MATERIALS experience

fundamentals of materials and design

edited by elvin karana, owain pedgley, and valentina rognoli
foreword by mike ashby

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Edited by

Elvin Karana

Owain Pedgley

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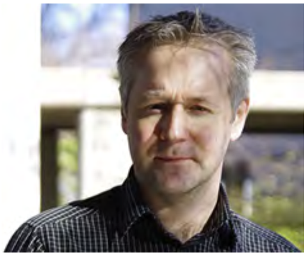
Biography

Elvin Karana is an Assistant Professor in the Faculty of Industrial Design Engineering (IDE) at Delft University of Technology (DUT), The Netherlands. She obtained her Bachelor and Master degrees from the Department of Industrial Design, Middle East Technical University (METU), in Ankara. She undertook her PhD research at DUT, where she developed a 'Meaning Driven Materials Selection Tool' to support designers in their materials selection activities. Some of her major publications can be found in *Materials and Design* journal, *International Journal of Design* and *Journal of Cleaner Production*. Elvin is one of the founders of the Natural Fibre Composites Design Platform in The Netherlands. She is also the developer and Coordinator of the materials library 'Made Of..' within IDE at DUT, Her current research interests include 'effective materials education in design', 'dynamic materials experiences' and 'designing with bio-based materials'.

Owain Pedgley is Associate Professor of Industrial Design at Middle East Technical University (METU), Ankara, Turkey. He undertakes research in the areas of materials and manufacturing for industrial design and user-product experiences, with a special emphasis on musician-instrument interaction. Owain is a partner in the musical instrument innovation project Cool Acoustics. He contributes to design education at bachelor, master and doctoral levels and is experienced in establishing and managing industrially collaborated projects with firms including Bosch und Siemens Hausgeräte, Vestel and Kale. Prior to his academic career, Owain served three years as a product designer in the sports equipment sector.



Valentina Rognoli is an Assistant Professor in the Department of Chemistry, Materials and Chemical Engineering "Giulio Natta" at Politecnico di Milano, Italy, where she conducts research in the field of materials and education. She teaches in the School of Design within Politecnico di Milano. After two years at Enzo Mari's studio in Milan, in 2000 Valentina started her academic activities focused on materials and their expressive-sensory dimension. In her PhD research she

developed an 'Expressive-Sensorial Atlas of Material' as a tool to improve materials education in the field of design. Valentina also developed and coordinated 'Materiali e Design', the materials library of Politecnico di Milano. Her current research topics delve into materials and their relationship with innovation, emotions, and sustainability.

Foreword: Materials Experience—Fundamentals of Materials and Design

We live, in the West, in a world with a surfeit of products. You want an electric kettle? You have a choice of at least 30, all with more or less the same technical specification. A vacuum cleaner? There are at least 30 models of those too. A refrigerator? A car? The same story.

Given this surfeit, how do consumers choose the products they buy? The answer has to do with value. A product has a cost—the outlay in manufacturing and marketing it. It has a price—the sum at which it is offered to the consumer. And it has a value—a measure of what the consumer thinks it is worth. Consumers buy products that they perceive as having a value (to them) that most exceeds their price. But what determines value? Sound technical design clearly plays a role: the product must work properly and be safe and economical. Beyond that, the product must be easy to understand and operate, and these are questions of usability. And there is a third requirement: that the product gives satisfaction, that it enhances the life of its owner. The value of a product is a measure of the degree to which it meets or exceeds the expectation of the consumer in all three of these—functionality, usability, and satisfaction. One might think of the three as forming the character of the product. It is very like human character. An admirable character is one who functions well, interacts effectively, and is rewarding to be with. An unappealing character is one that does none of these. Unappealing products are kept only as long as they are useful and are then cast aside. By contrast, as Valentina Rognoli and Elvin Karana point out in Chapter 11 of this remarkable collection of essays, well-designed products are cherished; they can acquire value with age, and—far from becoming unwanted—can outlive their design-life many times over. The auction houses and antique dealers of New York, London, and Paris thrive on the sale of products that, often, were designed for practical purposes but are now valued more highly for their aesthetics, associations, and perceived qualities. People do not throw away things for which they feel emotional attachment.

The rapid turnover of products we see today is a comparatively recent phenomenon. In earlier times, furniture was bought with the idea that it would fill the needs not just of one generation but of several—treatment that, today, is reserved for works of art. A wristwatch, or a gold pen, was a thing you used for a lifetime and then passed on to your children. No more. Changing lifestyles and fashions, promoted by seductive advertising, reinforce the desire for the new and urge the replacement of the old. Industrial design carries a heavy responsibility here—it has, at certain periods, been directed toward creative obsolescence, designing products that are desirable only if new, and urging the consumer to buy the latest models, using marketing techniques that imply that acquiring them is a social and psychological necessity. As Jonathan Chapman points out in Chapter 10, this has led to an ecological crisis, a society that consumes natural resources at an accelerating rate, not conserving them but degrading and discarding them, with environmental consequences that are now a cause of real concern.

Here, the concept of the material life cycle and life cycle assessment, explored by Carlo Vezzoli in Chapter 8, is helpful. The idea of a life cycle has its roots in the biological sciences. Living organisms are born; they develop, mature, grow old, and, ultimately, die. The progression is built in—all organisms follow broadly the same path—but their development and their behavior, life span, and influence, depend on their interaction with their environment—the surroundings in which they live. Life sciences track the development of organisms and the ways in which they interact with their environment. Materials in products have a rather similar life story. Ore, feedstock, and energy are drawn from the natural resources of the planet and processed to give materials. These are subsequently manufactured into products that are distributed, sold, and used. Products have a useful life at the end of which they are discarded, a fraction of the materials they contain perhaps entering a recycling loop, the rest committed to incineration or landfill.

Increasing global population and affluence have inflated consumption to a level that is not, in the long term, sustainable. The average ecological footprint[1] per person in developed nations now exceeds the per capita carrying capacity of the planet, although the consequences of this are not yet evident, masked by the many nations with far lower footprints. Part of the footprint is technology driven, a direct result of increased transport, manufacture, and domestic consumption. This perception has, over the last 20 years, motivated many projects aimed at more sustainable technology: lightweight design to provide sustainable transport (Erik Tempelman, Chapter 18), "intelligent" materials with sensing and energy-harvesting ability (Sybrand van der Zwaag, Dan van den Ende, and Wilhelm Albert Groen, Chapter 16), biobased materials to replace those that draw on nonrenewable resources (Prabhu Kandachar and Sascha Peters, Chapters 7 and 13), and an increasing emphasis on material-efficient design. There is also a growing movement, in parallel with these technical responses to environmental concerns, to explore the creative use of what you might call "waste"—material that is discarded by the first owner of a product but which, in the hands of an imaginative designer, can be reused or reprocessed to make new, more environmentally friendly objects (David Bramston and Neil Maycroft in Chapter 9, and Jakki Dehn in Chapter 12).

One might pause at this point to reflect on the origins of waste. A product reaches the end of its life when it is no longer valued. The cause of death is, frequently, not the obvious one that the product just stopped working. The life expectancy is the least of[2]

- The physical life, meaning the time in which the product breaks down beyond economic repair;
- The functional life, meaning the time when the need for it ceases to exist;

[1] The ecological footprint is an indicator of human pressure on the environment. It is a measure of the biologically productive land and marine area required to produce the resources and absorb the waste of a human population.
[2] This list is a slightly extended version of one presented by Woodward D.G. (1997), "Life cycle costing", *International Journal of Project Management*, Vol. 15, pp.335–344.

- The technical life, meaning the time at which advances in technology have made the product unacceptably obsolete;
- The economic life, meaning the time at which advances in design and technology offer the same functionality at significantly lower operating cost;
- The legal life, the time at which new standards, directives, legislation, or restrictions make the use of the product illegal;
- And finally the desirability life, the time at which changes in taste, fashion, or aesthetic preference render the product unattractive.

One obvious way to reduce resource consumption is to extend product life by making it more durable and more adaptable to change in the surrounding world. But durability means survival in more than one sense: we have just listed six. Materials play a role in them all, particularly the last.

As Aart van Bezooyen (Chapter 19) suggests, materials inspire design. Painters paint with pigment; writers paint with words; designers paint with materials. A diverse palette, a mastery of words, and a comprehensive grasp of materials are, for each, tools of the trade—necessary professional skills. But the most exciting creations are not usually those that use a radiant rainbow of colors, or a lavish lexicon of words, or a cluttered cornucopia of materials. Simplicity and restraint can be more appealing than drama and display. Thus good design can be inspired by a single material, as in the "Frida" chair that Elvin Karana, Owain Pedgley, and Valentina Rognoli choose, in the Introduction to this volume, as one of the exemplars of products that had particular appeal to them.

We interact with materials through products. The interaction involves both the technical and aesthetic attributes of the product. Aesthetics (like "inspiration") is a difficult word, having too many shades of meaning to convey a sharp message, yet there seems to be no other that quite captures the sensory attributes of materials and products. What do we mean by it? It is easier to start with its opposite: anesthetics. Anesthetics numb the senses, suppress feeling; anesthesia is a lack of all sensation. Aesthetics do the opposite; they arouse interest and stimulate and appeal to the five senses, particularly the sense of vision. It is through the senses that we experience materials. Designers manipulate these senses—and the reactions to each sense—to create a product's personality. Paul Hekkert and Elvin Karana (Chapter 1), Henrik Schifferstein and Lisa Wastiels (Chapter 2), and Blaine Brownell (Chapter 5) explore in depth the relationships between materials and experience and the ways they can be manipulated. Aesthetic experience might seem a difficult attribute to measure but that is only partly true. The sense of the soft or hard, cool or warm, dull or bright, matt or shiny can be quantified and linked to material properties. Zoe Laughlin and Philip Howes (Chapter 4) describe what can be learned from a study of these sensoaesthetic attributes of materials and how closely they can be linked to the physical, chemical, and thermal properties familiar to the materials scientist and engineer. This exploration of subjective feeling and underlying physical properties is also raised in the studies of Hengfeng Zuo, Tony Hope, and Mark Jones, described in Chapter 3, concerning the interaction of geometry and material properties with emotional response.

These interactions evoke the aesthetic response to a product but that is not all. A product has perceived attributes and associations—it might be seen as "feminine", or "classical", or "avant-garde", or "decadent". It is these, in part, that give it its personality, something designers work hard to create. But can a material be said to have perceived attributes or indisputable associations? A personality? At first sight, no—it only acquires them when used in a product. Like an actor, it can assume many different personalities, depending on the role it is asked to play.

And yet… think of wood. It is a natural material with a grain, a surface texture, color, and feel that other materials do not have. It is tactile—it is perceived as warmer than many other materials, and seemingly softer. It is associated with characteristic sounds and smells. It has a tradition; it carries associations of craftsmanship. And it ages well, acquiring additional character with time. Objects crafted from wood are valued more highly when they are old than when they are new. There is more to this than just aesthetics; there are the makings of a personality, to be brought out by the designer, certainly, but there none the less.

And metals… metals seem cold, clean, precise. They ring when struck. They reflect—particularly when polished. They are accepted and trusted; machined metal looks strong, its very nature suggests it has been engineered. The strength of metals allows slender structures—the cathedral-like space of railway stations or the span of bridges. Metals can be worked into flowing forms like intricate lace or cast into solid shapes with integral detail and complexity. And—like wood—metals can age well, acquiring a patina that makes them more attractive than when newly polished—think of the bronze of sculptures, the pewter of mugs, the lead and copper of roofs.

And ceramics or glass? They have a long tradition: think of Greek pottery and Roman glass. They accept almost any color; this and their total resistance to scratching, abrasion, discoloration, and corrosion gives them a certain immortality, threatened only by their brittleness. They are—or were—the materials of great craft-based industries: Venetian glass, Meissen porcelain, and Wedgwood pottery, valued, sometimes, as highly as silver. And ceramic today has an additional association—that of advanced technology: kitchen stove tops, high-pressure/high-temperature valves, space shuttle tiles… materials for extreme conditions.

And, finally, polymers. "A cheap, plastic imitation" used to be a common phrase—and that is a hard reputation to live down. It derives from an early use of plastics, to simulate the color and gloss of Japanese handmade pottery, much valued in Europe. Commodity polymers are cheap. They are easily colored and molded (that is why they are called "plastic"), making imitation easy. Unlike ceramics, their gloss is easily scratched, and their colors fade—they do not age gracefully. You can see where the reputation came from. But is it justified? No other class of material can take on as many characters as polymers: colored, they look like ceramics; printed, they can look like wood or textile; metalized, they look exactly like metal. They can be as transparent as glass or as opaque as lead, as flexible as rubber or as stiff—when reinforced—as aluminum. But despite this chameleon-like behavior they do have a certain personality: they feel warm—much warmer than metal or glass; they are adaptable—that is part of their special character; and they lend themselves, particularly, to brightly colored, lighthearted, even humorous, design.

So there is a character hidden in a material even before it has been made into a recognizable form—a sort of embedded personality, a shy one, not always visible, easily concealed or disguised, but one that, when appropriately manipulated, can contribute to good design. Rob Thompson and Elaine Ng Yan Ling (Chapter 14) develop this theme, exploring, as they put it, some of the most exciting collisions between design, engineering, and materials science. Daniel Schodek and Julian Vincent (Chapters 15 and 17) carry it further with visions of the design opportunities suggested by nature and made possible by nanotechnology. Even more exciting are the developments described by Sybrand van der Zwaag and his coauthors (Chapter 16) of the potential for bringing materials to life, able to sense and actuate like human nerves and muscle, by embedding piezoelectric particles in polymer fibers and fabrics.

How, then, do designers choose their materials? Studies of the ways in which the human brain manipulates information suggest two rather different processes. The first, the domain of the left hemisphere of the brain, utilizes verbal reasoning and mathematical procedures. It moves from the known to the unknown by analysis—an essentially linear, sequential path. The second, the domain of the right hemisphere, utilizes images, both remembered and imagined. It creates the unknown from the known by synthesis—by dissecting, recombining, permuting, and morphing to form new images with new associations. The first way of thinking, the verbal-mathematical, is based on learned rules of grammar and logic. The second way of thinking, the visual, makes greater use of the imagination; it is less structured but allows greater conceptual jumps through free association.

The literature on materials selection suggests a similar pattern. The technical designers' instinct is for methods that are systematic and deterministic. They are trained in mathematical modeling and numerical analysis—they are tools of their trade. As Eddie Norman (Chapter 21) and Luigi De Nardo and Marinella Levi (Chapter 22) discuss, selection via deductive reasoning is now a well-developed route to meeting technical design requirements and powerful software and databases exist to support it. It has great strengths. It is systematic. It is based on a deep ("fundamental") understanding of the underlying phenomena. And it is robust—provided the inputs are precisely defined and the rules on which the modeling is based are sound. This last provision, however, is a serious one. It limits the approach to a subset of well-specified problems and well-established rules. And—as Jonathon Allen points out in Chapter 6—there is more to creative selection than this; there are the deeper aesthetic, cultural, emotional, and social dimensions. There the analytical method breaks down and methods of a different sort are needed. The method of synthesis, by contrast, has its foundations in previous experience and analogy. Here, the inputs are design requirements expressed as a set of features describing intentions, aesthetics, and perceptions. The path to material selection exploits knowledge of other solved problems ("product cases") that have one or more features in common with the new problem, allowing new, potential solutions to be synthesized and tested for their ability to meet the design brief.

There is a risk, in a discussion of this sort, that we lose sight of the human dimension. Owain Pedgley, in Chapter 24, reminds us that product design is essentially user-centered, with emphasis not on the study of materials as such but on the study of people and their relationship with materials. He points out that tools for computer-aided design are highly developed and universally available, but that these tools, so good at guiding the tangible aspects of a design, are as yet incapable of supporting the intangible. Web sites exist that attempt to fill this gap by providing images and brief descriptions of material collections (examples are Material ConneXion,[3] mâtério,[4] and Materia[5]), but these have not entirely succeeded. Research into more innovative approaches continues, exemplified by Ilse van Kesteren's Material

[3] www.materialconnexion.com.
[4] www.materio.com.
[5] www.materia.nl.

Perception tool, Elvin Karana's Meanings of Materials tool, Valentina Rognoli's Expressive-Sensorial Atlas and Hengfeng Zuo's Material-Aesthetic database, described in Pedgley's chapter.

This diversity of approaches carries the risk of isolation. As Kevin Edwards and Eddie Norman (Chapters 20 and 21) suggest, the differing educational paths and resulting cultures of technical and industrial designers can lead to difficulties of communication. Too much can perhaps be made of this point; the extremely successful programs at the Politecnico di Milano, at the Technical University of Delft, and at the Royal College of Art in London, among others, produce designers that are equally comfortable with both the technical and the aesthetic, a point developed further in Chapter 22 by Luigi De Nardo and Marinella Levi and in Chapter 23 by Marc de Vries. Beyond that, the success of design companies and consultancies such as Seymour Powell (London), Industrial Facility (London), Alberto Meda Industrial Design (Milan), Eek & Ruigrok BV (Eindhoven), and Artful (Ankara) impressively demonstrate the integration of technical and industrial design in successful products.

So this is a rich collection, touching on the many different aspects and influences of design, further enriched by face-to-face interviews with successful designers. I hope you will find it as rewarding as I have.

Michael Ashby
Cambridge, UK
March 2013

Preface

Our starting point for contemplating *Materials Experience* was to create a book having a composition that reflects the fundamentals for turning a design idea into a materialized outcome. There has existed for a long time an abundance of materials selection advice for designers. However, we saw that there was a human touch missing from the proceedings: a touch that would uncover not only the complex ways in which materials influence how products are embodied and how they function, but also how they affect people's experiences of products, and the complexity of materials decision making facing the designer. Let us explain a little further.

In reviewing current literature, we came across three types of material-related books used by design educators, students, and professionals. First are inspirational books that use strong imagery to showcase selected materials and their applications, serving as a kind of catalog or reference that can be quickly consulted (e.g., the "Materials for Inspiration" series by Chris Lefteri and the "Transmaterials" series by Blaine Brownell). Second are books dealing with materials selection in mechanical engineering (e.g., Ashby's "Materials Selection in Mechanical Design" and Grover's "Fundamentals of Modern Manufacturing: Materials, Processes, and Systems"). This second group comprises valuable resources on how materials can be chosen to solve technical requirements; however, they understandably do not reach into the area of how materials can be used to help realize a planned user experience. Third are books on materials selection and design, where we see an approach that is something of an integration of the first two book types. In our opinion, there has existed two widely recognized books that can be regarded as seminal texts in the field of materials selection and design falling under this third category: *The Material of Invention* by Ezio Manzini (1986) and *Materials and Design* by Mike Ashby and Kara Johnson (2002). Why did these two books leave such a positive impression on us, and why do we regard them today as still essential reading? Partly, it is the intellectual level that they present. They poke us—as designers or consumers—to think more deeply about relationships we have with the materials of our world. These two books go beyond merely a procedural matching of material properties to performance specifications, into a more troublesome but fascinating arena of personal, social, and cultural perception and experience of materials. The second reason for our fondness of these texts is their positioning within the design field. As editors, each of us has a background in industrial design; we understand firsthand the designer's desire to reach that essential balance between product function and product expression through clever or unusual material choices. We also understand that reaching such a balance requires inspiration, advice, and practical experience.

This prompted us to think deeply about how we could strengthen the materials and design arena with a new book: inspired by the seminal works of Manzini, Ashby, and Johnson, but drawing upon the wealth of new research and topics that have emerged in the last decade. It soon became clear that collectively as editors, although each of us has been active in the materials and design domain for some considerable time and completed our PhDs on the subject matter, the recent expansion of knowledge in the domain has meant that to do justice to such a book we should not work alone. So we set about defining a "wish list" of the most eminent or pioneering academics and designers in the field according to four themes we considered as fundamental to the domain: user experience, sustainability, technology, and selection. We wanted to piece together a web of authors with extraordinarily diverse competences and perspectives. The stipulation was that each author should bring a valuable contribution to explaining why, and in which ways, their field of expertise has influence not only on the materials experiences of end users of products, but also on the materials experiences and selection activities of designers.

We think we have achieved a compilation of critical new essays that provoke us to think more deeply and more widely about the materials we specify for products (as designers) and the materials used in the products that we purchase (as consumers). We have been privileged to secure contributions not only from leading academicians but also from outstanding designers. Collectively, our contributors' willingness to share their material thoughts has been remarkable. The end result is, we believe, truly a treat for our readership of, among others, design educators, design students, design researchers, and professional designers. We sincerely thank all our chapter authors and interviewee designers for their contributions.

This book could also not have been realized without the support of our institutions and staff: the Department of Design Engineering at Delft University of Technology, the Netherlands, in particular Professor Prabhu Kandachar and Professor Jo Geraedts; the Department of Industrial Design at Middle East Technical University, Turkey, in particular Professor Gülay Hasdoğan; and the Department of Chemistry, Materials and Chemical Engineering "G. Natta" at Politecnico di Milano, Italy, in particular Professor Marinella Levi.

We are indebted to Professor Mike Ashby, for so eloquently laying out the materials and design field in his Foreword and preparing our readers for the rich subject coverage they will encounter throughout the book.

Our gratitude is also owed to Steve Merken, Jeff Freeland, and their colleagues at Elsevier, for enthusiastically sharing our vision for this book and for their prompt reactions and great support at every step of the process.

Finally, our special personal thanks go to our beloved partners and families who have encouraged us throughout the book journey: Jaap Rutten, Semra-Erol-Elçin Karana; Bahar Şener-Pedgley (with Jessica and Lucas); and Yunier Virelles (with Ernesto and Camilo).

Editors
March 2013

Introduction to Materials Experience

Elvin Karana,[1] Owain Pedgley[2] and Valentina Rognoli[3]
[1]*Delft University of Technology,* [2]*Middle East Technical University,* [3]*Politecnico di Milano*

If we regard materials as "actors" playing a particular role that designers have assigned to them, as emphasized by Professor Ashby in his Foreword, then we soon begin to understand that some materials are chosen for lead roles in certain applications, while others go unnoticed as essential background actors. Deciding upon the role that a material will play within a product is one of the large challenges faced by designers. It necessarily entails a focus away from designing for product–product interactions toward designing for user–product interactions and consequent experiences. Thus, when a decision is to be made on the materials to be used in a new design, competence is needed in predicting and defining both the experiential qualities and the performance qualities of materials. Within new product development teams, it is the (industrial) designer who usually assumes responsibility to tackle "human factors" in relation to materials selection. In other words, it is the designer's remit to use materials to create particular experiences for people in particular contexts of use: to define the materials experience.

The "materials experience" (Karana et al., 2008a) refers to the experiences that people have with, and through, the materials of a product. That is, to use Desmet and Hekkert's experience framework (2007), a concern not only for aesthetic experiences provided by materials, but also for meanings that materials may evoke, and emotional responses that may originate from materials. In planning for this present book, we must admit that our initial approach was to adopt the definition of "materials experience" originally proposed by Karana in 2008. However, the expression grew conceptually much larger as we started to pool together the work of contributing authors. It became apparent that we should look to the experiences not only of *end users* of materials (through products), as mentioned, but also to the experiences of *designers* who have the initial interactions with those materials. This dual attention reflects the classic demarcation between attending to the *outcomes* of design (as particular material experiences) as well as the *processes* of design. So, with the conceptual groundwork of *materials experience* laid, we continued in our quest to define what a "designerly" perspective on material properties, materials selection and material discourse more generally would entail. We reflected on the question, "what are (and will be) the key issues affecting designers' material choices for the creation of intended user experiences?"

Manzini in his well-known work, *The Material of Invention* (1986), talked about designerly competences in materials selection, aesthetics of materials and the role of materials in shaping positive user experiences. The materials of products are often a way to lure people's initial attention, while in the longer term they can define a lasting positive or negative experience. We can be captivated by materials and

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inspired by their application; we can take great pleasure in their existence or we can be extremely put off. Thus, our internal material dialogues can be exposed to reveal ways in which materials draw us into a product or push us away. We interact with materials via our five senses. We pet the smooth surface of a ceramic vase, we tap on a wooden box and hear the vibrant sound, we watch the water drops on a glass window, we smell a new leather case, and so forth. These material–user interactions are modulated in time, across cultures and individuals, and in different contexts of use. Designers have a responsibility to consider each of these variables when taking material decisions.

The topic of materials experience has taken some time to come to prominence. As most of our readers will recognize, Ashby and Johnson (2002) made a considerable impact in the domain of materials and design. Their work helped make materials selection activities more transparent, more manageable, and more inspiring for product designers. They were the first authors we came by, who treated in an intellectual and in-depth manner the significance of the aesthetic attributes of materials for a proper materials selection in product design. Besides the general, technical, and ecoattributes, they added aesthetic attributes of materials into the material properties list for designers. In their definition, aesthetic attributes originate from the sensorial properties of materials, such as warmth, softness, appearance, and so forth. Additionally, Ashby and Johnson reinforced the two overlapping roles that materials play in product design: providing technical functionality while creating product personality. Accordingly, they pointed out that intangible issues such as perceptions and intentions (of the designer) should take a role in the materials selection activity for products. Since the publication of Ashby and Johnson's book, the number of research studies concerning material interactions and product design (covering sensorial properties, attribution of meanings, and elicitation of emotions) has grown considerably. Important contributions have been made by, for example, Zuo et al. (2001), Rognoli (2004), Miodownik (2007), Karana et al. (2009), Van Kesteren (2008), Rognoli (2010), and Karana (2009).

In a study conducted prior to the emergence of "materials experience" (Karana et al., 2008b), a review was made of pioneer books concerned with materials selection. The review covered both industrial design and mechanical design, and included books published between 1967 and 2005. We were able to track the variety of topics and emerging issues throughout the years, one of which was "sustainability". Interestingly, in most of the pre-1996 sources, environmental (and later on "sustainability") issues were placed at the bottom of listed material requirements for designers and engineers to take into account. However, only a few years later, Mangonon (1999) organized material selection factors under three main topics: property profile, processing profile, and environmental profile. He emphasized that selection based on an environmental profile covers multiple impacts of a material: its inherent properties, its manufacture, its use, its reuse, and its disposal. Today, we see these collective impacts under the wider umbrella of sustainability, with their recommended consideration moved considerably further up from the bottom of materials selection criteria.

In parallel to the concerns of sustainability, technological advancement of materials, for example, having superior properties such as conductivity, sensing, thermal stability, and mechanical resistance, as well as significant improvements in additive manufacturing, has been essential for product development and has affected designers' material decisions. These technological developments inevitably influence (or will influence) how we—as users—experience materials, and how we—as designers—create materials experiences. Manzini (1986) emphasized that technologies in the mid-1980s were radically altering the meanings that once endowed materials with cultural and physical depth. Having witnessed three further decades of technological development, there can be no doubt that our everyday experiences of materials are more diverse than ever, and that the designer's opportunity to build meanings into products through materials is wider but more complex.

If we survey the field of materials and design in 2013, we can see exciting new developments in relation to the fundamental issues, which for the purposes of this book we have collated under three themes: "Touched by Materials" (user experience), "Living with Materials" (sustainability), and "Futures through Materials" (technology). Some of the captivating developments under these three issues are the emergence of evidence-based materials selection for product personality and expression; the functional opportunities of nanotechnologies; the imperative to consume less material, use existing resources more wisely, and design for graceful aging; and the increasing discretion and knowledge of end users seeking pleasurable and memorable experiences from products. These fundamental issues are shaping, and will continue to shape, our future materiality. Our fourth and final book theme, "Proficiency in Materials" (selection), is essentially transitory—referring to the practical issue of choosing one material over another, gaining the basic necessary grounding to make sound material decisions, while taking into account the influence of issues arising from the preceding three themes.

In Section 1, Touched by Materials, we focus on the fundamentals of user experience, that is, how people approach to materials, how they sense them, how they attribute meanings to them, and how they love or hate them. Pioneers in the domain offer chapters on the role of materials in product experience, sensory pleasure, multisensory approaches that bring about positive (or negative) materials experience, universal and cultural meanings in relation to material aesthetics, sensoaesthetics of materials focusing on sound and taste, and different (cultural) design approaches in transferring material meanings. The last chapter of this section, with its particular focus on ethical issues in material decisions concerning our future of living, serves as a bridge to the next section, Living with Materials.

In Section 2, Living with Materials, we present contributions that discuss materials and design in relation to sustainability. The section covers the roles of materials in achieving social sustainability, "emotionally" durable design, and alternative design approaches including designing with waste and design for imperfection and graceful aging. The last chapter of this section presents a number of novel multipurpose materials with good environmental credentials and brings us to the next section, where we discuss novel approaches and technologies in the materials and design world.

Section 3, Futures through Materials, brings together chapters concerned with technological developments in materials and manufacturing. Fundamental "technology-driven" issues discussed in the materials and design domain are covered, alongside their effects on our daily experiences with materials and products. Lightweight design, for example, presents a new approach to design thinking and the selection of materials and shaping processes. The design potential of new generations of smart, reactive, and multipurpose materials are discussed, as are nanomaterials and bioinspired materials (biomimetics).

The chapters under these three themes are heavily intertwined, thus it was in some cases challenging to place a particular chapter under a particular theme—essentially reinforcing the point that the three themes fundamentally affect each other, designers' material choices, and ultimately our materials experiences. The integral consideration of user experience, sustainability, and technology is essential for teaching and practicing materials selection and design. Accordingly, in Section 4, Proficiency in Materials, we present contributions concerned with the practical task of choosing one material over another. The chapters include diverse topics including balancing functionality and expression through materials, ways of learning about material properties, and the development of new experiential-based materials selection tools and methods that can complement well-established technical-based selection.

In between the four main sections of *Materials Experience* you will find the results of interviews with eight internationally renowned designers from the countries we as editors are associated with (Italy, the Netherlands, Turkey, and the United Kingdom). Each designer communicates a material dialogue in relation to the processes and outcomes of their design activity. In other words, these invited designers kindly divulged their thoughts on how they go about selecting materials, the influence of the book themes on their work, and the anticipated materials experience of the end users to whom they are targeting their created products. Within these material dialogues it is easy to detect the high regard that designers have for careful material use. All the subjects covered in *Materials Experience* collide in the designers' studios and workshops.

Having immersed ourselves in the chapters and interviews contained in *Materials Experience*, we indulged ourselves somewhat and asked "what would be *our* choices to present herein, as remarkable cases of materials experience, focusing on one or more of the book themes?" We selected six product examples to share with our readers, as a taster for the kinds of keywords and discussions that permeate throughout the book. For each of the six products, there could easily be another six, and then another six. But we included some personal favorites to illustrate in a very direct way the subjectivity of material appraisals and the very personal nature of materials experience.

Valentina's first example is the "Frida" chair by Odoardo Fioravanti (Figure 1).

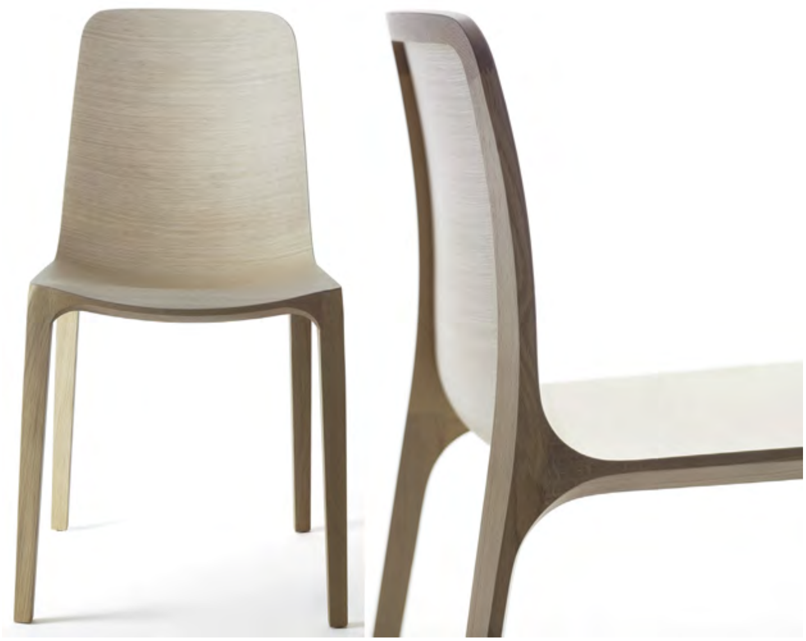


FIGURE 1 "Frida" chair by Odoardo Fioravanti for Pedrali, 2008 (www.pedrali.it). *Photo by Leo Torri.*

It is a traditional material (oak and plywood), which is embodied in an unconventional design with a very thin structure and a strong resistance. The thin plywood shell is shaped using 3D veneered technology. The designer has used a new veneering technique that allows the creation of challenging shapes with thin surfaces. This is the very first chair made that marries this kind of thin veneer with a solid wood structure. It is a good example of how a new 'technology' (in this case a manufacturing technology) triggers a unique material experience. It is elegant, simple, and a sculptural beauty – and also extremely lightweight at only 2.7 kg.

Valentina's second example is the "Biscuit" table, with which the designer Patricia Urquiola earned the best marble designer award in 2010 (Figure 2).

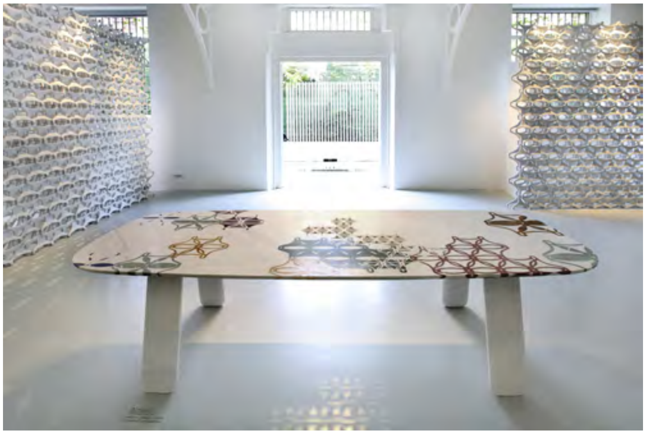


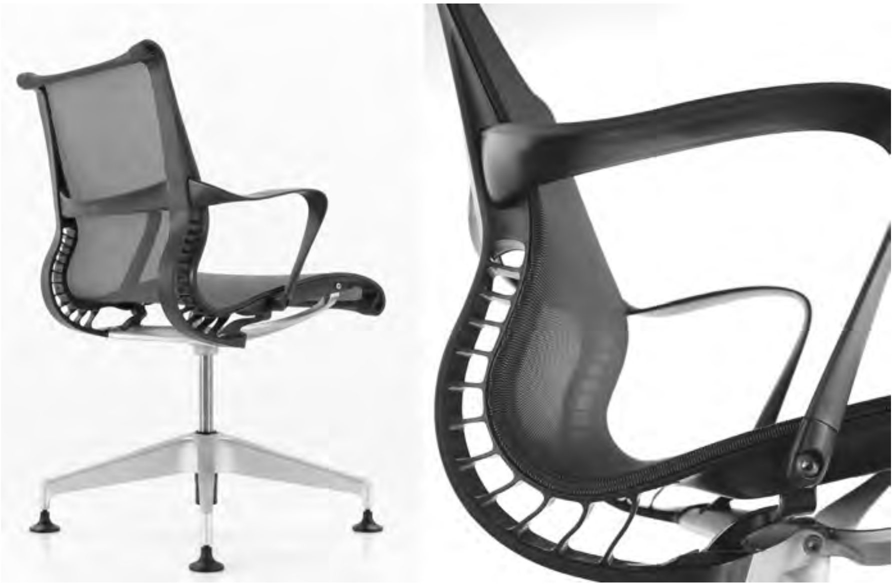
FIGURE 2 "Biscuit" table by Patricia Urquiola for Budri, 2010 (www.budri.com).

It is produced from a very well-known material, marble, but in a very innovative way to create a unique sensory experience, especially to gratify vision. The designer has played with transparency, to create a translucent material rather than be satisfied with a conventional opaque appearance. This is quite a surprise to anyone who interacts with the table.

Elvin's first example is the "Setu" chair designed by "Studio 7.5" from Germany for Herman Miller (Figure 3).

Setu is an example of how materials embark upon—or even create—an excellent user experience when they are considered thoroughly alongside process-shape-function and use. The materials used are not extravagant, for example polypropylene – a commodity thermoplastic – is used for the spine. However, the kinematic function of the spine works properly because of the mechanical properties of polypropylene. When you sit on the chair, the textile material touches you elegantly, softly; it envelops you gently. And the alloy base of the chair makes a great contrast with the light feather feeling of the seat: robust and durable. The designers have taken the principle of 'honesty

FIGURE 3 Setu Multi-purpose Chair by Herman Miller (www.hermanmiller.com).

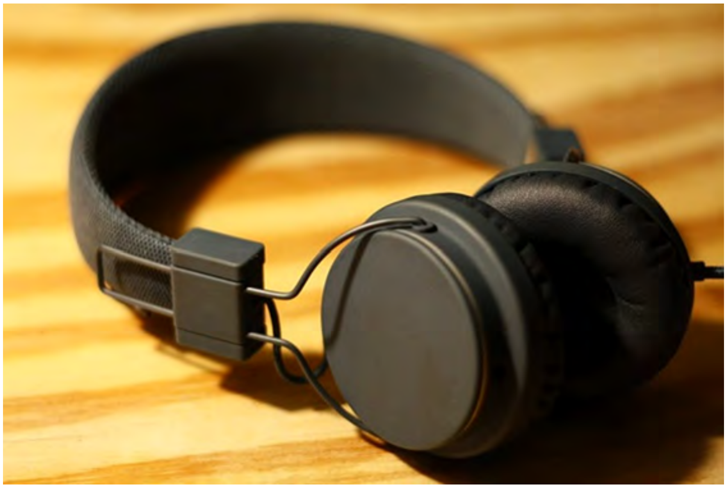


in materials' as a key component in their design, avoiding the use of any kind of toxic coatings. Setu is 93% recyclable. The final result is environmentally sensitive, elegant, and truly comfortable: a life-long chair with a well-considered material-shape-process combination.

The second example of Elvin is the "Plattan" headphones by Urbanears (Figure 4).

This product exemplifies the combination of multiple materials in a sensible way, which is a great challenge for industrial designers. As a company, Urbanears aims to create headphones that are experienced rather like clothes, with a combination of utility and semantics heavily influenced by

FIGURE 4 "Plattan" headphones by Urbanears. © *2013 Jaap Rutten.*



material choices. Material combinations are a main characteristic of the product: they select velvet-like plastics that are complementary to the soft leather cushioning and textile 'heading'. Another challenge is that each of the different materials has the same colour, yet the product still appears balanced and of high quality.

Owain's first example is the "Stretch" pot stand by Joseph Joseph (Figure 5).

This handy kitchen utensil is a great application of co-injection moulding. A rigid thermoplastic core provides the structure, while a thermoplastic elastomer is used on the outer surfaces for its high temperature resistance and non-slip properties. As a collapsible lattice with fluorescent coloring and rubberized texture, 'Stretch' is irresistible to interact with! It is also functionally superb – able to support very small pots through to large baking trays.

The second example of Owain is the "RA1" acoustic guitar by Rob Armstrong, developed in collaboration with Cool Acoustics (Figure 6).

I have been privileged to work with some great guitar makers during my involvement with the Cool Acoustics project to develop technology and know-how for instruments made from synthetic alternatives to spruce, cedar, mahogany etc. This particular prototype, constructed mostly from foamed polycarbonate and plywood, emphatically defies people's reservations about plastics and musical instruments. It sounds stunning and plays beautifully. In blind tests people can't tell it apart from an expensive wooden guitar. If one of the designer's responsibilities is to push product design, innovation and differentiation through materials, then I think this product is a perfect example.

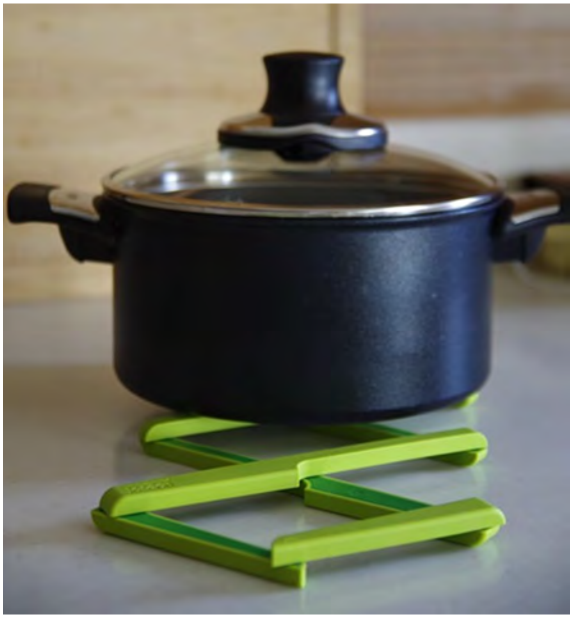


FIGURE 5
"Stretch" pot stand by Joseph Joseph. © *2013 Owain Pedgley.*

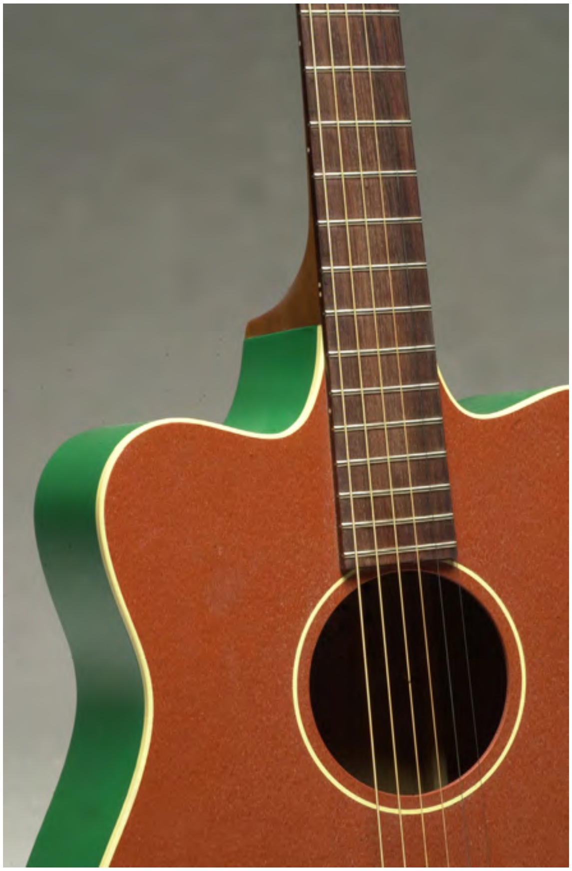


FIGURE 6
"RA1" acoustic guitar by Rob Armstrong/Cool Acoustics. © *2003 Cool Acoustics.*

So much has been done and discussed in the materials and design domain in the last decade, some of which has found its place in design practice and design education, while some has yet to come to the fore and remains at a level of noteworthy points to be considered for the future of our society and material possessions. We aim to present a panorama of completed works and on-going discussions that are shaping, and will continue to shape, our materiality, our selection of materials, our understanding of products, and our materials experience. What has occupied the materials and design domain in the last decade that should be transferred to design education and to the professional practice of design?

In conclusion, our hope is that on reading *Materials Experience* you will be left challenged yet energized to bring a principally human-centered perspective to the materials decisions you take in future design projects, or to the materials and design curricula you may develop for future generations of designers, or to the appraisals you make when encountering new products.

Now, go experience!

References

Ashby, M., Johnson, K., 2002. Materials and Design: The Art and Science of Material Selection in Product Design. Butterworth–Heinemann.

Desmet, P.M.A., Hekkert, P.P.M., 2007. Framework of product experience. International Journal of Design 1 (1), 57–66.

Karana, E., Hekkert, P., Kandachar, P., 2008a. Materials experience: descriptive categories in material appraisals. In: International Conference on Tools and Methods in Competitive Engineering 2008. Izmir, Turkey.

Karana, E., Hekkert, P., Kandachar, P., 2008b. Material consideration in product design: a survey on crucial material aspects used by product designers. Materials and Design 6 (29), 1081–1089.

Karana, E., 2009. Meanings of materials, Ph.D. Thesis. Design Engineering, Delft; 2009. ISBN: 9789051550559, TU Delft.

Karana, E., Hekkert, P., Kandachar, P., 2009. Meanings of materials through sensorial properties and manufacturing processes. Materials and Design 30 (7), 2778–2784.

Mangonon, P.L., 1999. The Principles of Material Selection for Engineering Design. Prentice Hall, New Jersey, 430–435.

Manzini, E., 1986. The Material of Invention. Arcadia Edizioni, Milano.

Miodownik, M., 2007. Toward designing new sensoaesthetic materials. Journal of Pure and Applied Chemistry 79 (10), 1635–1641.

Rognoli, V., 2004. Materials for Design: An Expressive Sensorial Atlas. Unpublished Ph.D. Dissertation, School of Design, Politecnico di Milano, Italy.

Rognoli, V., 2010. A broad survey on expressive-sensorial characterization of materials for design education. METU Journal of the Faculty of Architecture 27, 287–300.

Van Kesteren, I.E.H., 2008. Product designers' information needs in materials selection. Materials and Design 29, 133–145.

Zuo, H., Hope, T., Castle, P., Jones, M., 2001. An investigation into the sensory properties of materials. In: Proceeding of 2nd International Conference on Affective Human Factors Design, London, pp. 500–507.

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SECTION 1

Touched by Materials

This section focuses on user–material interactions and the experiences that result from those interactions. The contributing authors explore how people approach to materials, how they sense them, how they attribute meanings to them, and how they build deeper relationships with them.

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Designing Material Experience

Paul Hekkert and Elvin Karana
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CONTENTS

> More than half of the world's population lives in city centres. This is putting an increasingly heavy burden on traditional means of inner city transport. We believe this asks for a new and fresh approach to inner city mobility. We are a young ambitious Dutch company that originated out of love for bicycles and hunger for change.
>
> At VANMOOF we pursue only one goal: help the ambitious city dweller worldwide move around town fast, confident and in style. We stripped the traditional Dutch bike from redundant hoo-ha, that can only break or frustrate, and added sensibility instead. The result? Simplistic striking bikes so smooth that they fit your style demands, yet so functional they make you go to work whistling. The no-nonsense VANMOOF bike is the ultimate urban commuter tool, anywhere around the globe. Be aware "cause we shake the unshakable"!

Both quotes are taken from the Web site of Van Moof (2012), a Dutch bike manufacturer. The first quote describes the future world of biking, as seen by the company, and the second, Van Moof's brand identity. Together they shape the context underlying the design (the "why") that boils down to the fictitious (mission) statement: "VANMOOF wants to fuel the ambition of commuters and make them 'go to work whistling'".

In the second quote, this goal is translated into an intended user experience (the "how") and the qualities of a subsequent bike design (the "what"; Hekkert and van Dijk, 2011). At the user experience

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level, the level that follows immediately from the context, the company promises to make you move around town *fast*, *confident* and *in style*. These qualities describe the interaction between a (future) user and the to-be-designed bike; they indicate how users will (or should) experience the bike. From these interaction qualities, the product qualities can be derived. In order to facilitate fast, stylish, and confident driving, the bike has to be nonredundant, simple, sensible, smooth, and no-nonsense.

This short example of experience-driven design by following a why—how—what model makes perfect sense and allows a designer to define up front what the product must do and express (what) in order to attain a desired user or product experience (how). Both are firmly rooted in a (future) world, a world that is viewed and shaped by the designer in order to decide what experiential and/or behavioral effects the product will have on people (why).

Now that a vision on the new bike is defined, the next design stage can take place: how to implement these product and interaction qualities in the design of a bike. The quoted paragraphs only suggest removing all nonessentials from a normal bike, a step toward this goal—"we stripped the traditional Dutch bike from redundant hoo-ha". But if we look carefully at the result, the VANMOOF bike (Figure 1.1), we could identify some further design decisions that support the intended user experience in the indicated way.

The bike has no visible extras; it looks very simple and basic. Its aluminum color adds to the impression of smoothness and no-nonsense. Significantly, and giving the bike its distinctive, stylish look, the lights are integrated in the top tube, in such a way that they allow for confident riding in the dark. The bikes are equipped with a Dutch-style kickback brake, further adding to the clean outlook. With so little visual noise and bulb, the bike affords fast and confident driving. The thick wide wheels make riding on and off pavements and obstacles problem free. The broad handlebar and durable Schwalbe tires top-off the smooth no-nonsense look. Maybe most importantly, the VANMOOF has a striking aluminum rust-free frame, a lightweight material that facilitates speedy riding.

From this brief analysis, we can see that the intended user experience has consequences for the product's technology (e.g., in-built lighting), form (e.g., top tube), color, and material selection: the material of the frame, tires, and brakes all significantly contribute to a fast, stylish, and confident driving experience. Apparently and intuitively, the VANMOOF designers did the right thing and materialized the

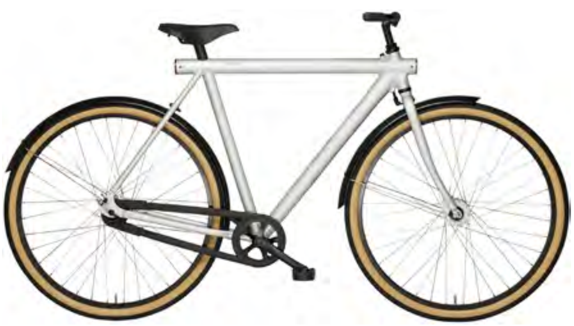

FIGURE 1.1
Standard VANMOOF bike. *Courtesy of VANMOOF.*

intended experience. To make such a process more deliberate, the question that will be addressed in the remainder of this chapter is "Can we design a material experience?"

FROM PRODUCT TO MATERIAL EXPERIENCE

Over the past years, we have seen a steady stream of publications reporting ways to capture and analyze "user experience" (e.g., Hassenzahl, 2011; Law et al., 2009) or "product experience" (e.g., Desmet and Hekkert, 2007; Schifferstein and Hekkert, 2008). Despite failed attempts to adequately define the two concepts, both refer to a similar phenomenon and their advocates seem to agree on the following characteristics:

1. *Experiences are inherently subjective*. Experiences take place in (the mind and heart of) the user and only he or she has access to the felt quality of this experience. This does not automatically imply that the user can always correctly recall and/or report experiences. Experiences are notoriously difficult to verbalize. Even more difficult for users is to correctly identify where experiences come from and what their causes are (e.g., Wilson, 2002). For that reason, we have seen an accumulation of sophisticated methods to capture and scrutinize experiences (e.g., experience sampling, Larson and Csikszentmihalyi, 1983; Day Reconstruction Method (DRM), Kahneman et al., 2004).
2. *Product (or user) experiences arise in interaction with a product.* By definition, product experiences refer to those experiences that are evoked by interacting with a product. They may result from actual use (hence, user experience), but could also be evoked by simply anticipating usage or thinking about a product (see Desmet and Hekkert, 2007). The product, with all of its properties, thus plays a main part in this process. When the product is an interactive device, we typically speak of user experiences.
3. *Experiences are affected by personal and situational factors.* Because of their subjective nature, experiences are determined by the mind(set) of the user, his or her goals, expectations, dreams, and desires. Also, experiences are heavily influenced by the context of use. That glass of Raki on the sunlit terrace during a holiday in Turkey tastes completely different from a similar glass 2 weeks later at home in the gray and cold Netherlands.
4. *Experiences develop or change over time.* During the episode of using a product—say, making a cup of espresso with your new machine—the experience will not be constant and similar over the full 45 s (e.g., Laurans et al., 2012). Product properties you are dealing with change over time, and so may your mood or expectations in response to the product. Accordingly, experiences may easily differ at different moments of use over time (e.g., Karapanos et al., 2010).

Types of experience

We may feel confident on our bike, astonished over the power of our new laptop, relieved to see the old record player still works, get frightened by the smoke coming out of our toaster, and proud to own a Tag Heuer watch. Product experiences come in many kinds and types. Some experiences are pleasant and companies (should) certainly make an effort to design for these and avoid unpleasant ones (Jordan, 2000). Or should they? Recently, design researchers have started to explore the relative benefit of unpleasant experiences in achieving our goals (e.g., Fokkinga and Desmet, 2012). Some talk of sensory experiences and, thereby, implicitly suggest that other experiences do not require sense perception, but may be merely cognitive.

The, so far, most sensible—admittedly, we are biased—distinction as to different types of experiences was proposed by us (Desmet and Hekkert, 2007; Schifferstein and Hekkert, 2008). It is defendable to speak of an aesthetic experience, an experience of meaning, and an emotional experience. Where the aesthetic experience involves the degree to which an object delights our senses, an emotional experience arises from goal attainment (e.g., happy) or violation (e.g., sad). The experience of meaning is all about attributing characteristics to objects, such as smooth, usable, or feminine. These three types of experience often appear as three components of a single experience, and may therefore be hard to separate while actually engaged in the experience. Moreover, they are clearly related and affect each other's quality (e.g., Desmet and Hekkert, 2007). Nevertheless, as to their underlying process, they can be conceptually separated.

Next, we will explain more in depth the underlying processes that result in each of the three types of experience. These processes not only explain why (and when) we have a particular experience, they also predict when such experiences are most likely to be universal—everybody will pretty much have the same experience—and when (groups of) people, such as different cultures, will have different experiences. It is our firm belief that one can only meaningfully talk about cultural or individual differences when one understands the psychological mechanism that is rooted in human nature and that may (occasionally) lead to universal agreement. Although the mechanisms are—obviously—generic and not specific for our interaction with objects, we will limit ourselves as much as possible to the way materials and material properties can lead to these experiences. When considering material experiences, we believe "the experience of meaning" is the most relevant category and this type of meaning will therefore be treated more extensively in Section Meanings of Materials.

Material aesthetics

Elsewhere, we have argued that there are good reasons to restrict the term aesthetic to the *pleasure attained from sensory perception* (Hekkert, 2006; Hekkert and Leder, 2008). Defined in this way, anything can be appreciated aesthetically, an artwork, a product, a landscape, an event, or even an idea. Needless to stress, materials can also be aesthetically pleasing.

Crucial to understanding why we like to see or touch something is to look at the evolutionary benefit of liking something (see Hekkert, 2006; Ramachandran and Hirstein, 1999, for similar views). Simply put, we like to look at (or feel, or listen to) things that are good for us. The main task of our sensory systems, including our brain, is to make sense of the world, to identify things, to navigate around, in sum, to create order in a chaotic environment. For that reason, we have "learned" to aesthetically appreciate those features, cues, or patterns that facilitate these functions.

Various aesthetic principles can be derived from this line of thought (see Hekkert, 2006) and we will now briefly discuss two of these and apply them to material aesthetics. First, we like to invest a minimal amount of means, such as effort, resources, or brain capacity, to attain the highest possible effect, in terms of survival, learning, or explaining: the principle of maximum effect for minimum means. From this, it could easily be predicted that products should minimize the amount of material used, while preserving the effect aimed for. Waste of material is not only undesirable from a sustainability point of view.

A second aesthetic principle that may affect material selection is the principle of most advanced, yet acceptable (Hekkert et al., 2003). People prefer products that are on the one hand maximally novel while being as familiar as possible. While the latter is most easily achieved by sticking to a well-known shape, novelty could very well be attained by a new material application (see, for example, "Soft Vase" by Hella Jongerius elsewhere in this book). Note that this novelty is a subjective and a relative assessment. First, what is regarded as novel depends, for instance, on your previous experiences with similar products and/or materials. Second, the material may be very novel for the product at hand, e.g., cork applied in an interactive device, but not in an absolute sense. Correspondingly, if you decide on a very novel shape, you may be well advised—from an aesthetic point of view—to stick to a familiar material for the product category.

Emotions to materials

There is wide consensus that an appraisal model most accurately describes the process underlying our emotional response (e.g., Frijda, 1986; Scherer et al., 2001; Ortony et al., 1988), also to products (Desmet, 2008). According to these appraisal theorists, an emotion is elicited by an evaluation (appraisal) of an event or situation as potentially beneficial or harmful to a person's concerns. For example, on seeing the new Renault Dezir, a person is expected to experience desire because it feeds his or her concern of being admired. An important implication of appraisal theory is that it is the interpretation of the object, rather than the object itself, which causes the emotion. Only when people share this interpretation and have the same concern, people will experience a similar emotion: we all experience fear when a gun is pointed at our head since we all interpret a gun as life threatening and share the concern of staying alive. Often, however, people differ as to the concerns they bring into a situation and interpret products very differently.

Just as a product, materials can also evoke emotions. One can be fascinated by the strength of a carbon fiber composite in a chair with an extremely thin surface thickness (Figure 1.2). One can also be disappointed over the easily scratched surface of a polypropylene lunch box or feel disgust toward the greasy touch of a rubber handle (Sonneveld, 2007). An interesting emotion to evoke by materials is surprise. Materials can be surprisingly light or heavy, smooth or rough, warm or cold, relative to

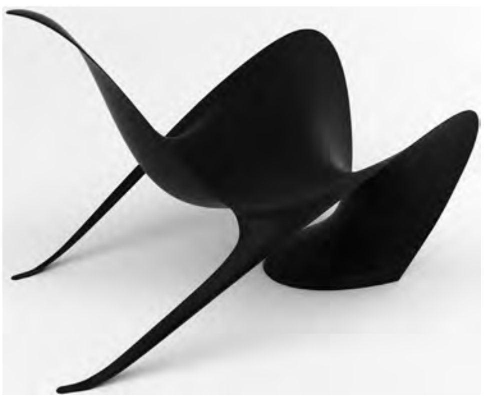

FIGURE 1.2
Manta chair made of carbon fiber, by Robby Cantarutti. *Courtesy of Mast Elements.*

previous encounters or expectations built upon visual inspection (see Ludden et al., 2008, 2009). As a result, the user is surprised to touch or lift the product and when this experience (of lightness, for example) is better or more appropriate then expected, a positive emotion such as relief, amusement, or happiness is to follow.

MEANINGS OF MATERIALS

We often and easily ascribe a character or meaning to a product and its material: these sneakers look *cool*, this glass is *fragile*, this plastic cover feels *artificial*, and this car seat is very *comfortable*. Just by looking at these examples, there are a couple of interesting observations to make. First, it is often very difficult to separate the meaning of a material from the meaning of the product in which the material is embedded. Are the sneakers cool because of the material used or despite its material? And is the material considered cool because of the sneakers? Second, product and material meanings are rooted in our sensory perception. The sneakers *look* cool and the plastic cover *feels* artificial.

The second observation also brings us to the third, and most important one: strictly speaking, materials do not possess a meaning (Hekkert and van Dijk, 2011). Just like our emotions and aesthetic responses, material or product meanings arise in interaction and are context sensitive (Karana, 2009; Karana et al., 2010). Although some material meanings may *appear* as a property or can be colloquially considered an intrinsic character of a material (e.g., wood is warm), and we will argue in Section Universal meanings why this is, they in fact are not. Meanings are attributes or labels, qualities assigned to products and materials and, theoretically, any material can inherit any meaning in a particular context. Nevertheless, there are patterns or regularities in material-meaning relationships (Karana and Hekkert, 2010). A material, for instance, may express professionalism when it is smooth and dark (colored), when it is used in an office environment and when certain technical properties are combined for enhancing its function (e.g., combining strength and lightness). Such material-meaning associations may be near universal because they are rooted in sensorimotor experiences (Section Universal meanings) or they result from learned conventions (Section Learned meanings) leading to less "stable" relationships and cultural/individual diversity.

Universal meanings

Some figurative qualities are attributed to things, and presumably materials, by means of embodied metaphors or "embodied projection" (cf. Van Rompay, 2008, for an overview). This process refers to theorizing in the field of cognitive science about the role of our body in understanding our world, and the concepts we have invented to describe our interaction with it. Warm temperatures are more pleasant than cold ones and so we see *a warm person* (or thing) as more *inviting* and *open*. If things get uncomfortably hot we tend to sense tension, as in *a heated debate*. Similarly, when someone is *down*, the expression refers to being emotionally *low*, and we are mentally *unstable* when we are psychologically *out of balance*. As many scholars in cognitive linguistics and embodied cognition have shown (e.g., Gibbs, 2006; Johnson, 2007; Lakoff and Johnson, 1980; Pinker, 2007), these spatial-relational references rooted in bodily experience are omnipresent in our daily language and concept formation. As we have shown elsewhere, they also allow us to explain and design the expressive character of objects (Van Rompay et al., 2005).

From this, we could easily predict why some materials appear to have designated, embodied meanings. Wood is literally warm to the touch and therefore perceived as *inviting* and *cozy*, whereas stone or steel are generally cold to the touch and thus tend to be perceived as more *distant*. These latter materials are, on the other hand, relatively heavy and would for that reason also be regarded as *high quality*. Similarly, light materials have a tendency to be considered *cheap*. Next, when a material is rough, people will perceive it as more *natural* than when it is smooth, and transparent materials are most likely, or should we say naturally, seen as *fragile*. Finally, soft materials are mostly regarded as being *alive* where hard materials are considered *dead*. Such material-meaning associations are, by their sensorimotor nature, very robust and persistent and not very sensitive to cultural or individual differences. Yet, for many new materials, with a much shorter history than, for example, wood or steel, the meanings still have to be learned. Also, some "cultural" meanings, which are not rooted in sensorimotor experience, such as "toylike", "modern", or "cool", must be learned through the kind of associative processes that will be discussed next.

Learned meanings

When a material is frequently used in a certain context, it becomes associated with particular meanings that are, for whatever reasons, dominant in that context. These meanings may, over time, act as if they are intrinsic characteristics of that material. Although ceramics may univocally be considered of *high quality* because of that material's rigidity and weight (see Section Universal meanings), its frequent use in expensive, long-lasting dinnerware, for instance, has certainly reinforced the attribution of this meaning to this material. Likewise, a leather and plywood combination in home/office furniture—which dominated the 1950s' lounge chair designs (e.g., Eames' Lounge chair & Ottoman)—is (still) appraised as *elegant*, *rich*, and *businesslike*. We have learned to attach these meanings to these materials, and one can dispute the extent to which intrinsic properties are responsible or whether the attribution is more or less arbitrary.

Hekkert and van Dijk (2011) emphasize that the user-product relationship is part of a larger context that consists of all kinds of factors, e.g., social patterns, technological possibilities, and cultural expressions, which affect the way people perceive, use, experience, respond, and relate to products. The effects of these contextual factors on the interaction are mediated by the concerns of the user in terms of goals ("what we want"), standards ("how we believe things ought to be"), or taste ("what we like") (Ortony et al., 1988). For example, Cleminshaw (1989) in his book *Design in Plastics* quoted Kenji Ekuan, a famous Japanese industrial designer, who explained that Japanese people had so entirely based their sensitivities upon the transience of time that they even project this approach on every aspect of their life, including materials. So, they not only feel uncomfortable with, but they even hold a horror of plastics that deny death.

Many material-meaning associations are learned within societies based mainly on the frequent use of a material in a particular context, its ease of formability, its utility function, etc., such that there will inevitably be variations in material-meaning associations between cultures. The results of a study conducted with Turkish participants revealed metal to be regarded as formal and less domestic compared to wood and ceramics (Karana, 2004). The Turkish participants associated metal with factory environments and mass production explaining that they would not choose metal for their kitchen interiors. In another study where we compared Chinese and Dutch people (Karana and Hekkert, 2010) in terms of their appreciation of plastic and metal products, we could show that these two cultures show significant differences in their valuation of metal and plastic products. Contrary to the Dutch participants, the Chinese valued plastic products more than metal ones by explaining that plastic is "more attractive" and "elegant". There might be a number of motivations behind their appraisals. For instance, one might explain this by the fact that people from Asian cultures are generally fond of natural and organic forms, which are mainly associated with plastics. It may also be partly explained by an expanding number of plastic products in Asian markets, which make Asian people more familiar with this material family. These various cultural studies underline how material selection across worldwide markets must be treated sensitively, and how difficult it can be to reach a single definable "global material experience" from a product.

How meanings change

Improvements in manufacturing technologies and materials science have stimulated new materials and forms in product design. An example is the Plopp stool, designed by Oscar Zieta. It is composed of two ultrathin steel plates cut into the desired shape and welded around the edges. Then air under high pressure is shot into the unit causing an expansion into the desired form. This results in a surprising material-form match that is not common to see in metal products. It looks soft and warm from a distance—just like a vinyl inflatable toy—but is found to be hard and cold when touched. The metal of the Plopp stool can certainly be evaluated as friendly and cozy, maybe even toylike, which are different meanings than those traditionally assigned to metal (i.e., cold, aloof, etc.).

Another example is the changing image of plastics in time. Many new kinds of plastics have emerged in the last decade. Each has different properties and is used in a variety of products. When plastics first emerged, they stood for cheapness, low quality, and inauthenticity (Sparke, 1990) and their tactile experience was generally unsatisfactory for people (Walker, 1989). They were toxic and perceived as not appropriate for hygienic uses. Now plastics are widely used in countless high-quality products, and are prevalent even in medical appliances requiring nontoxicity and outstanding hygiene. A recent design from Lana Agiyan perfectly illustrates this altered status of plastics. It is a vacuum-thermoformed and blow-molded acrylic baby cradle: Bubble Baby (Figure 1.3). The following is a quote from the Design42Day Web site (Design42Day, 2012) on how the materials of the product are described:

> One of the most fascinating features of the cradle is its innovative nano tech coating, which was developed together with an Estonian factory and prevents the plastic from potential scratches. Due to the treated surface, the crib obtains improved optical transparency, repels dirt and can be cleaned easily just by using a dry piece of old cloth without the use of chemical detergents. Due to the photocatalytic effect of the nano particles of titanium dioxide, contained in the liquid polymer base, the coating degrades dirt as well as air pollution when it is exposed to sunlight. In other words, strong light starts the ionization effect and therefore acts self-cleaning and at the same time "heals" potential unhygienic scratches. The coating is absolutely safe for children, eco-friendly and even certified for the EU.

This example shows how advanced material technologies change the application of a certain material for particular domains. Plastics, yesterday's toxic material, are today applied to baby cradles for being an extremely hygienic, safe, and self-cleaning material.

FIGURE 1.3
Bubble Baby, by Lana Agiyan. *Courtesy of Lana Agiyan, photo by Eugen Zahoroshko.*

In brief, some meanings tied to a material have loosened because of technological advances. Histories of materials are shifting. The meanings attributed to plastics in 20 years by someone whose first experience with plastics will be through his/her Bubble Baby will certainly be different from what plastics mean to those of us still in possession of a Bakelite radio.

DESIGNING MATERIAL EXPERIENCE

We ended the first section with the main question driving this chapter: can we design a material experience? If the experience we aim for can rely on universal patterns, it is obvious we can. For example, it is safe to predict that everyone will perceive the lightweight VANMOOF bike as *flexible* and its smooth surface as relatively *clean*. These qualities will probably even hold when we change the context, and apply the same material properties in the design of another product, such as a baby stroller. Other (components of the) experiences, however, are more prone to cultural or individual differences as to learned traditions, background, and personal concerns. Here, designers could rely on segmentation; the VANMOOF bike may look cool to Western commuters, but not to Indian farmers. Also, the product and the communication around it, i.e., marketing, can help to bring people into the right mind-set, to ensure they look at the product similarly, and have the same expectations and background knowledge.

References

Cleminshaw, D., 1989. Design in Plastics. Rockport, MA.

Design42Day, 2012. http://www.design42day.com/2012/07/baby-bubble-bed/.

Desmet, P.M.A., 2008. Product emotion. In: Schifferstein, H.N.J., Hekkert, P. (Eds.), Product Experience. Elsevier, Amsterdam, pp. 379–397.

Desmet, P., Hekkert, P., 2007. Framework of product experience. International Journal of Design 1, 57–66.

Fokkinga, S.F., Desmet, P.M.A., 2012. Darker shades of joy: the role of negative emotions in rich product experiences. Design Issues. MIT Press 28 (4), 42–56.

Frijda, N., 1986. The Emotions. Cambridge University Press, Cambridge, MA.

Gibbs, R., 2006. Embodiment and Cognitive Science. Cambridge University Press, New York.

Hassenzahl, M., 2011. User experience and experience design. In: Soegaard, M., Dam, R.F. (Eds.), Encyclopedia of Human–Computer Interaction. The Interaction Design Foundation, Aarhus, Denmark. Available online at http://www.interaction-design.org/encyclopedia/user_experience_and_experience_design.html.

Hekkert, P.P.M., 2006. Design aesthetics: principles of pleasure in design. Psychology Science 48, 157–172.

Hekkert, P., Leder, H., 2008. Product aesthetics. In: Schifferstein, H.N.J., Hekkert, P. (Eds.), Product Experience. Elsevier Science Publishers, pp. 259–285.

Hekkert, P., Snelders, D., Van Wieringen, P.C.W., 2003. 'Most advanced, yet acceptable': Typicality and novelty as joint predictors of aesthetic preference in industrial design. British Journal of Psychology 94, 111–124.

Hekkert, P., van Dijk, M.B., 2011. Vision in Design: A Guidebook for Innovators. BIS Publishers, Amsterdam.

Johnson, M., 2007. The Meaning of the Body: Aesthetic of Human Understanding. The University of Chicago Press, Chicago.

Jordan, P.W., 2000. Designing Pleasurable Products: An Introduction to the New Human Factors. Taylor & Francis, London, UK.

Kahneman, D., Krueger, A.B., Schkade, D.A., Schwarz, N., Stone, A.A., 2004. A survey method for characterizing daily life experience: the day reconstruction method. Science 306, 1776–1780.

Karana, E., 2004. The meaning of the material: a survey on the role of material in user's evaluation of a design object. Paper Presented at the 4th International Conference on Design and Emotion.

Karana, E., 2009. Meanings of Materials, PhD Thesis. TU Delft, Delft.

Karana, E., Hekkert, P., 2010. User-material-product interrelationships in attributing meanings. International Journal of Design 4 (3), 43–52.

Karana, E., Hekkert, P., Kandachar, P., 2010. A tool for meaning driven materials selection. Materials and Design 31, 2932–2941.

Karapanos, E., Zimmerman, J., Forlizzi, J., Martens, J.-B., 2010. Measuring the dynamics of remembered experience over time. Interacting with Computers 22, 328–335.

Lakoff, G., Johnson, M., 1980. Metaphors We Live by. Chicago University Press, Chicago.

Larson, R., Csikszentmihalyi, M., 1983. The experience sampling method. New Directions for Methodology of Social and Behavioral Science 15, 41–56.

Laurans, G., Desmet, P.M.A., Hekkert, P., 2012. Assessing emotion in human-product interaction: an overview of available methods and a new approach. International Journal of Product Development 16, 225–242.

Law, E., Roto, V., Hassenzahl, M., Vermeeren, A., Kort, J., 2009. Understanding, scoping, and defining user experience: a survey approach. Paper Presented at the ACM SIGCHI Conference on Human Factors in Computing Systems (CHI 2009), April 4–9, Boston, MA.

Ludden, G.D.S., Schifferstein, H.N.J., Hekkert, P., 2008. Surprise as a design strategy. Design Issues 24 (2), 28–38.

Ludden, G.D.S., Schifferstein, H.N.J., Hekkert, P., 2009. Visual–tactual incongruities in products as sources of surprise. Empirical Studies of the Arts 27 (1), 61–87.

Ortony, A., Clore, G.L., Collins, A., 1988. The Cognitive Structure of Emotions. Cambridge University Press, Cambridge, UK.

Pinker, S., 2007. The Stuff of Thought. Penguin Books, London.

Ramachandran, V.S., Hirstein, W., 1999. The science of art: a neurological theory of aesthetic experience. Journal of Consciousness Studies 6, 15–51.

Scherer, K.R., Schorr, A., Johnstone, T. (Eds.), 2001. Appraisal Processes in Emotion: Theory, Methods, Research. Oxford University Press, New York.

Schifferstein, H.N.J., Hekkert, P. (Eds.), 2008. Product Experience. Elsevier, Amsterdam.

Sonneveld, M., 2007. Aesthetics of Tactile Experiences. Delft University of Technology, Delft, The Netherlands.

Sparke, P., 1990. The Plastics Age: From Modernity to Post-Modernity. B.A.S Printers, England.

Van Moof, 2012. http://vanmoof.com/.

Van Rompay, T.J.L., 2008. Product expression: bridging the gap between the symbolic and the concrete. In: Schifferstein, H.N.J., Hekkert, P. (Eds.), Product Experience. Elsevier Ltd, Amsterdam, pp. 333–351.

Van Rompay, T., Hekkert, P., Muller, W., 2005. The bodily basis of product experience. Design Studies 26 (4), 359–377.

Walker, J.A., 1989. Design History and the History of Design USA. Pluto Press.

Wilson, T.D., 2002. Strangers to Ourselves: Discovering the Adaptive Unconscious. The Belknap Press, Cambridge, MA.