for example, the Titanic has been a symbol for our society at the moment. Has it already crashed into the iceberg? We do not know for sure. We are seeing that more upper deck people, not enough lifeboats... I do not know. But it is not about that. How can we create new ships for people reaching shore in case of an accident? So it is about being fully integrative symbiosis with nature is what we need. Technology can help with that. Absolutely and especially, the technology that has been developed now based on nature and biology. But the technology must be something that we, as human beings, give value to. What is the value of our systems? We see nature as a cost instead of value; that is an issue.

Berrak Kirbas Akyurek: What is the main intention and motivation behind the biophilic approach?

I would say it is about questioning the system where the problem resides. It is all about the system. So if you look at society at the moment, it is like we invest billions of dollars in the desire to innovate. But in this system, we could never solve it. As Einstein says, "Problems cannot be solved by the same level of thinking that created them." I would want people to have the same level of thinking, and you could say consciousness, awareness.

So in this system, to tackle CO₂ emissions, we would actually cut down the trees in Amazon because that is good for the economy. That would be our way of being able to do that. We need a new system in order to solve the problem. So problem solution, if you look from another perspective, there is no problem at all.

Berrak Kirbas Akyurek: Are you saying, like seeing as such waste is also a part of nature?

Exactly, waste for nature is a resource. Suppose it was a natural product. It does quickly become philosophical. I mean, they are already trying circular economy models, but still, our production ways are not natural. Therefore, it is difficult to have that full circle. And economics is holding us back again. But that will change, and it is changing. That will be a tipping point where we can be circular quite quickly. Looking at genetics, and that is technology. I have big hopes for that. I used to be very much against genetic modification. I am now consciously optimistic in the sense that if we can understand genetics. We can work with nature to create the world we want to. But, we need to be very, very cautious. Most probably, we will create other problems. As an example, I see that in the fire. I see all the technologies coming in line by now. It is like a fire. At the time fire was invented, I could imagine that people were saying I do not do that. You could burn yourself. God does not like that. I bet that people burned down their huts, forests. But could we say we are masters of fire?

The answer is both yes and no. Even after so many years, we can work with it. We know it to a certain extent. But we have actually done awareness and fundamental knowledge. We created a good system that we could manage the risk. But still, we do not have full control over it.

We have to manage the risks. I think it is like cybersecurity at the moment. The security is only there because you have the attackers and defenders. I think they balance each other out. I think the same goes for AI technology, Artificial intelligence, the only way to check AI is to create AI. That is the paradox, that is, the double bind. We would never in control. We are always be balancing two sides, hopefully in the right way. I think that's how the evaluation of species comes forward. Now we are in too much on a non-sustainable side, so like the building industry does on nature. I think 3D printing is a nice example to look that because, for the first time, we have been able to create structures as nature does.

Berrak Kirbas Akyurek: Could you describe the 'novelty' that you see?

So I believe that if you want to change the system, the system should be better and easier. For example, let's take UBER. The system UBER created a better taxi

service, cheaper, safety... So I feel that in a new system, you always have early adopters and innovators those are the people that they like to be first that are interested in that. They will put more effort. But for the early majority and late majority, it needs to be better and easier.

It is not about technology at all in the sense that technology should be in the background. Like clothes, we forget them; they are technology. We are going into a phase in that technology could understand us; it will be personalized. So it will interact with who I am. It will be all around us, and we will just interact with it without having to learn about that technology. Because technology on the foreground, the usability of technology is still not there yet. So why UBER works is because it has the right time and right space. Because everybody has a smartphone, we have GPS systems. So the ease of use is a very important one.

The integration of multiple technologies leads us to see the experiments easier. For example, a car is the same thing. Maybe a couple of decades ago, you have to know more about cars on how to disassemble their parts. These days still having a sustainable house is not easy. You have to buy different elements, all different parts, and elements that you need to take into account. Which of them are better to work with together? That is quite a significant barrier for people to do that. If you say we have sustainability as a service, you pay us X amount, and we guarantee your sustainability.

Berrak Kirbas Akyurek: So you are saying if solutions are in the foreground, you need to think about it, take care of it. Suppose they were like a part of the building itself, so people are willing to be part of it.

Apple did that with white phones, so make it sexy and trendy, desirable. That is a perfect example of Tesla. People do not buy a Tesla car because it is electric. People buy a Tesla car because it is cool, sexy, and fast.

Berrak Kirbas Akyurek: And also the governments are supporting?

Exactly, with the taxes and everything. You know Toyota Prius. That is the early innovator people bought that because they wanted to be sustainable. You need to

be the next model. In this case, it is Tesla, cheaper, better, and sexy. That's how we move all markets.

We are getting there right now. I have been around sustainability for around twenty years now, and I know people who have been around sustainability for approximately thirty years. It used to be called tree hugger communities. People have been living like that since the 1960s, but they have seen it like this. Now we have a new word called 'circular economy.' It is nothing different than 10-20 years ago. But for the wording, it is different. It is becoming interesting as a business model, post-reduction value creation model. And wording attracting other people with bigger market more power of change.

So many elements to be able to change. Technology is just one part of that. I would say nothing is a technological problem. Technology is there. Let me give you an example; solar energy has been around for a long time. If you look at exponential technologies from the Singularity standing point, it is not so much technology itself that is on the exponential curve; it is the price-performance. That is on the exponential curve. An example is photovoltaic solar cells; they have been around thirty years of something. In the mid-1960s, one kVA power of energy produced by solar cells cost 75 USD.

Berrak Kirbas Akyurek: It sounds too much.

It was too much; therefore, who was going to invest in that? It was not feasible in that current economic structure. For a long time, it was too expensive. If I want to invest, I want to spend money on something that has certainty. So people chose to invest in oil. They did not see that oil also has risks like a spill. Then, Warren Buffett, 2012, invested not the technology per se, but in big solar cell farms. When he was the first mover, many others followed. He said technology is more secure than oil. I will invest in this farm, and there will be a return. After that, many people invested, money poured into that industry. Because of that, it got industrialized, and the factoring process ramped up. Therefore, price-performance has gone right.

The point of the exponentially to understand is essential, and also to understand price performance is important. That is also related to how much we trust and invest in technology.

Another example is stem cell technology. When I was back in the physical therapist, I thought of stem cell technology in 2002. I thought I have no future as a physical therapist. We just inject stem cells into joints then you do not need a physical therapist anymore. So the technology is exponential, then people said no. Because you have to take stem cells from an embryo, that is not something a good ethical-moral. Therefore the investments and research on stem cells were slowed down. Now, they got new technology to get any cell and change that into a stem cell. And now the barrier is gone. So it is important to realize where technology is at, what is the potentiality of it. But also what is human, society thinking of it.

Crispr cas9, you heard of it imagine. It is the editing tool for genes. We came across that 5-6 years ago. It is a very precise cheap way to be able to find certain genes to cut them out and placed them into other genes of other species. And people working in that field saying that apparently, it is very easy. But such profound effects, because you can change DNA on the level that also affects generations afterward. So scientists said, OK, let's put it on the fridge and discuss how we are going to utilize it. But China said we would just go ahead anyway. So when the technology is out to the world. As together as a society, we should decide how do we keep each other in check.

It is quite complicated. That's why they say it is a VUCA world, 'volatile,' 'uncertain,' 'complex,' and 'ambiguous.' And all these technologies are interacting with each other and converting. AI, as an example, the enabler for other technologies. As electrification similar to AI, all the opportunities are unimaginable.

I was also thinking that we are going towards a society where circularity becomes smaller in a small area. We have already had a global circular system we needed to speed it up. But you can also say that we could say that once the house can be completely autonomous in terms of energy supply. That's the issue in the West.

Next ten years, we need to put another infrastructure. Ok, let's get back to your questions.

Berrak Kirbas Akyurek: I was going to ask about potential impacts, but I think with several examples, you exemplify the impacts.

Yes.

Berrak Kirbas Akyurek: We also talked about the challenges, but can you tell which one has more crucial than the others?

I think one of the most challenging things is that we created systems that are so large. Anyone does not feel involved anymore. As an example, insurance companies these days, a lot of people do not like them. And when something goes wrong, people are trying to get the most from the companies. But insurance company becomes so strict, and policies go up. Not good for the whole system. The insurance company was used to be twenty people that knew each other. If something happens to one person, we will come together and help you to build your house. And we have security. That works because people know each other. After all, there is a relationship there. There is no relationship within people anymore, and security becomes all numbers. People do not feel responsible anymore or do not think they have any influence. I believe that is the analogy of all the systems we created. And because of that, people feel powerless. What is my influence? We have been a kind of separated. If I do not do it, someone else does. I think our separateness that is the root cause of willing the change.

Berrak Kirbas Akyurek: It is very interesting. So people feel kind of worthless.

And I do not have direct feedback. Ok, if I do something not sustainable now. I do not get personal feedback. So the system feedback loop is so fuzzy and so non-directional.

For example, if you get sick. You get an allowance. That also like in between twenty farmers, and if you get sick, you will get your food anyway. And that ill person felt very grateful. People did not easily stay sick for a long time. Because

other people could see directly, in these days, the system is so non-personal—the tragedy of the commons all over again on another bigger problem.

It is also the same as flying. At the moment, flying is not taxed very cheaply. It gives a lot of added value. But we all know that it is really bad for the environment. In Sweden, people started to feel shame because of flying. But still, I fly, a lot of people fly. Because, again, it is very abstract.

Berrak Kirbas Akyurek: It is tough to comprehend the connection between flying and sustainability for regular people, I guess.

This, I feel, is the biggest issue in the change, and innovation is how do you bring all these really big things to small actions that people do not think small actions are meaningless. I think the most significant barriers is this. The feedback loop of our actions is just too slow and too fuzzy. People feel less empowered in all aspects of life. There is not togetherness, a feeling of separation.

Berrak Kirbas Akyurek: Regarding what we discussed here, Could you tell me about your expectations for the future?

Change is coming anyway. Because the system has at the moment is not sustainable at the moment and will change. How will it change, and what will change? That is the question. We are in a special time. We are in a special time as people do have the possibility of directing what we want to change into. Now is the time to stand up and to take as much responsibility as anyone can to be guided into what everybody wants it to be. But it will change anyway for good or bad.

Berrak Kirbas Akyurek: Do you have any recommendations for future designers and architects when this change is happening?

I think our habitat where we live is a basic need. Unfortunately, the land is property; therefore, you can speculate, and it can become too expensive. But how we manufacture where we live can be automated now. It has already been done, of course. Therefore, making it more affordable for people to be able to live that would be amazing in equilibrium with ecosystem and nature. I think I am not sure how big the impact of the built environment, but around %25 of the total negative

impact. So that is a huge benefit to be made there. I think in the building industry, there are tremendous opportunities over there. I believe there are a lot of people wanting to do that. The investments and money are a bit defensive. Also, other people think, OK, how can I live myself sustainably? It is not an easy question. But do what you can.

The smallest actions and the intentions of what and why we do are indeed matter. For me, when I was young, to throw something away, not into the bin, is something that hurts. But not anymore, for many people. We need to get this kind of behavior again. To have people to get in contact with surroundings and also building dwellings and houses. People need to connect with nature instead of being separated. Creating communities making people coming together, and also with nature, is important. How do we design that? Again it is more social than technological.

B DOUBLE DOCTORATE REQUIREMENTS BY YILDIZ TECHNICAL UNIVERSITY

This Ph.D. study represents a collaboration between the Department of Built Environment at TU/e (Eindhoven, NL) and the Department of Architecture at YTÜ (Istanbul, Turkey). The double doctorate diploma protocol was signed by the two institutions on 11.09.2018. Therefore, this Ph.D. will be both accessible from Eindhoven University of Technology and Yildiz Technical University. Two different versions of the same study were composed by applying prevailing rules of each University in line with the signed agreement.

According to the agreement, Article XIV, this part of the study includes abstract, contents, and results in Turkish.

Bu doktora çalışması TU / e (Eindhoven, NL) Yapılı Çevre Bölümü ile YTÜ (İstanbul, Türkiye) Mimarlık Bölümü arasındaki bir işbirliğini ile oluşturmuştur. Çift doktora diploması protokolü 11.09.2018 tarihinde iki kurum tarafından imzalanmıştır. Böylelikle, bu doktora çalışmasına hem Eindhoven Teknoloji Üniversitesi'nden hem de Yıldız Teknik Üniversitesi'nden erişilebilir. İmzalanan protokol doğrultusunda her iki üniversitenin geçerli kuralları uygulanarak aynı çalışmanın iki farklı versiyonu oluşturulmuştur.

Anlaşmaya göre, Madde XIV, çalışmanın bu bölümünde çalışmanın genişletilmiş özet ve içindekiler ve sonuç bölümünün türkçe çevirileri yer almaktadır.

B.1 Genişletilmiş Özet ve İçindekiler

Yaşayan organizmalarla tasarım yapmak, son yıllarda artan sayıda çalışma ve mevcut endüstriyel uygulamadaki yeniliklerle bina tasarımında gün geçtikçe popüler bir hale gelmektedir. Öyle ki, bitkiler ve algler gibi doğanın canlı organizmaları, modern öncesinden çağdaş mimariye kadar bina tasarımındaki canlı bileşenlerin önemli maddesi ile ilgili olarak mevcut çevresel bozulma dahilinde binalar için sıklıkla yenilikçi çözümler sağlamıştır. Aynı zamanda,

elektrik prizlerinden ev aletlerine kadar çok sayıda ürünün binalarda alışıldık hale gelmesi ile birlikte dünya çapındaki sanayileşme sürecinden bu yana bina tasarımında otomasyon sistemleri, yapay zeka ve nesnelerin interneti (IoT) gibi akıllı teknolojiler yer almıştır. Bu noktada çağdaş araştırmalar, ortaya çıkan teknolojik gelişmelerin canlı organizmaların tasarıma dahil edilmesinin mümkün olduğunu, dolayısıyla canlı ve üretilen bileşenlerin ‘arada’ olma eğiliminde olduğunu altını çizer. Ve böylece, bina tasarımında yapı bileşenlerinin tasarımının ‘biyo yapı bileşenlerine’ dönüşmesi varsayılmaktadır.

Tez kapsamında biyo yapı bileşenleri, doğadaki canlı organizmalarla (algler, mantarlar, bitkiler gibi) birleşen yapı bileşenlerini (cephe panelleri, sütunlar, duvarlar, iç elemanlar gibi) kapsayarak, yaşayan ve üretilen bileşenlerin birbiriyle ilişkisini temsil eder. Günümüzde, biyo yapı bileşeni örneklerinin sayısı giderek artmaktadır öyle ki günlük yaşam ve yapıli çevremize sızmak üzeredir; bu sebeple, bina tasarımının biyo yapı bileşenlerinden nasıl etkileneceği, bina tasarımı alanında ayrıntılı olarak ele alınmalıdır. Böylelikle bu tez, biyo yapı bileşenlerinin beklenen etkilerini bina tasarımındaki olası anlam(lar)ı ile keşfetmeyi amaçlamaktadır.

Tezin amacı, teorik ve pratik sonuçlarını değerlendirerek biyo yapı bileşenleri hakkında bilgi veren açıklayıcı bir çalışma sunmaktır. Tez konusuna, Nietzsche’nin perspektivizminden (vazgeçilmez ‘gerçek’ kavramını eleştiren felsefi bir yaklaşım) esinlenen perspektifçi bir düşünme biçimini kucaklayarak yaklaşılmıştır. Bu düşünme biçimi, ortaya çıkan teknolojik başarıların yönlendirdiği bu araştırmanın eleştirel bir bakış sunmasını sağlar ve bu da, bina tasarımında biyo yapı bileşenlerinin anlamı(ları) ve potansiyel kullanım(lar)ına ilişkin farklı hatta çelişkili yorumların ve yaklaşımların bir arada ve derinlemesine irdelenmesini sağlar.

Bu tez, öncelikle biyo-yapı bileşenlerini farklı açılardan değerlendiren kapsamlı literatür araştırmasını, ikinci olarak güncel biyo-yapı bileşenleri örneklerini, üçüncü olarak da nitel araştırma yöntemleriyle (Protokol Analizi, Sözlü Tarih ve Tematik Analiz) analiz çalışmalarını kapsamaktadır. Bu bağlamda, araştırma üç

kısım olarak sunulmuştur: *Literatür Araştırması* (Bölüm 2), *Veri Toplama ve Değerlendirme* (Bölüm 3, Bölüm 4) ve *Analiz* (Bölüm 5, Bölüm 6).

Tezin *Literatür Araştırması* kısmı, doğa, teknoloji ve bina tasarımı arasındaki ilişkiler aracılığıyla yaşayan ve üretilmiş bileşenlerin karşılıklı ilişkisini değerlendiren çoklu literatür incelemelerini sistematik olarak birleştirerek biyo yapı bileşenleri hakkında giriş niteliğinde bir arka plan sağlar. Böylelikle çalışmanın bu kısmı hem *Veri Toplama ve Değerlendirme* kısmında hem de *Analiz* kısmındaki nitel çalışmalar için teorik bir temel oluşturmaktadır.

Tezin *Veri Toplama ve Değerlendirme* kısmı, ilgili terimleri, kavramları ve metodolojik yaklaşımları açıklayan terminoloji üzerine bir literatür taraması ile biyo yapı bileşenleri hakkında ayrıntılı bilgi sunar. Daha sonra yetmiş (70) biyo yapı bileşeni örneği endüstriyel uygulama alanları, *domain*, amaçları, hedefler, hedefler, uygulamaları, ve yaşayan bileşenleri ve bunların bina tasarımıyla ilgisi ile birlikte tartışılır. Elde edilen veriler, analitik bir araç olan *Multi-level perspective* (MLP) yardımı ile farklı etki ölçekleri (mikro, mezo ve makro) arasındaki bağlantılar ile değerlendirilir. Çalışmanın bu bölümü, mevcut literatür ve mevcut endüstriyel uygulamadaki yankıları ile biyo yapı bileşenlerinin bina tasarımındaki mevcut anlamlarını kullanımını ve uygulamalarını tartışmamızı sağlar. Bu sayede bu bölümündeki bulgular, mimarlık öğrencileriyle yapılan tasarım deneylerinin ve biyo yapı uzmanları ile yapılacak görüşmelerin kapsamlarının belirlenmesini sağlar.

Tezin *Analiz* kısmı iki nitel çalışma ile biyo yapı bileşenlerinin beklenen etkilerini bina tasarımına entegre ederek iki aktör grubu ile araştırır; mimarlık öğrencileri (geleceğin mimarları) ve biyo yapı uzmanları (mimarlar, iç mimarlar, ürün tasarımcıları / geliştiricileri, biyologlar, akademisyenler, mühendisler, moda tasarımcıları). Mimari tasarım stüdyosunda yürütülen tasarım deneyleri, geleceğin mimarlarının bakış açıları aracılığıyla bina tasarımında biyo-bina bileşenlerinin entegre edilmesini teşvik eden fırsatları ve aynı zamanda engelleyen problemleri ortaya koyar. Bu çalışma, biyo yapı bileşenlerini bina tasarımına ve entegre etmenin arkasındaki yaklaşımın daha fazla anlaşılması ihtiyacının altını

çizer. Bu nedenle, uzmanlar ile mülakat çalışması (*Veri Toplama ve Değerlendirme* bölümündeki örneklerden seçilen ve zincir örnekleme stratejisi ile devam eden 21 uzman ile 20 görüşme), uzmanların deneyimlerini paylaşmaları için motive ederek (tercihen) yüz yüze derinlemesine yürütülmüştür. Yarı yapılandırılmış açık uçlu sorular ve destekleyici ek sorular ile mülakat alışmalarında sözlü tarih yöntemi benimsenmiştir. Bu görüşmeler, *Veri Toplama ve Değerlendirme* bölümündeki bulgulara ek olarak biyo-yapı bileşenleri hakkında ayrıntılı bilgi sağlar ve *Literatür Araştırması* bölümünde sunulan çalışmalar ile bağlantılı yeni ve farklı tartışma ve eleştiriler sunmayı sağlar. Ayrıca görüşmelerin transkripsiyonları Tematik Analiz yöntemi ile analiz edilir. Böylece, biyo yapı bileşenlerinin geliştirilmesinin ve binalara entegrasyonunu sağlayan aşamalar hakkında bilgi edinilir.

Sonuç olarak, bu tez, biyo yapı bileşenlerinin tarihsel, fenomenolojik, pratik, teknolojik, mimarlık ve eğitimsel anlamlarını bir arada detaylandırmaktadır. Bu, biyo yapı bileşenlerinin beklenen mimari ve sosyal etkilerini ortaya çıkarır, böylece biyo yapı bileşenlerinin bina tasarımını nasıl etkileyeceğine dair yanıtlar sunar. Çalışma en son olarak mimarlar için öneriler ve bina tasarımı alanında gelecekteki araştırmalar için yönlendirmeler sunar.

Genişletilmiş özete ek olarak çalışmanın içindeki Bölümler aşağıda ayrıntılı olarak anlatılmıştır.

Bölüm 1, Giriş

Tezin giriş bölümünde ilk olarak kapsamlı bir literatür taraması içerisinde tezin kapsamı ve ele aldığı problem ve potansiyeller ayrıntılı olarak tartışılır. Daha sonra tezin amacı ve araştırma soruları ile bu araştırma sorularının çalışma kapsamında nasıl araştırıldığı çalışmanın yöntemi bölümünde detaylı olarak irdelenir. Çalışmanın özgün değeri ve tezin bölümlerinin nasıl organize edildiği de yine aynı şekilde ayrıntılı olarak anlatılır.

Bölüm 2, Bina Tasarımında Doğa ve Teknoloji Kavramları

Tezin girişten sonraki ilk bölümü, problem alanını destekleyen çalışmanın teorik bir arka planını sunar. Literatür incelemeleri (doğa ve bina tasarımı, teknoloji ve bina tasarımı, doğa ve teknoloji, doğa ve teknoloji ve bina tasarımı), aşağıdaki Bölümlerin daha iyi anlaşılmasını sağlayarak, teoride biyo yapı bileşenlerinin daha geniş yönlerini aydınlatmamıza yol açmaktadır. Bu bölüm, canlı organizmaları tasarıma dahil etmenin bina tasarımını önemli ölçüde etkilediği hipoteziyle sona ermektedir. Bu nedenle, doğa ve teknolojinin değişen kavramlarını gösteren çağdaş çalışmalarla ilgili biyo-bina bileşenleri ile bina tasarımında bu olgunun tartışılması gerekmektedir.

Bölüm 3, Bina Tasarımında Biyo-Bina Bileşenlerinin Terminolojisi Üzerine Araştırma

Çalışmanın bu bölümü, mevcut literatürdeki "biyo" kaynaklı kavramlar, terimler ve tanımlar üzerine bir literatür taraması sunmaktadır. Bu bölüm, mevcut literatürde biyo-yapı bileşenlerine ilişkin doğru terminoloji eksikliği olduğu sonucuna varılmıştır. Bu nedenle çalışma, biyo yapı örneklerindeki tanım ve terimleri ve uygulayıcıların terminoloji tercihlerini inceleyerek tezdeki terminoloji üzerine araştırma yapılmasını önermektedir.

Bölüm 4, Bina Tasarımında Biyo Yapı Bileşenlerinin Belirlenmesi

Bu bölümde, biyo-yapı bileşenlerinin örnekleri sunulmakta ve incelenmektedir. Bu bölüm, biyo yapı bileşenleri hakkında bilgi sağlar, böylece bizi çalışmanın aşağıdaki analiz bölümünü oluşturmaya yönlendirir.

Bölüm 5, Biyolojik İnşa Bileşenlerini Geleceğin Mimarlarının Bakış Açısından Keşfetmek

Bina tasarım deneyi geleceğin mimarları ile yapıldı; biyo bina bileşenleri ile bina tasarımı arasındaki ilişkiyi analiz eden mimarlık öğrencileri bu bölümde ayrıntılı olarak açıklanmaktadır. Bu bölüm, biyo-yapı bileşenlerinin bina tasarımına entegre edilebileceği ve tasarım yaklaşımının kritik bir rol oynadığı sonucuna varmıştır.

Bölüm 6, Biyo İnşa Bileşenlerini Uygulayıcının Bakış Açısından Keşfetmek

Uygulayıcılarla yapılan görüşmeler, her görüşmenin transkripsiyonunu gösteren Ek A ile birlikte bu bölümde açıklanmıştır (talep üzerine gizli tutulan ikisi hariç). Tezin bu bölümü, biyo-yapı bileşenlerinin nasıl geliştirildiğine ve bina tasarımına nasıl entegre edilebileceğine dair tasarım sürecini ortaya koymaktadır. Bu bölüm, endüstriyel tasarım ile bina tasarımı arasındaki köprülere cevaplar sağlayarak tezde kritik bir rol oynamaktadır.

Bölüm 7, Sonuç ve Öneriler

Bu Bölüm, her araştırma sorusunun yanıtlarını sunar ve tezin temel bulgularına dayanarak, bina tasarımı alanında mimarlar ve gelecekteki çalışmalar için öneriler sunar. Son olarak tez, bina tasarımı alanındaki biyo-yapı bileşenlerinin gelecekteki beklentileri de dahil olmak üzere varsayımsal sonuçlarla kapanış konuşmalarıyla sona erer.

B.2 Sonuç ve Öneriler

Biyo yapı bileşenleri, farklı ölçeklerde binalara karışan teknolojiler arasında dikkat çekicidir, çünkü bina bileşenlerini canlı organizmaları dahil ederek bağımsız olarak aktif, büyüyen, dinamik varlıklara dönüştürmeyi vaat ederler. Bu arada, binaları, insanların ve binaların daha bağlantılı ve uyumlu olduğu çeşitli teknolojilerle çevreliyorlar. İnsanların yeteneklerini geliştirmek için giyilebilir teknolojiler, kendi kendine büyüyen mobilyalar ve kendi kendini iyileştiren malzemeler gibi çeşitli faydalar sunarlar. Buna göre, mevcut çevresel bozulma dahilinde binalar için çeşitli akıllı ve sürdürülebilir çözümler sunarak ürün pazarındaki biyo yapı bileşenlerinin sayısı katlanarak artmaktadır. Böylelikle binalarımızın, çevremizin ve hatta günlük yaşamımızın ve alışkanlıklarımızın - hatta insan, doğa ve teknoloji arasındaki tüm ilişkinin çok yakında biyo bina bileşenlerinden etkilenebileceğini iddia etmek mümkündür.

Bu tez, canlı organizmalarla tasarım yapmanın son yıllarda mimaride ilgi konusu haline geldiğinin altını çiziyor. Bence yapı tasarımında olduğu kadar mimaride de canlı organizmalarla tasarım yapmak önemini sürdürecektir - hatta bu ilgi artmaya

devam edecek. Başka bir deyişle, binalar, yaşayan ve üretilmiş kelimelerin kesişme noktasında ilerleyen yıllarda gelişecek ve değişecektir. Bu anlamda, daha fazla biyo yapı bileşeninin yapıli çevreye entegre edilmesiyle, binalar aynı zamanda daha doğal ve daha teknolojik hale gelecektir. Bununla birlikte, bunların bina tasarımı üzerindeki etkileri ve anlamı konusunda hala belirsiz olması gereken çok şey var. Bu nedenle, bu tez, biyo yapı bileşenleri hakkında derin bilgileri bu yeni ortaya çıkan alana getirerek bina tasarımı alanında güvenilir bir adım atarak kritik öneme sahiptir.

Çalışmanın son bölümü kapsamında, öncelikle tezin ana araştırma sorusu, biyo yapı bileşenlerinin çok yönlü etkisi şemsiyesi altında tüm araştırma ve alt sorular tekrar ziyaret edilerek cevaplandırılmıştır. Çalışmanın bu bölümü, araştırmadaki bulguları özetlemek yerine araştırma sorularına kısa ve derin cevaplar sunmaktadır. Bu şekilde önemli konuları vurgular; bu tezde oluşturulan bilgi içerisinde biyobinanın bileşenlerinin olası anlamlarını kurdu. Dahası, mimarlar ve gelecekteki araştırmalar için öneriler sunulmaktadır. Son olarak tez, bu tezde keşfedilen biyo yapı bileşenlerinin beklenen etkilerinden bina tasarımının nasıl etkilendiğine ilişkin varsayımsal sonuçlar da dahil olmak üzere kapanış sözleriyle sona ermektedir. Bu varsayımsal sonuçlar, ilgili sorular, varsayımlar ve bina tasarım alanındaki biyo yapı bileşenlerine ilişkin gelecekteki beklentiler dahil olmak üzere kendi bakış açımı belirler. Bu nedenle, bu yeni ortaya çıkan biyo yapı bileşenleri alanına kendi bakış açımı ve katkımı yansıtan kritik iddialar ve ifadeler sunar.

B.2.1. Araştırma Sorularını Cevaplamak

Bu tez, temel araştırma sorusunu, yani bina tasarımının biyo yapı bileşenlerinden nasıl etkileneceğini cevaplayarak, amacına ilişkin bilgi verir. Bence Nietzsche, bilgi yaratma sürecinde, bu yeni ortaya çıkan alanı derinlemesine keşfederek bu çalışmanın farklı fikirleri, kavramları ve biyo yapı bileşenlerinin üretim sistemlerini dikkate almasına yardımcı oluyor. Onun yaklaşımı bize, bilgideki nesnelliğin ancak mümkün olduğunca farklı perspektiflerden bakılarak güçlendirilebileceğini hatırlatıyor. Bu düşünme biçimi, özneliği ve nesnelliğin

içindeki öznelliğin değerini vurgulayarak nesnelliği sorgulamaya götürür. Bunu, öznelliğin nesnellik yaratmanın verimli bir yolu olduğunu, ancak değerinin ancak çoğullukları yoluyla artırılabilceğini yorumladım.

Teknoloji odaklı bir çalışmada felsefi bir yaklaşımı benimsemenin yeni olduğuna inanıyorum. Kanımca, çalışmalar geliştirilirken çelişkili bakış açıları ve incelemelerin dikkate alınması gerekiyor. Bu sayede literatür çalışmalarındaki çeşitlilik, uygulanan yöntemler ve farklı aktörlerle yürütülen çalışmalar her zaman yeni sorular ve cevaplar doğurabilir. Buna göre, biyo yapı bileşenleri ile tasarım yapma konusunda keşfedilecek çok şey olduğunun altını çiziyorum; bu nedenle bu konuya farklı ve daha çok bakış açısıyla bakmak gerekiyor.

Aşağıda verilen cevaplar önemli ve değerlidir, ancak aynı zamanda daha fazla ve farklı yorumlara da açıktır. Bu noktada, bu çalışmada perspektifçiliğin rolünü anlamak önemlidir. Çünkü bu araştırma sorularının cevapları ve soruların kendileri, bu çalışmanın yazarı olarak bina tasarımında yaşayan ve üretilmiş bileşenlerin karşılıklı ilişkisine yönelik kendi bakış açımı gösteriyor. Bu şekilde, bu tez bu soruları cevaplayarak bilgi yaratır, ancak daha da önemlisi, ortaya çıkan bu alanda giderek daha fazla soru ortaya çıkarır. Bu yolla, benim Nietzsche yorumumdan, bilgi, çoğulluğu, öznelliği ve sorgulanabilirliği sayesinde daha değerlidir. Bu, yanıtların değerini küçümsemiyor; diğer yandan bu tezin mevcut literatüre katkısının yeniliğinin altını çizmektedir.

Çalışmadaki araştırma soruları, teorik ve pratik yönleriyle ilgili ana araştırmalar keşfedilerek birbirine bağlanmıştır. İlk soru, bina tasarımında yaşayan ve üretilmiş bileşenlerin birbiriyle olan ilişkisinin teorisini, uygulamasını ve diğer anlamlarını sorguluyor. Dahası, ikinci soru, biyo yapı bileşenlerinin pratik uygulamalarını daha da araştırıyor. Üçüncü soru, biyo-yapı bileşenlerinin pratik bir bakış açısıyla daha iyi anlaşılmasını sağlamayı amaçlamaktadır.

İlk araştırma sorusuna yanıt olarak, biyo yapı bileşenlerinin, doğa kavramına ilişkin yapı tasarımında yaşayan yapı bileşenlerinin anlamları üzerinden yapı tasarımını etkileyebileceği bulunmuştur. Yapı tasarımında yaşayan yapı bileşenlerinin anlamlarını keşfetmek için, değişen doğa kavramlarının öznelliğinin

altını çizerek sosyal bilimlerdeki çalışmaları hatırlamak gerekir. Bu öznellik, doğa 'fikrinin' zamana bağlı ve değişen yorumlarını gösterir ve böylece modern mimariden çağdaş mimariye değişen kavramlar, tarzlar ve yaklaşımların anlaşılmasını sağlar. Bu öznellik bina tasarımına yansıtılır ve sembolik, analogik, metaforik anlayışlarla, dolayısıyla uygulamalar ve kavramsal düşünme biçimiyle sonuçlanır. Örneğin, mimaride art nouveau tarzında, doğanın kavramı kendini dekoratif, biçimsel ve yapısal bir ifade olarak göstermiştir. Böylelikle, fenomenolojik ve felsefi olarak binalar, canlı yapı bileşenlerinin estetik bir düzeyde dahil edilmesiyle doğaya bağlanabilir. Modern mimari örneklerinde, yapı ile doğal çevre arasında bir denge kurulup anlaşılacak doğa kavramı benimsenmiştir. Bu, binaları doğal çevrenin bir parçası olarak ele alarak doğa ve binalar arasındaki ilişkiye felsefi ve fenomenolojik bir yaklaşım getirmiştir. Günümüzde yaşayan bina bileşenleri, enerji verimliliği, atık yönetimi ve enerji verimliliği, atık yönetimi endişeleri ile artan çevre sorunlarına, çevre dostu yapı taleplerine ve yerel ve yenilenebilir malzemelerin kullanımına yönelik pratik faydaları ile bina tasarımında yer aramaya başlamıştır.

Dahası, biyomimikri ve biyofili gibi kavramlar, mimaride doğa ve teknolojinin farklı bağları yaratma dürtüsünü gösteriyor. Böylelikle analogik, sembolik veya metaforik doğa anlayışlarının yanı sıra teknolojik gelişmeler sayesinde doğanın mantığını derinlemesine anlayarak ve taklit ederek canlı organizmaları taklit etmek mümkün hale gelir. Nitekim, mimesis fikri Quatremère de Quincy'nin eserlerinde modern öncesi mimariye kadar izlenebilir, ancak teknolojik yeteneklerle mimaride biyomimikri çeşitli örnekler sunar. Özellikle, mevcut çevresel bozulmaya sürdürülebilir ve akıllı çözümler sağlanmıştır. Yani yaşayan yapı bileşenlerinin sembolik, analogik ve metaforik yorumlarıyla doğanın tarihsel anlamları, son teknolojik gelişmeler sayesinde tasarım pratiklerine dönüştürülmüştür.

Biyo yapı bileşenlerinin bina tasarımını etkilemesinin nedenleri, teknolojiye gelişmelerle ilgili olarak bina tasarımında üretilen yapı bileşenlerinin anlamlarında yatmaktadır. Heterojenliği ve karmaşıklığı nedeniyle, çeşitli teknolojiler binalara karışabilir. Teknolojinin üstel ve kapsamlı gelişimi, günlük

yaşamları, çevreyi, alışkanlıkları ve aslında bunların yapıları çevreye sızmalarıyla ilgili yaşam tarzlarını etkilemiştir. Bu argüman, günümüzün internet, akıllı telefonlar ve daha pek çoğu gibi hayati teknolojilerinin sadece birkaç on yıl önce "ulaşılması zor" olduğunu göstererek desteklenebilir. Burada vurgulanan, üretilen bileşenlerin ölçeklerine bakılmaksızın bina tasarımı üzerinde önemli sosyal etkilere sahip olabileceği ve akıllı teknolojilere benzer şekilde binalara entegre edilerek bina tasarımını etkileyebileceğidir.

Doğa ve binalar arasındaki bağa kıyasla, teknoloji ile bina tasarımı arasındaki bağlar nispeten geç. Böylelikle teknolojideki üstel büyüme ve değişimi dikkate alarak projeksiyon yapmayı zorlaştırmaktadır. Teknolojilerin entegrasyonu ile bina tasarımı üzerinde beklenen teknolojik etkilerin altını çizmek mümkündür, ancak bazı etkiler diğerlerinden daha belirgin olabilir. Örneğin bina tasarımı, yerli teknolojilerin yükselişinden dolayı olarak etkilenmektedir. Buna karşılık, güneş sistemleri ve mekanik çekirdekler gibi teknolojiler, bina tasarımını doğrudan ve büyük ölçüde etkiledi. Bu nedenle, şimdilik herhangi bir yeniliğin, gelecek vaat eden işlevleri, potansiyel kullanımları ve avantajlarının altında yatan pratik anlamlarıyla bina tasarımını etkileyebileceğini iddia etmek mümkündür. Ancak hangi teknolojilerin onu etkileyeceğini gerçekten tahmin etmek mümkün değil.

Şu anda çağdaş araştırmalar, doğa ve teknoloji arasındaki değişen dinamiklere işaret ediyor. Doğa kavramının değişen anlayışlarının bina tasarımı üzerindeki zamana bağlı ve öznel etkileri göz önünde bulundurulduğunda, bu çağdaş araştırmalar, yaşayan ve üretilmiş bileşenlerin birbiriyle olan ilişkisinin bina tasarımı üzerindeki etkisini vurgulamaya yöneltmiştir. Bu sayede yaşayan ve üretilen bileşenlerin birliği, günlük yaşam ve çevre üzerinde olası sosyal etkileri de beraberinde getirecektir.

Benim görüşüme göre, canlı ve üretilmiş bileşenlerin karşılıklı ilişkisi, bina tasarımında yaşayan ve üretilmiş bileşenlerin mevcut anlamlarına ek bir önem getirerek bina tasarımını etkileyebilir. Yapı tasarımı alanındaki deneysel çalışmalar, son yıllarda mimaride doğanın yeni fenomenolojik ve felsefi anlamlarını araştırmaktadır. Modern öncesi mimaride yaşayan bileşenlerin

tarihsel anlamının aksine, bina tasarımında biyo yapı bileşenleri ile yapılan son deneyler. Örneğin İpek köşk ve Büyüyen Köşk, canlı organizmaları maddi düzeyde kullanarak doğa ile görsel bağlar oluşturarak, onların ilk estetik değerlerini kabul ederek dinamizmini deneyimlememizi sağlıyor. Bu, modern mimaride kullanım ve sanatsal tasarım arasındaki ilişkinin benzerliği ile değerlendirilebilir. Bununla birlikte, biyo yapı bileşenlerinin canlılıklarıyla diğer yapı bileşenlerinin tektonik anlamlarından farklı bir şeyi desteklediğini iddia etmek mümkündür. Bu sayede, biyo-yapı bileşenleri, canlı organizmaların kullanımıyla birlikte ek tasarım uygulamaları getiriyor. Bu anlamda, mekan üretimi için alternatif yollar sağlamanın yanı sıra biyolojik olarak parçalanabilen, büyüyen ve geçici yapı bileşenleri. Bu nedenle, yukarıda çizilen beklenen mimari etkiler içerisinde, biyo yapı bileşenlerinin teorik etkilerinin yanı sıra pratik etkilerine de işaret etmek mümkün görünmektedir.

Çalışma, doğa ve teknolojinin "kaynaşmasını" bir başlangıç noktası olarak benimseyerek, biyo-bina bileşenlerinin pratik uygulamalarının olası sosyal etkilerini tartışıyor. Bu tez aynı zamanda bu "füzyon" un biyo yapı bileşenlerinin bina tasarımına farklı şekillerde entegre edilmesiyle sonuçlanmış olabileceğini de ortaya koymaktadır. Canlı organizmaların dahil edilmesi malzeme ve ürünlere kaynaştırılabilir. Bu sayede, biyo-bina bileşenleri sıradan ürünler oldukları için geleneksel ve doğal hale gelebilir. Bu değişim yakın gelecekte, aslında çok yakında yönetmeliklerin yardımıyla ve seri üretimin hızlanmasıyla gerçekleşebilir. Benzer şekilde, uygulayıcılarla yapılan görüşmeler bu argümanın temelini oluşturmaktadır. Örneğin, Ermi van Oers, Canlı Işık projesi örneğinde tartışıldığı gibi, canlı organizmalar ve insanlar arasında yeni davranışların sağlanabileceğini iddia ediyor.

Ayrıca, biyo-algılayıcı yer karoları örneklerinde olduğu gibi kendi kendini iyileştiren ve temizleyen malzemeler, konut çekirdeklerine alternatif çözümler getirebilir ve böylece öncelikle binalardaki sosyal yaşamı etkileyerek dolaylı olarak bina tasarımını etkileyebilir. Öte yandan, Fab Three Hab ve Growing Pavilion örnekleri, canlı organizmalar beklenmedik, öngörülemeyen görsellik, gerçekleştirilebilirlik ve işlevsellik kullandığı için daha radikal bir yaklaşım

getiriyor gibi görünüyor. Bu nedenle, bana göre, günlük hayatımızda yakında 'doğal' olmayacak gibi görünüyor. Ve daha geleneksel hale gelseler bile, doğa ve teknolojinin kaynaşması yerine yaşayan, büyüyen, dinamik varlıkları aracılığıyla vurgulanacak gibi görünüyorlar. Bu şekilde, biyo yapı bileşenlerinin entegrasyonunun toplumda farklı değişiklikleri tetikleyerek bina tasarımını etkileyebileceğini iddia ediyorum.

Biyo yapı bileşenleri, yapılı çevreyi değiştirmek için amaçlarından ve işlevlerinden daha geniş uzun vadeli hedefleri ele alır. Bu noktada, insanlar ve doğal dünya arasındaki bağları güçlendirmek için biyofilik bir çevre talep ederek toplumun etkilenmesi beklenmektedir. Bu açıdan bakıldığında, biyo yapı bileşenlerinin binalara entegrasyonu teknolojik bir geçişi tetikleyebilir ve ilk olarak bu, bina tasarımını biyo bina tasarımına dönüştürebilir. Uygulayıcıların görüşmelerdeki ifadeleri de bu argümanı desteklemektedir.

Ek olarak, tasarım deneyi, biyo-yapı bileşenlerinin teknik özelliklerine kıyasla tasarım yaklaşımının rolünü vurgulamaktadır. Tasarım deneyi, biyo yapı bileşenlerine yaklaşarak, uzun vadeli hedeflerini benimsemenin, biyo yapı bileşenlerini bina tasarımına entegre etmeyi teşvik ettiğini gösteriyor. Biyofilik bir ortama ulaşmanın yakında gerçekleşmesinin pek olası olmadığına inanıyorum. Ancak bu tez, insanlar, doğa ve bina çevresi arasında bir denge ve uyum yaratmanın, biyo-yapı bileşenlerini bina tasarımına entegre etmede yattığını ortaya koymaktadır.

Böylelikle bina tasarımında biyo yapı bileşenlerinin değerlendirilmesi gerekliliği teorik ve pratik perspektifleri ile cevaplanmaktadır. Dahası, çalışma ikinci araştırma sorusuna cevap veriyor: biyo-yapı bileşenleri mevcut bina tasarımı pratiğinde nasıl bir yer bulabilir.

Biyo yapı bileşenlerinin çoklu alanlarla ilgili multidisipliner yönleri göz önünde bulundurularak, biyo yapı bileşenleri ile ilgili terimler, tanımlar ve kavramlara ilişkin içgörüler sağlanır. Literatürde biyo-yapı bileşenlerine ilişkin belirli bir terminoloji yoktur. Bu arada uzmanların önceliği, tasarımlarını ve fikirlerini ifade etmek ve vurgulamaktır. Uzmanlar çoğunlukla bağlamsal terminolojiyi

kullanmayı tercih ediyor. Örneğin, akıllı terimi kullanıcıya açıklamaları için kullanabilirler ve profesyonel uygulamalarında biyonik, biyotasarım ve biyomimikri gibi kapsamlı kavramları kullanabilirler.

Bana göre terminolojideki sorun devam edecek ve çok yakında çözülemeyecek, önümüzdeki birkaç on yıl içinde bile. Aslında, yakın gelecekte, mevcut terminolojiye giderek daha fazla terim ve tanım eklenecektir. Bunun nedeni, artan sayıdaki biyo yapı bileşenlerinin yanı sıra, canlı ve üretilmiş bileşenlerin kesişme noktasının deneyimlenecek, denenecek ve daha fazla çalışmada eleştirilecek olmasıdır. Bu, çeşitli disiplinlerin bu tür yöntemler, kavramlar ve yaygın olarak bilinen terimler gibi kodlarını yansıtan daha fazla terim, tanım, kavram ve metodolojik yaklaşımla sonuçlanacaktır. Bu anlamda, çoğulluk, dolayısıyla terminolojideki belirsizlik, bu yeni ortaya çıkan alan için bir sorun ve aynı zamanda bir potansiyel olarak kalacaktır.

Terminolojideki çeşitlilik, biyo yapı bileşenlerinin multidisipliner potansiyelinin yanı sıra ekoloji ve sürdürülebilirlik gibi temel kavramlarla kapsamlı bağlarının da altını çizdi. Bu çeşitlilik, aynı zamanda, birden çok disiplin, alan ve çalışmadaki kavramlara bağlanarak, birden çok tasarım alanındaki biyo yapı bileşenlerinin potansiyelinin altını çizmektedir. Biyo yapı bileşenlerinin özellikleri ve bina tasarımıyla ilgisi hakkındaki soruyu yanıtlamanın yolu, bu tezi, özelliklerini, alanlarını, başlatıcılarını, amaçlarını, hedeflerini, uygulamalarını, birleştirilmiş canlı bileşenleri ve entegrasyonu sunarak mevcut uygulamadaki biyo yapı bileşenlerini keşfetmeye götürür. katmanlar. Bu sorunun beklenen sonucu, benzer amaçların, hedeflerin ve ilgili alanların tespit edilmesi gibi örnekler arasındaki benzerlikleri belirlemektir.

Bununla birlikte, biyo yapı bileşenleri, birden çok alanla ilgili çeşitli işlevlere sahip birden çok amaç, hedef ve uygulamayı gösterir. Bulgulardaki bu çeşitler, biyo-yapı bileşenlerinin sınırlı / belirlenmiş teknolojiler, ürünler veya sistemler olmadığı sonucuna götürür. Aksine, birçok alan ve endüstri ile ilişkilendirilerek binalara entegre edilebilecek çeşitli formlarda, ürünlerde, malzemelerde ve sistemlerde olabilirler.

Genel olarak bu tez, biyo-yapı bileşenlerinin farklı kullanımlarını ve faydalarını pratik anlamları içinde vurgulamaktadır; birden çok işlev, amaç, hedef ve ardından bunların birden çok alanda, disiplinde ve tasarım alanlarında kritik rolleri. Bu noktada, endüstriyel tasarım ve bina tasarımı arasındaki bilgi boşluğu, biyo bina bileşenlerinin bina tasarımına entegrasyonunu engelleyebilir. Bilgi boşluğunu kapatmak için çalışma, biyo yapı bileşenlerinin bina tasarımına entegrasyonuna odaklanan üçüncü araştırma sorusunu sordu.

Tasarım deneyleri, mimarlık öğrencilerinin verilen biyo yapı bileşenlerinden herhangi birini tasarımlarına entegre etmede herhangi bir sorunla karşılaşmadıklarını, çünkü bina tasarım stüdyosunun kapsamı soyut fikirleri tasarıma çevirerek kavramsal düşünme biçimini geliştirdiğini gösteriyor. Bu nedenle öğrenciler, tasarım süreçlerindeki farklılıklardan bağımsız olarak verilen biyo yapı bileşenlerini tasarımlarına entegre edebilirler. Biyo yapı bileşenlerinin bina tasarımına entegrasyonunu etkileyen şey, endüstriyel ve bina tasarımı arasındaki bilgi boşluğunun varlığıdır.

Tasarım deneyleri bize gösteriyor ki mevcut mimarlık çerçevesi içinde eğitim teknolojik gelişmelere çok az önem veriyor. Bu nedenle, teknolojik gelişmelerin katılımı ve mimarlık eğitiminde bina tasarımına etkileri ile burada fırsat ve engel yatmaktadır. Gelecekteki mimarlar gerçek uygulamada biyo yapı bileşenleri ile karşı karşıya kaldıklarından, bunun biyo yapı bileşenlerinin bina tasarımına entegrasyonunu güçlendirebileceğine inanıyorum. Böylelikle, tasarım deneyleri, sınırlamalarına rağmen, bu tezin mimarlık eğitiminde biyo-yapı bileşenlerinin potansiyeline dikkat çekmesine yol açmıştır. Bu nedenle, eleştireldirler ve iki farklı arka planın eğilimi içinde bilgi yaratmanın gerekliliği hakkındaki bu çalışmanın argümanına kredi sağlarlar; akıllılık ve sürdürülebilirlik birbirine doğru büyüyor.

Buna ek olarak, röportajlar, biyo-yapı bileşenlerinin performansının, yenilik ve avantajlarının yanı sıra çok önemli bir rol oynadığını ortaya koymaktadır. Teknik özellikler, etik ve estetik gibi diğer hayati tartışmalar, uygulayıcıların cevaplarıyla desteklenen biyo-bina bileşenlerinin gerçekleştirilebilirliğini karşılaştırarak daha az kritik görünmektedir.

Ayrıca çalışma, farklı tasarım aşamaları olan Gerçekleştirme, Üretim, Keşif, Çeviri'nin yinelemeli yapısını sunmaktadır. Bu aşamalar, çalışmanın multidisipliner yönlerini ve biyo-yapı bileşenlerinin farklı disiplinlerdeki değişen anlamlarını bir kez daha vurgulamaktadır. Dahası, her aşama bireysel fırsatları ve engelleri gösterir. Bu noktada, avantajlarına rağmen tematik yaklaşım analizinin sınırlılıkları vardır. Belirli tasarım aşamalarını ortaya çıkarmaya yardımcı olur ve tasarım sürecinin genel bir anlayışını verir. Öte yandan, farklı aşamalar arasındaki hiyerarşiyi, gerekliliği üzerinden değerlendirmek açısından yetersiz görünmektedir.

Gerçekleştirme aşaması, teknolojinin başlangıçta malzeme teknolojisi ve ürün geliştirme disiplinleriyle ilgili olarak geliştirildiği aşamadır. Teknolojik başarılar ve biyolojinin tasarlanmasına yönelik artan ilgi, devam eden çalışmaları teşvik ederek önemli fırsatları işaret ediyor gibi görünmektedir. Bunun aksine, mantar, bakteri ve alg içeren malzemeler için Avrupa standartlarının eksikliği ve canlı bileşenlerin kullanımına yönelik etik kaygılar konusunda eksik bilgi gibi düzenlemelerin eksikliği, gerçekleştirme aşamasındaki engeller gibi görünüyor. Üretim aşaması ancak belirli malzemelerin ve teknolojinin geliştirilmesi ile başlayabilirdi. Radikal bir yaklaşım sağlayan yeni ürünlere olan ilginin artması ile çevresel bozulmaya yönelik bilinç oluşturmak önemli bir fırsat gibi görünmektedir. Düzenleme eksikliği de tartışmalı bir konudur çünkü standartların eksikliği, gelişmiş ürünlerin mevcut pazarda yer bulmasını çoğu zaman engelledi. Endüstriyel tasarımda üretim aşaması bittikten sonra bina tasarımı alanında keşif aşaması başlar. Bu noktada, keşif aşamasının üretimden sonra bile neden bu kadar geç gerçekleştiği sorulabilir, çünkü farklı tasarım disiplinleri arasındaki boşluk devam ediyor.

Biyo yapı bileşenlerinin, binalara olası avantajları nedeniyle bina tasarımında araştırılması gerekir. Yapı tasarımında keşfedilmeye başlanırken işlevleri ve faydaları değişebildiğinden, biyo bina bileşenleri, farklı bina katmanları arasındaki etkileşimi artırarak bina tasarımında aktif roller kazanır. Örneğin, Tedarik Bakanlığı Mercury Isıtmalı Ceket, kullanıcıya termal konfor sağlayarak bina tasarımında aktif bir rol oynayabilir. Bu sayede hizmetliler hizmet gibi

davranmaya başlar. Bu nedenle keşif aşaması, endüstriyel tasarımdan bina tasarımına bilgi aktarımı açısından kritik bir rol oynamaktadır. Entegrasyon stratejileri, sızma, adaptasyon ve etkileşim gibi çeşitli fırsatlar bu aşamayı güçlendirerek bina tasarımında yaşayan ve üretilen bileşenleri birbirine bağlama yollarını sunar. Ek olarak, bakteri ve mantar kullanımına ilişkin mevcut standartlara ilişkin eksik bilgiler, etik ve mahremiyet sorunları gibi insanlara bağlı teknolojilere ilişkin düzenlemelerin eksikliği gibi düzenlemelerin eksikliği de bu aşamada bir engeldir. Ancak daha da önemlisi, profesyonellerin mevcut zihniyetleri, hijyen fobisi, disiplinler arası çalışma ve kullanıcı, ürün ve bina arasındaki kesintiye uğramış ilişki yoluyla önemli bir engel gibi görünüyor.

Bu anlamda, keşif aşaması, bina tasarımında biyo-yapı bileşenlerinin ilk aşaması olduğu için kritik bir rol oynar. Başarısız olduğunda, biyo-bina bileşenleri bina tasarımına entegre edilemez. Çeviri aşaması, teknolojilerin endüstriyel tasarım alanından bina tasarımı alanına dönüştürülmesini ifade eder. Bu aşamadaki fırsatlar, bağlamsallaştırma yoluyla teknolojilerin benimsenmesi ve alternatif çözümler sağlanmasıdır. Bu şekilde, biyo bina bileşenleri, bina tasarımına sorunsuz bir şekilde sızacaktır. Bu aşamada, ana engel paydaşları ve mevcut sistem düşüncesini mevcut inşaat teknolojileri ve bina tasarım süreçleri aracılığıyla ikna etmektir.

Biyo yapı bileşenleri, bina tasarım süreçlerini tamamen değiştirebileceğimiz yeni bir üretim biçimini gösterebilir. Örneğin mantar temelli teknolojiler için istenen malzemenin yetiştirilmesi için zamana ihtiyaç vardır. Bu, mevcut uygulamaya kıyasla gerçekten aşırı. Bu tasarım aşamaları ve aralarındaki ilişkiler, birden çok aktörün katılımının, birden çok disiplin ve alanın işbirliğinin altını çizmemize neden oluyor.

Bana göre, tasarım aşamaları tasarım sürecine genel bir bakış sağlar, ancak bize uygulanacak nihai bir model sağlamaz. Biyo yapı bileşenleri ancak çevirilerinden sonra bina tasarımına entegre edilebilir. Bu tasarım aşamalarının endüstriyel ve bina tasarımı arasındaki bağlantıları, belli aktörlerin rolünü ve elbette mimarların rolünü anlayarak önemli olduğunu söylemek mümkündür. Bununla birlikte, biyo

yapı bileşenlerinin mevcut teknoloji düzeyi, bunların bina tasarımına entegrasyonlarını daha fazla tartışmak için geliştirilmemiştir.

Sonuç olarak, araştırma sorularının cevapları, temel olarak mimari ve sosyal etkilerini detaylandırarak biyo-bina bileşenlerinin beklenen etkilerini tartışır. Bu arada, tüm farklı anlamların ışığında, biyo yapının önemi, bina tasarımındaki çoklu kullanım yararları ve rolleri aracılığıyla birden çok alana, çalışmaya ve disipline bağlanır. Bu aynı zamanda bina tasarımı üzerindeki çok yönlü etkiyi de gösterir. Farklı bakış açıları, aynı noktaya odaklanmak yerine biyo yapı bileşenlerinin çeşitli anlamlarını ortaya çıkarır. Tez kapsamında uygulanan tüm yöntemler, bizi biyo yapı bileşenlerinin beklenen başka bir etkisiyle sonuca götürür. Bu çok yönlülüğü, ana araştırma sorusuna son bir yanıt olarak biyo yapı bileşenlerinin "çok yönlü etkisi" olarak adlandırıyorum. Bu araştırma aynı zamanda mimari ve sosyal etkileri hakkında bilgi vererek mevcut literatüre katkıda bulunmuştur.

B 2.2 Öneriler

Bu tezden, araştırma çıktıları olarak iki tür öneri çıkarılabilir: mimarlar için öneriler ve biyo yapı bileşenleri üzerine gelecekteki araştırma ve uygulamalar için öneriler. Bu öneriler mimarlar, geleceğin mimarları ve bina tasarımı alanında çalışan / çalışmayı düşünen araştırmacı ve uygulayıcılar içindir.

B 2.2.1 Mimarlar için Öneriler

Bana göre bu öneriler, mimarların çalışmanın nihai çıktısı olarak tasarımlarındaki biyo-yapı bileşenlerine yönelik kararlarında 'bilinçlerini' geliştirmelerine yardımcı oluyor.

Tezde sonuçlanan öneriler, uygulayıcıların mimarların farkındalıklarını artırmaları gereken belirli konularda bilgi eksikliğine vurgu yapmasının bir sonucu olarak 'farkındalık' şemsiyesi altında tartışılmaktadır. Başlangıçta, ilk öneri 'biyo yapı bileşenlerinin çok perspektifli etkilerinin farkında olmaktır.' Bu öneri aynı zamanda bina tasarımında biyo yapı bileşenleri aracılığıyla vaat edilen

olasılıkların ve alternatif çözümlerin sayısının farkında ve açık fikirli olma gerekliliğini de ifade eder.

Bir diğer önemli öneri ise, "disiplinler arası işbirliğine dayalı çalışmadan haberdar olmaktır." Biyo-inşa bileşenleri, geliştirme ve entegrasyon sürecinde birden çok aktörün işbirliği ile birden çok alanı ele alır. Bu nedenle, mimarların birden fazla disiplinden profesyonellerle işbirliği yapma gerekliliğinin farkında olmaları gerekir.

Dahası, önemli bir öneri, 'biyo yapı bileşenlerinin doğa ve teknoloji kavramları ile bağlarının farkında olmaktır.' Biyo yapı bileşenleri yalnızca yeni bir malzeme teknolojisini veya yükseltilmiş bir teknolojiyi göstermez. Biyo-bina tasarımına ve biyofilik bir ortama doğru ortaya çıkan teknolojik geçişteki niş yenilikleri temsil ediyorlar. Bu nedenle, ürün geliştirme ve inşaat teknolojisi ile ilgili mevcut görüş sistemine yönelik radikal bir düşünme şekli önermektedirler. Buna göre mimarlar bu olası sistem değişikliğini göz önünde bulundurmalı ve tasarımlarını uygulamalıdır.

Dahası, mimarlara 'terminolojideki belirsizlik ve karmaşıklığın farkında olmalarını' tavsiye etmek esastır. Aslında, disiplinler arası çalışmalarda, terminoloji genellikle bir tuzak gibi görünmektedir. Biyo yapı bileşenleri ve bunların bina tasarımına entegrasyonu için terminolojideki belirsizlik ve karmaşıklık, hem bir potansiyeli hem de bir sorunu gösterir. İlgili kavramların, terimlerin ve tanımların çeşitliliği, bizi birden çok çalışma, disiplin ve alanlarla bağ kurarak biyo yapı bileşenlerinin çok perspektifli etkilerinin altını çizmemize götüren kritik konulardan biridir. Aynı zamanda, bu çeşitlilik, bina tasarımı alanında araştırma yapmak için biyo-yapı bileşenlerinin tespitini engeller. Biyolojik yapı bileşenlerinin güncel örnekleri, akıllı, sürdürülebilirlik ve biyomimikri gibi farklı terimler ve kavramlar altında tartışılmaktadır. Canlı organizmaların bu geniş kavramlar altında birleştirilmesini ele almak, biyo yapı bileşenlerinin yeniliğinin ifadesini engellemektedir. Mimarların terminolojideki bu çok yönlülüğün farkında olması ve projelerini ve çalışmalarını belirlerken belirli kavram ve terimleri kullanırken dikkatli olmaları gerekir.

Bana göre bu öneriler, mimarların çalışmanın nihai çıktısı olarak tasarımlarındaki biyo-yapı bileşenlerine yönelik kararlarında 'bilinçlerini' geliştirmelerine yardımcı oluyor.

Tezde sonuçlanan öneriler, uygulayıcıların mimarların farkındalıklarını artırmaları gereken belirli konularda bilgi eksikliğine vurgu yapmasının bir sonucu olarak 'farkındalık' şemsiyesi altında tartışılmaktadır. Başlangıçta, ilk öneri 'biyo yapı bileşenlerinin çok perspektifli etkilerinin farkında olmaktır.' Bu öneri aynı zamanda bina tasarımında biyo yapı bileşenleri aracılığıyla vaat edilen olasılıkların ve alternatif çözümlerin sayısının farkında ve açık fikirli olma gerekliliğini de ifade eder.

Bir diğer önemli öneri ise, "disiplinler arası işbirliğine dayalı çalışmadan haberdar olmaktır." Biyo-inşa bileşenleri, geliştirme ve entegrasyon sürecinde birden çok aktörün işbirliği ile birden çok alanı ele alır. Bu nedenle, mimarların birden fazla disiplinden profesyonellerle işbirliği yapma gerekliliğinin farkında olmaları gerekir.

Dahası, önemli bir öneri, 'biyo yapı bileşenlerinin doğa ve teknoloji kavramları ile bağlarının farkında olmaktır.' Biyo yapı bileşenleri yalnızca yeni bir malzeme teknolojisini veya yükseltilmiş bir teknolojiyi göstermez. Biyo-bina tasarımına ve biyofilik bir ortama doğru ortaya çıkan teknolojik geçişteki niş yenilikleri temsil ediyorlar. Bu nedenle, ürün geliştirme ve inşaat teknolojisi ile ilgili mevcut görüş sistemine yönelik radikal bir düşünme şekli önermektedirler. Buna göre mimarlar bu olası sistem değişikliğini göz önünde bulundurmalı ve tasarımlarını uygulamalıdır.

Dahası, mimarlara 'terminolojideki belirsizlik ve karmaşıklığın farkında olmalarını' tavsiye etmek esastır. Aslında, disiplinler arası çalışmalarda, terminoloji genellikle bir tuzak gibi görünmektedir. Biyo yapı bileşenleri ve bunların bina tasarımına entegrasyonu için terminolojideki belirsizlik ve karmaşıklık, hem bir potansiyeli hem de bir sorunu gösterir. İlgili kavramların, terimlerin ve tanımların çeşitliliği, bizi birden çok çalışma, disiplin ve alanlarla bağ kurarak biyo yapı bileşenlerinin çok perspektifli etkilerinin altını çizmemize götüren kritik konulardan biridir. Aynı

zamanda, bu çeşitlilik, bina tasarımı alanında araştırma yapmak için biyo-yapı bileşenlerinin tespitini engeller. Biyolojik yapı bileşenlerinin güncel örnekleri, akıllı, sürdürülebilirlik ve biyomimikri gibi farklı terimler ve kavramlar altında tartışılmaktadır. Canlı organizmaların bu geniş kavramlar altında birleştirilmesini ele almak, biyo yapı bileşenlerinin yeniliğinin ifadesini engellemektedir. Mimarların terminolojideki bu çok yönlülüğün farkında olması ve projelerini ve çalışmalarını belirlerken belirli kavram ve terimleri kullanırken dikkatli olmaları gerekir.

B 2.2.2 Gelecek Teorik Araştırma ve Pratik Çalışmalar İçin Öneriler

Bina tasarımında biyo yapı bileşenlerinin kritik yönlerini sunarak, bu tez, bina tasarımı alanında daha fazla araştırma ve uygulama hakkında bilgi sağlar. Bu bölümdeki bu öneriler, bina tasarımında biyo yapı bileşenleri üzerine gelecekteki çalışmaların olası yönlerini aydınlatmaktadır.

Ortaya çıkan bu alanda, bina tasarımı ile sağlık, moda ve tekstil gibi diğer alanlar ve daha pek çok alan arasındaki ilişkileri değerlendirmek gerektiğine inanıyorum. Bu şekilde, bu çalışmalar, bina tasarımı ile sağlık hizmetleri ile ilgili ortaya çıkan biyo-yapı bileşenlerinin sayısı gibi diğer alanlar arasındaki diyalogu anlamamızı sağlayabilir. Bu yollarla, daha fazla araştırma ve uygulama, özellikle bina tasarımındaki belirli biyo-bina örneklerinin belirli etkilerine odaklanabilir ve buna göre içgörüler sağlayabilir. Ek olarak, yapı tasarımı için tektonik anlamlarını detaylandırarak malzeme seviyesinden biyo yapı bileşenlerine odaklanmak için daha fazla çalışma yapılması gerekmektedir.

Daha sonraki çalışmalarda, bu konudaki çalışmaların sayısına göre sistematik literatür taramaları açık ve kapsamlı bir genel bakış sağlayabilir. Bu farklı ve sistematik veri toplamanın rehberliğinde, çeşitli biyo-yapı bileşenlerini inceleyerek, daha fazla araştırma ve uygulama, onları farklı bir metodoloji yoluyla keşfederek ve böylece farklı araştırma yaklaşımları ve yöntemleri kullanarak sınırlı örneklerle odaklanabilir.

Ayrıca, ileri çalışmalar, biyo-yapı bileşeninin vekillik yönüne ve mimari ve tasarıma önerilen yeni yaklaşımdaki tasarımcı veya mimara odaklanacaktır. Bu konuya bu şekilde yaklaşmak, mimaride tasarım düşüncesine ilişkin daha fazla yanıt bulmamızı sağlayacaktır.

Tasarım deneylerinin farklı aktörlerle tekrarlanmasını öneriyorum, böylece daha fazla sonuç sunuyorum. Protokol analizi yöntemi, bina tasarım sürecini değerlendirmek için derinlemesine içgörüler elde ediyor gibi görünmektedir, ancak başka yöntemler de uygulanabilir ve tartışılabilir. Bu tasarım deneyi, öğrencilere belirli örnekler vererek ve bunları tasarımlarına entegre etmelerini bekleyerek, böylece tasarım yaklaşımını ve zihniyetini anlayarak biyo yapı bileşenlerini bir araç seti olarak benimser. Bununla birlikte, bu, öğrencilerin biyo-yapı bileşenlerini ve potansiyellerini deneyimleyerek ve tasarımlarını gözlemleyerek, test ederek ve deneyimleyerek bunları entegre ederek araç setinde de kalabilir. Dahası, biyo yapı bileşenlerinin mimarlık eğitimi için kritik anlamı argümanı da görüşmelerde destekleniyor. Uygulayıcılar, mimarların biyo yapı bileşenleri konusundaki bilgi eksikliğinin altını sürekli olarak vurguladıkları için, biyo yapı bileşenlerini mimarlık eğitiminin bir parçası olarak tartışmak gerekir. Bu nedenle, bu tez, mimarlık eğitiminde biyo-yapı bileşenleri hakkında daha fazla araştırma ve uygulamaya ihtiyaç duyulduğunun altını çiziyor ki bu daha ileri çalışmalar için verimli bir alan olacaktır.

Ayrıca görüşme çalışmasının farklı bağlamlarda tekrarlanmasını öneriyorum, bu da bizi farklı sonuçlar bulmaya yönlendirebilir. Bu tezin rehberliğinde ve zaman içinde biyo yapı bileşenlerinin bina tasarımına entegre edilmesiyle, daha geniş bir kitleye sahip anketler ve kullanıcı deneyimleri gibi daha spesifik konular gibi nicel araştırmalar uygulanabilir.

Tüm bunlara ek olarak, bu araştırmanın amacına ulaşmak için birden çok yöntem ve birden çok analitik ve yardımcı araç kullanılmaktadır. Tabii ki ileride yapılacak çalışmalarda başka yöntemler de kantitatif yöntemler de uygulayarak çalışmalar yapılmasını öneriyorum. Bunun nedeni, sınıflandırmalar ve kategorilendirmelerle

birlikte mevcut yöntemler, biyo-bina bileşenlerini doğru bir şekilde değerlendirmek için yetersiz görünebilir.

B 2.3 Son Söz

Çalışma, biyo yapı bileşenlerinin beklenen mimari ve toplumsal etkileri ile ilgili varsayımsal çıkarımlarla sona ermektedir. Bu varsayımsal çıkarımlar, bu çalışmanın bulgularından türetilen kendi görüşlerimi, anlayışlarımı, tavrımı ve gelecek beklentilerimi göstermektedir.

Benim düşünceme göre, mevcut pazardaki artan ürün sayısına bağlı olarak, önümüzdeki bir ve yirmi yılda bile, bina bileşenleri, yakın gelecekte biyo-bina bileşenleri ile değiştirilebilir. Böylelikle, biyo yapı bileşenlerinin, devam eden çevresel bozulma için canlı ve üretilmiş bileşenleri birleştirerek ve çağdaş toplumun taleplerini değiştirerek çözümler sunarken, bizi mevcut bina tasarım ve inşaat yöntemlerini 'yeniden düşünmeye' yönlendirmesidir.

Benim bakış açımına göre bu çalışma, biyo-bina bileşenlerinin akıllı ve sürdürülebilir yapıları çevre ile bina tasarımı arasında bir bağlantı oluşturduğunun altını çiziyor. Ve bu bağlantı, herhangi bir teknolojinin üretilmesine yönelik yeni düşünme yolları getiriyor. Aslında, sürdürülebilirlik ve akıllılık, biyo-yapı bileşenlerinin "katma değerleri" haline gelme yolunda. Bu şekilde, mimaride devam eden sürdürülebilirlik ve akıllılık tartışmaları, yeni bir tasarım yaklaşımı ve praksişi ile 'biyo-bina tasarımı' olarak tanımlanabilir. Döngüsel sistem düşüncesi, biyo-bina bileşenlerinin kısa sürede tamamen elde edilemeyecek ancak daha da ileriye taşınacak temel faydalarından biridir. Tasarım düşüncesi ve üretim sistemlerinde yeni bir olasılık yolu getirerek, biyo yapı bileşenleri, özellikle büyümeyi üretimle değiştirerek çevresel bozulmayı çözmede kritik bir rol oynayacaktır.

Biyo yapı bileşenlerinin pratik anlamlarına ek olarak, bunların yapıları çevreye olası katkıları, tarihsel ve fenomenolojik anlamlarıyla ilişkili olarak biyo yapı bileşenlerinin felsefi anlamları etrafında da merkezlenebilir. Biyo yapı bileşenlerinin tarihsel anlamlarına bakılarak, yakın gelecekte doğa ve teknoloji kavramının yorumlanmasıyla farklı anlamlar ekleneceğini iddia etmek mümkündür. Bu yolla, ideolojik olarak mimarlar, doğa, insanlar ve binalar

arasındaki ilişkileri felsefi bir şekilde güçlendirerek kavramsal düşünme biçimlerini tasarımlarına vurgulamak için biyo-yapı bileşenlerini benimseyebilirler.

Mevcut akademik ve popüler tartışmalarda, canlı organizmaların dahil edilmesi kulağa yeni ve yenilikçi gelebilir; kasıtlı olarak bile bu uygulama bu şekilde sunulabilir. Ancak bu teze dayanarak, özellikle biyo-yapı bileşenlerinin tarihsel anlamlarıyla, bunun bir yanlış varsayım olduğunu ortaya koyuyorum. Nitekim canlı organizmalarla tasarım yapma motivasyonu her zaman bina ve mimari mekan üretiminin merkezinde kalmıştır. Kanımca yakın gelecekte yaşanabilirlik, büyüme ve zamansallık, mekan üretiminin ve bina tasarımının disiplinler koşulları haline gelecektir. Buna göre, tasarım konseptleri bu koşulları tercih etme etrafında merkezlenecektir; böylece bina tasarımı buna göre şekillendirilmiş olur.

Benim düşünceme göre, biyo bina tasarımının felsefi anlamları enerji verimliliği, atık yönetimi, insan vücudunun iyileştirilmesi gibi çeşitli pratik faydalarla güçlendirilecektir. Bu pratik faydalar mimarları tasarımlarını buna göre geliştirmeye teşvik ederken, biyo bina bileşenlerinin binalarda entegrasyonu toplumsal etkiler getirmesi bekleniyor. Biyo yapı bileşenlerinin entegrasyonu, biyo yapı bileşenlerinin günlük hayatımızın bir parçası haline gelme sürecini hızlandırabilir. Uygulayıcıların da desteklediği gibi bu, insanlar, teknoloji ve doğa arasındaki ilişkileri güçlendirebilir. Bu noktada, bu, mimarları tasarımlarına daha fazla biyo yapı bileşeni eklemeye motive ediyor. Bu arada, bu uzun vadeli bir süreci temsil ediyor. Bu nedenle, biyo bina bileşenlerinin sızması, binaları toplum tarafından fark edilmeden biyo binalara dönüştürebilir. Binalar biyo bina haline geldiğinde, biyo bina bileşenleri zaten geleneksel ürünler olarak kabul edilmiş olacaktı. Biyo bina bileşenleri, giyilebilir teknolojiler, canlı duvar sistemleri gibi çeşitli şekillerde binalara sızmaya başladı ve mimarları, oldukça gelişmiş Batı toplumunun taleplerine yanıt vererek bu entegrasyonu kontrol etmek ve yönetmek için daha aktif roller oynamaya teşvik ediyor.

Benzer şekilde, uygulayıcılar yavaş ama kademeli olarak topluma entegrasyonlarını öneriyorlar. Bu noktadan hareketle biyo yapı bileşenlerinin

toplumun taleplerine hitap ederek daha da geliştirilmesinin beklendiğini söylemek mümkündür. Başka bir deyişle, canlı ve üretilmiş bileşenlerin bu karşılıklı ilişkisi toplumun talepleri ile şekillenecektir. Uyarlanabilir, yeniden tasarlanabilir, farklı teknikler ve malzemelerle birleştirilebilirler. Örneğin, biyo yapı bileşenlerinin estetik kaygıları, canlı organizmaların fark edilir olup olmayacağını veya teknolojiyle tamamen kaynaşıp kaynaşmayacağını belirleyebilir. Benim görüşüme göre bu, mevcut tasarım estetiğini ve bina tasarımının endişelerini değiştirebilir.

Biyo yapı bileşenlerinin teknolojik anlamları yakın gelecekte iki ana yolu izleyecektir. Doğa ve üretim ilkeleri, temel farklılıklarını inkar etmeden birbirleriyle buluşabilir. Dolayısıyla yakın gelecekte doğa ve teknoloji kavramlarının birleştirilmesiyle bu ilişkinin bir birliğe dönüşmesi benim bakış açıma göre mümkün görünüyor. Bu arada, canlı ve üretilmiş bileşenler arasındaki bu temel farklar teknoloji ile aşılabılır. Bu sayede her şey teknolojik olarak kabul edilebilirken, doğa teknolojiyle kaynaşabilir. Ancak her iki durumda da bu, yeni bir yaklaşım veya konsept olarak bina tasarımına dahil edilebilir.

Biyo yapı bileşenlerinin teknolojik anlamlarının, yapılı çevrenin biyofilik bir yapılı çevreye dönüşmesine yol açan toplumsal değişiklikleri tetikleyeceğine inanıyorum. Kanımca, biyolojik bina bileşenlerinde ajans rolü, gelecekte herhangi bir binanın içindeki teknolojik entegrasyon seviyesini de artırıyor. Görüşmelerde tartışıldığı gibi, bu teknolojiler temelde insanları kararlarında ve yaptıklarında daha fazla zaman ayırmaya teşvik ediyor ve destekliyor. Bu yaklaşımı anlamak, tasarımcıların veya mimarların daha karmaşık, bakım gerektirmeyen, döngüsel ve sürdürülebilir projeler oluşturmalarına ve aynı zamanda çekici kullanıcıların ihtiyaç ve gereksinimlerine sahip olmasına izin verecektir.

Toplumsal değişimlerle ilgili olarak, biyo yapı bileşenlerinin entegrasyonu yoluyla, insanların mimari mekanla yeni davranışlar ve ilişkiler geliştirebileceğine inanıyorum. Örneğin, biyo yapı bileşenleri yaşayan, büyüyen ve aynı zamanda ölmekte olan malzeme ve ürünleri sunar. Bu geçicilik, binaların geleneksel anlayışlarının istikrarıyla karşılaştırıldığında insanların günlük rutinlerini, alışkanlıklarını ve yaşam tarzlarını etkileyebilir. İnsan boyutları sabittir, bu

nedenle mimari mekanlarda belirli sınırlamalar vardır. Bununla birlikte, yeni teknolojiler her zaman insanların ve binaların dinamik ilişkilere, özellikle giyilebilir teknolojilere sahip olduğu daha fazla olasılık getirebilir. Örneğin, giyilebilir teknolojiler, mimari alanda belirli sistemleri ve nesneleri zaten kontrol etmekte ve yönlendirmekte ve bunlar, gelişmiş temizleme, düzenleme, hatta değiştirme ve dönüştürme yetenekleri gibi yakın gelecekte artırılabilir. Mimari mekanlar, uygun insan vücut ısısının ayarlanmasını değiştirebilir, tercih edilen iç tasarımlar, müzik çalabilir ve eğlence aktiviteleri sunabilir, hatta arzu edilen kokuları açığa çıkarabilir. Bu anlamda, bedene genişlemeleri ortak yetenekleri ve duyuları değiştirebilir ve böylece yeni tasarım olasılıkları açabilir.

Sonuç olarak, bina tasarımının yakın gelecekte yaşayan ve üretilmiş dünyalar arasına yerleştirileceğini düşünüyorum. Çünkü benim açımdan biyo yapı bileşenleri, çok yönlü etkisi sayesinde, yenilikçi malzeme teknolojisi, ürün geliştirme sistemleri aracılığıyla bina tasarımında ve yapımında dairesel sistem düşüncesine ulaşmaya yardımcı olacak. Bu, binaların algler, bakteriler, bitkiler ve miselyum gibi canlı organizmalar içereceği anlamına gelecektir. Böylelikle insanlar, kullanıcılar, uyarlanmış zamansallık yoluyla mekanın daha dinamik olacağı bina ortamında canlı organizmalarla daha bağlantılı ve etkileşimli ilişkiler kuracak. Bu bağlantılı ilişki, uygulayıcılar tarafından yaratılan mevcut tahminler biçiminde olabilir, ancak canlı organizmalarla tasarım yapmanın belirsizliği göz önüne alındığında daha beklenmedik ilişkiler de mümkündür. Bu arada insanlar da bir binanın parçası olacak. Bina ortamı, günlük yaşam görevlerini kolaylaştıran, insanlarla iletişim kuran ve onların ihtiyaçlarına cevap veren daha fazla biyo-bina bileşeniyle çevrelenecek. Canlı ve üretilmiş bileşenler arasındaki farklar azalırken, teknolojinin daha "canlı" hale geldiğine inanıyorum.

Bu noktada, malzeme bilimcileri ve ürün tasarımcıları biyo yapı bileşenleri geliştirse ve mühendisler ve programcılar kodu yazsa da, mimarlar bunları bina tasarımına entegre etme, paydaşlara aracılık etme ve kullanıcıların ihtiyaçlarını ve faydalarını dikkate alma sorumluluğuna sahiptir. Bu nedenle, mimarların bu teknolojilere yaklaşımı, günlük hayatımızın yanı sıra çevremizi de büyük ölçüde etkiler. Yaklaşımları doğrultusunda mimarların rolleri de günlük aktivitelerdeki ve

günlük yaşamdaki değişikliklerle değişecektir. Bu nedenle, mimarlardan biyo yapı bileşenleri ve bunları tasarımlarına nasıl entegre edecekleri konusundaki bilgilerini güçlendirmeleri gerektiğini son bir vurgu ile bitirmek istiyorum.

Biyo yapı bileşenlerinin entegrasyonunun yanı sıra, bina tasarımında devam eden bir değişiklik yoğun bir şekilde somut ve beklenmektedir. Bu değişim içinde, bu araştırmanın en önemli katma değerlerinden biri, bina tasarımında canlı organizmalarla tasarım yapmaya yönelik mevcut arzunun arkasındaki ürün ve bina tasarımı, binaların teorik ve pratik yönleri ve mimari teori arasındaki kritik bağlantıları ele almaktır.

PUBLICATIONS FROM THE THESIS

Contact Information: berrakkirbas@gmail.com

Kirbas Akyurek B., Mohammadi, M., Ciravoglu, A., Yegenoglu, H. (30 September 2020). Technological Transition in Building Design at the Intersection of Living and Manufactured. *TECHNE Journal of Technology for Architecture and Environment Special Issue 2*, In publication.

Kirbas Akyürek, B., Ciravoğlu, A., Mohammadi, M., & Yegenoglu, H. (July 2020). Building Design in between Living and Manufactured : A Research on Terminology. *Online Journal of Art and Design*, 8(3), 75–89.
<http://www.adjournal.net/articles/83/836.pdf>

Kirbas Akyurek B., Mohammadi, M., Ciravoglu, A., Yegenoglu, H. (2020). Exploring the Potential Impact of Biobuilding Components into Building Design: An Experiment in Architectural Design Studio (*Under Review at The Journal of Design and Built Environment*).

Kirbas Akyurek, B., Sanders - Kortekaas, M. H., Fisscher, J. L., & Mohammadi, M. (2018). Technological integration of the ‘house of the future’: case study analyses of the integration level of technology for innovative housing projects between 1920 and 2010. In J. Veuger (Ed.), *3rd conference of interdisciplinary research on real estate: book of proceedings* (pp. 130-148). Ljubljana: Institute of Real Estate Studies. (Published in the conference proceedings).

Kirbas Akyurek, B., Fisscher, J., Kortekaas, M., & Mohammadi, M. (2018). Technological integration of the ‘house of the future’: Case study analyses of the integration level of technology for innovative housing projects between 1920 and 2010. *Barometer Public Real Estate Special Issue 2018* (pp.127-144), Groningen: Spryg Real Estate Academy En Bariet Ten Brink. (Published as a book chapter).

Kirbas Akyurek B., Ciravoglu, A.,(2018). Man-Made to Born-Made : Shifting Perspectives in Architecture. In *Virtual + Actual, Process and Product of Design, Proceedings of Design Communication Conference* (pp. 604-610). New York, United States Of America, 07 October 2018.