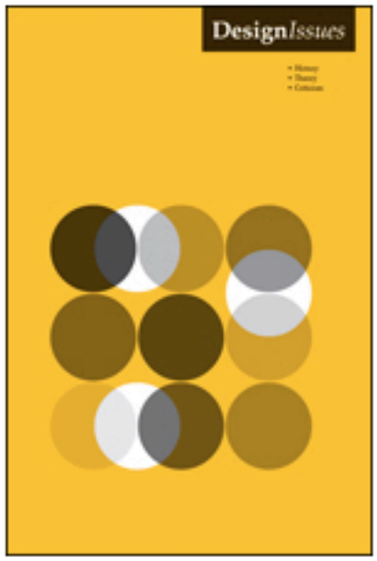

Quarterly (winter, spring, summer, autumn)
112 pp. per issue
7 x 10, illustrated
Founded: 1984
ISSN 0747-9360
E-ISSN 1531-4790

Inside the Journal

About *Design Issues*
Design Issues at JSTOR
Editorial Info
Abstracting and Indexing
Release Schedule
Advertising Info
Submission Guidelines
Most Downloaded Articles
Most Cited Articles
Rights & Permissions

DesignIssues

Summer 2015, Vol. 31, No. 3, Pages 16-27
Posted Online July 2, 2015.
(doi:10.1162/DESI_a_00335)

On Materials Experience

Elvin Karana
Elvin Karana is assistant professor in the Department of Design Engineering (DE) at Delft University of Technology (DUT), The Netherlands. Her research interests include *materials driven design, understanding and mobilizing materials experience in design*, and *designing with bio-based materials*. She recently led a nationally funded project on Meanings of Bio-Plastics, and is a principal researcher/task leader of a European Project (FP7) on Smart Material Interfaces. She is published in *Materials and Design Journal, International Journal of Design, Journal of Cleaner Production*, and *Design Issues*. Elvin is main editor of Materials Experience: Fundamentals of Materials and Design (Elsevier, 2014). She is the developer and coordinator of the materials library 'Made Of…'—a permanent exhibition at DUT (http://www.io.tudelft.nl/madeof).

Owain Pedgley
Owain Pedgley is a senior lecturer in Industrial Design at the University of Liverpool, UK. His principal research and educational expertise centers on how materials can be used to positively affect product interaction, product personality and user experiences. Owain has extensive experience coordinating student project-based innovation partnerships with firms including Nokia, Bosch Siemens Hausgeräte and Vitra. Prior to his academic career, he practiced product design in the sports equipment and musical instrument sectors, and co-founded the guitar innovation venture "Cool Acoustics."

Valentina Rognoli
Valentina Rognoli is assistant professor in The Design Department, at the School of Design, at Politecnico di Milano (Italy), where she conducts research activity in the field of materials and design. After two years at Enzo Mari's studio in Milan, Valentina focused her PhD research on materials and their expressive-sensory dimension, and developed an "Expressive-Sensorial Atlas of Material" to improve materials education in the field of design. She contributed to define the concept of materials experience and tinkering with materials. Her current research topics delve into materials and their relationship with user experience, education, additive manufacturing, sustainability, DIY, imperfection and repair. She has published fundamental books and articles in the domain of materials and design.

On Materials Experience

Elvin Karana, Owain Pedgley, Valentina Rognoli

A decade ago, in 2003, Denis Doordan published an article titled "On Materials" in *Design Issues*.[1] His emphasis was on "how the material employed affects the form, function, and perception of the final design." Accordingly, he suggested a new framework to discuss materials based on the following three terms: *fabrication*, concerning the preparation of materials for initial use; *application*, dealing with transformation of materials into artifacts; and *appreciation*, dealing with the reception of materials by users. During the past decade, the third term appreciation has lured attention in the materials and design domain, which has adopted a broader sense that corresponds with the experiences we have with the materials embodied in the artifacts around us. It refers to the mix of sensory (or aesthetic) appreciations, meanings, feelings, and thoughts that we have toward—or that are triggered by—a material, at any certain time and place.

In this essay, we elaborate on the notion of the appreciation of materials and its wider implications. Our starting point is a simple observation: In the material infrastructure of today's world, whether in products, buildings, or other creations, we see such variety of materials, driven largely by advances in technology. The layperson's knowledge of these materials, in the sense that they are recognizable and identifiable, is probably at an all-time low.[2] Similarly, new and emerging materials, along with the increasing demand to seriously adopt a discourse of sustainability, conspire to continually challenge the designer's competence in materials selection. The morphological character of materials—as expressive as they are functional and structural—leads to the proposition of new forms and an experimental approach toward design.[3] Materials are like words: The richer one's vocabulary (in materials), the larger is the number of design solutions that can be seen and expressed.[4] We argue that within the complexity inherent to materials and design—whether driven by technological or sustainability perspectives—users are the ones who determine the ultimate success (or not) of material choices. That is, success is a reflection of how people positively experience and react to the materials chosen by designers. A decade after "On Materials," this essay elaborates on the topic of materials experience.[5]

1 Dennis P. Doordan, "On Materials," *Design Issues* 19, no. 4 (Autumn 2003): 3–8.

2 See Ezio Manzini, *The Material of Invention* (Milano: Arcadia Edizioni, 1986) for a foundational discussion on the abundance of new materials that has caused a shift in the relationship that people once had with materials, compared with previous eras of far fewer materials and finishes.

3 Paola Antonelli, *Mutant Materials in Contemporary Design* (New York: Museum of Modern Art, 1995).

4 Inna Alesina and Ellen Lupton, *Exploring Materials: Creative Design for Everyday Objects* (Princeton: Architectural Press, 2010).

5 This article is a considerably modified and extended version of the introduction to Elvin Karana, Owain Pedgley, and Valentina Rognoli, *Materials Experience: Fundamentals of Materials and Design* (Oxford: Elsevier, 2014).

Design*Issues:* Volume 31, Number 3 Summer 2015 doi: 10.1162/DESI_a_00335

Foundation of Materials Experience

The materials of artifacts are often a way to attract people's initial attention. We can be captivated by materials, excited by their application; we can take great pleasure in their existence, or we can be extremely uninspired. In time, our material experiences may evolve because of physical material changes, or changes in our own personal appreciation systems. Materials can degrade, as well as age gracefully. Materials can reflect fashions in a particular era, or they can exhibit timelessness. People's internal material dialogues can be quite fascinating. When exposed, they reveal ways in which materials draw us into an artifact or push us away.

As a helpful starting point, we suggest inquiring about how people experience materials and, accordingly, considering in what ways designers can approach the subject of *design for experience* from a materials perspective. The relationship between materials (as the matter or substance of things) and experience (as a way to know the world and to enrich knowledge of it) has long been emphasized in pioneer philosophical works. In the field of art, Focillon[6] and Dewey[7] emphasized the unique role of material engagement in one's process of thinking and reflecting. Physical interaction with materials, or at least the aesthetic experiences that derive from hands-on manipulation of materials, can positively influence the creative process. Maldonado posited that we (as designers) have to experience the "real" side of materials, and not just be acquainted with "virtual" materials data.[8]

One of the most fundamental issues, if we are to look at materials from an experiential perspective, is to establish that material interactions occur through our senses. Materials are sensorially abundant in the everyday world around us. We stroke the smooth surface of a ceramic vase, we tap on a wooden box and hear the vibrant sound, we watch the water drops gather 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. In the longer term, they can define lasting positive or negative relationships with materials and the artifacts that they embody. Understanding sensory modalities is therefore a critical step if we are to design for materials experiences.

Another principle issue is what we call the hierarchy of materials in everyday materials experiences. If we regard materials as actors playing a particular role that designers have assigned to them, 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.[9] Deciding on the role that a

6 Henri Focillon, *Vie des Formes* [Life Forms] (Paris: Presses Universitaires de France, 1934).

7 John Dewey, *Arts as Experience* (New York: Perige Books, 1980).

8 Tomás Maldonado, *Reale e Virtuale* [Real and Virtual] (Milano: Feltrinelli, 1993).

9 Mike Ashby, "Foreword: Materials Experience," in *Materials Experience: Fundamentals of Materials and Design,* ed. Elvin Karana, Owain Pedgley, and Valentina Rognoli (Oxford: Elsevier, 2014), xvii–xxii.

material will play in an artifact is one of the creative challenges that designers face. Designers need a good auditioning process, which necessarily entails evaluating potential materials against the dual criteria of people's functional and hedonic needs.[10] Through such a process, they arrive at a material that as far as possible not only meets the practical demands of the design but also offers intangible sparks that captivate people's appreciation and that affect the ultimate experience of an artifact in and beyond its utilitarian assessment. By recognizing a designer's full engagement in deciding the materials to be used in a new design, we can understand that competence is needed in predicting and defining both the *experiential* qualities and the *performance* qualities of materials. Because materials are inherently physical, it is no surprise that user–product interaction is viewed as the foundational model from which material experiences may be planned.[11]

The topic of materials experience has taken some time to come to prominence. In his well-known work, *The Material of Invention,* Manzini wrote about designerly competences in materials selection, aesthetics of materials, and the role of materials in shaping positive user experiences. He emphasized that new materials were characterized by their functionality. Thus, rather than asking "What is it?" in reference to a material, designers needed to ask "What does it do?"; the latter question reflects an understanding that a material's potential applications, performance, and ultimate effects on users give rise to materials experiences. About 15 years later, Ashby and Johnson treated in an intellectual and in-depth manner the significance of the aesthetic experience of materials for a proper materials selection in product design.[12] In addition to the well-established "general," "technical" and "eco" attributes, they added "aesthetic" attributes of materials—which originate from sensorial properties of materials, such as warmth and softness—to the material properties list for designers. In addition, Ashby and Johnson reinforced the two overlapping roles that materials play in product design: providing technical functionality and creating product personality. Accordingly, they pointed out that intangible issues, such as perceptions and associations, should have a role in the materials selection activity for products. These steps were significant in moving toward the foundation of materials experience as a separately identifiable body of knowledge.

Since the publication of Ashby's and Johnson's book, the number of research studies concerning material interactions and product design (and the subtopics of sensorial properties, attribution of meanings, and elicitation of emotions) has grown considerably. For example, important contributions have been made by Zuo et al.,[13] Rognoli,[14] Miodownik,[15] Van Kesteren,[16] and Karana.[17] The term "materials experience" was first coined by Karana et al.[18] and defined as the experiences that people have with, and through, the

10 Marc Hassenzahl, *Experience Design: Technology for All the Right Reasons* (San Rafael: Morgan & Claypool, 2010).

11 Elvin Karana and Paul Hekkert, "User-Material-Product Interrelationships in Attributing Meanings," *International Journal of Design* 4, no. 3 (2010): 43–52.

12 Mike Ashby and Kara Johnson, *Materials and Design: The Art and Science of Material Selection in Product Design* (Oxford: Butterworth-Heinemann, 2002).

13 Hengfeng Zuo, Tony Hope, Paul Castle, and Mark Jones, "An Investigation into the Sensory Properties of Materials," in the proceedings of *The 2nd International Conference on Affective Human Factors Design* (London: Asean Academic Press, 2001).

14 Valentina Rognoli, I Materiali per Il Design: Un Atlante Espressivo-Sensoriale [Materials for Design: An Expressive-Sensorial Atlas] (PhD diss., School of Design, Politecnico di Milano, 2004).

15 Mark Miodownik, "Toward Designing New Sensoaesthetic Materials," *Pure and Applied Chemistry* 79, no. 10 (2007): 1635–41.

16 Ilse Van Kesteren, "Product Designers' Information Needs in Materials Selection," *Materials and Design* 29 (2008): 133–45.

17 Elvin Karana, Meanings of Materials (PhD diss., Delft University of Technology, 2009).

18 Elvin Karana, Paul Hekkert, and Prabhu Kandachar, "Materials Experience: Descriptive Categories in Material Appraisals," in the proceedings of *The International Conference on Tools and Methods in Competitive Engineering,* ed. Imre Horvath and Zoltan Rusak (Delft: Delft University of Technology Press, 2008): 399–412.

materials of a product. The phrase acknowledges that while product (or user) experiences may originate from—or be moderated by—a wide variety of sources, one of the prominent sources is the physical reality of an artifact: the wood of the furniture, the plastic of the kitchen utensil, the leather of the handbag, the rubber of the bicycle handlebar, the ceramic of the floor tile. Using one material across various applications creates a set of different experiences. Realizing one application through a series of different materials results in another set of experiences. The artifact mediates and shapes the experience; the material itself is only interesting because it mediates a personally meaningful experience. Accordingly, materials experience acknowledges and emphasizes that—by shaping what we feel, think, and do—materials have the power to foster meaningful experiences.

Materials Experience Deconstructed

In developing our understanding of materials experience, we found it useful to adopt the affective product experience framework of Desmet and Hekkert, which integrates not only a concern for aesthetic experiences provided by materials, but also meanings that materials may evoke and emotional responses that may originate from materials.[19] We elaborate on each of these *kinds* of experience, but with some notes of caution. First, we should be mindful that real-life material experiences are not so separable, in the sense that aesthetics, meanings, and emotions are not easily isolated. When people recount materials experiences, these experiences are usually intertwined within a material story moderated by a variety of extrinsic attributes—for example, where an artifact was purchased, the extent to which it fulfills expectations, perceived brand value, country of origin, and so forth. However, what we can claim is that aesthetics, meanings, and emotions are invariably seen to be present to some degree when we retrospectively deconstruct people's experiences, even though in the moment of user interaction or acquaintance, their relative presence and role can be quite opaque.

The *aesthetic* experiences of a material originate from the perception and notice of material sensorial information, such as softness, warmth, smoothness, sound, weight, and stickiness. As a direct conduit from the human sensory system, the aesthetic component of experience is omni-present and inevitable. We might find ourselves appreciating a material in and of itself, being captivated—for good or ill—by the material sensorial information. This is the essence of an aesthetic experience of materials. It does not imply that there is absence of judgment about *what the material represents to us* (meanings) or *how the material makes us feel* (emotions), but that the focus of attention is on the sensoriality.

19 Pieter Desmet and Paul Hekkert, "Framework of Product Experience," *International Journal of Design* 1, no. 1 (2007): 57–66.

Figure 1
'RA1' acoustic guitar with polymer soundboard, by Rob Armstrong / Cool Acoustics (© 2003 Cool Acoustics).

Multiple sensory modalities can be simultaneously active during an aesthetic experience (e.g., seeing + touching + hearing).[20] A perfect example of this multiplicity is the acoustic guitar—an artifact in which the materials are at once satisfying demanding structural requirements alongside hedonic needs related to pleasures of playing and interacting with a musical instrument. The guitar shown in Figure 1 is the RA1 acoustic guitar developed by Rob Armstrong and Cool Acoustics. It is highly unusual in that it is constructed primarily from foamed polycarbonate and plywood as alternatives to spruce, cedar, mahogany, rosewood, and other traditional solid woods. The new materials bring appreciable changes in visual and tactile properties, opening up a world of product differentiation through materials. But perhaps the most important aesthetic experience for this particular product is sonic.

20 Rick Schifferstein and Lisa Wastiels, "Sensing Materials: Exploring the Building Blocks for Experiential Design," in *Materials Experience: Fundamentals of Materials and Design,* ed. Elvin Karana et al. (Oxford: Elsevier, 2014): 15–24.

Figure 2
'Plattan' headphones by Urbanears
(© 2013 Jaap Rutten).

The instrument emphatically defies people's general reservations about plastics and musical instruments. In blind (hearing) tests, people are unable to tell it apart from an expensive wooden guitar.[21]

Meanings evoked by materials relates to what we think about materials and what kind of values we attribute after the initial sensorial input in a particular context.[22] We attribute meanings to materials on the basis of the characteristics of a situational whole in which those materials are experienced. This attribution happens as a result of a dynamic action between the user and the material embodied in an artifact. The basic operational structure is relatively simple: A user with his or her particular prior experiences comes into visual or physical contact with the material of an artifact, appraises that material–artifact combination, and attributes a meaning (or meanings) to it. The operational structure is described in detail by Hekkert and Karana:

> The attributed meaning will be (partly) based on the material's technical and sensorial properties and is affected by aspects of the product in which the material is embodied. 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 or they result from learned conventions leading to less "stable" relationships and cultural/individual diversity.[23]

From this quotation, we can understand that material meanings are highly intertwined, subjective, time- and context-dependent attributes. We can offer another product example to illustrate the meaning component of materials experience: the *Plattan* headphones by Urbanears (see Figure 2). As a company, Urbanears aims

21 Owain Pedgley and Eddie Norman, "Materials Innovation in Acoustic Guitars: Challenging the Tonal Superiority of Wood," *Leonardo Music Journal* 22 (2012):17–24.

22 Karana, Hekkert, and Kandachar, "Materials Experience: Descriptive Categories in Material Appraisals."

23 Paul Hekkert and Elvin Karana, "Designing Material Experience," in *Materials Experience: Fundamentals of Materials and Design,* ed. Elvin Karana et al. (Oxford: Elsevier, 2014): 3–11.

to create headphones that are experienced rather like clothes, with a combination of utility and semantics heavily influenced by material choices. In this particular example, material combinations are the main characteristic: velvet-like plastics that are complementary to the soft leather cushioning and textile heading. Our evaluation of the materials of this product suggests to us a modern, high-quality, and lively headphone. Notice here the flow of ascription: The *materials* moderate the *product judgment.* We are not suggesting that the materials themselves, when isolated, do not evoke meanings. (They certainly can and do.) Rather, we are saying that in the context of an application, the material appraisals are made with regard to how that application is *enhanced* or *undermined* through the choice of materials. As we enter discussions that relate meanings and product design, inevitably we are drawn to the subject of product semantics and, in our case, the relative role of materials in affecting how a product is read. Denotations and connotations for products can have varied origins—with our headphone, for example, form, colors, sound quality and sound leakage, country of manufacture, and place of use are all points of departure for recognizing denotations and connotations. We cannot assign any kind of simple rule about the relative importance of these factors, either to headphones specifically or products generally; yet the physical nature of materials—in the sense that without materials, a product cannot even exist—leads us to suggest that it is quite high up on the list in influencing product meanings. Empirical research studies can reveal such insights on a case-by-case basis for the products that we encounter in our daily lives.

The experience realized with an artifact is determined and influenced by the *emotions* that the artifact can elicit in users, as well as the emotional state or mood that the user brings to the interaction.[24] The emotional effect of an artifact can depend, among other things, on its material qualities,[25] influencing the visceral level of emotions and immediate reactions that Norman refers to as the "wow factor."[26] For example, Ludden conducted an important in-depth study into the specific emotion of surprise as a design strategy, with considerable effort given to understanding circumstances in which designers might govern the presence of surprise through choices of materials.[27] The example chosen for this essay, the *Biscuit* table by Patricia Urquiola (see Figure 3), is significant in that it cleverly demonstrates a way in which a designer can mobilize a material of an artifact to elicit surprise. The table is produced from a very well-known material, marble, but uses an innovative approach to create a unique sensory experience, especially to gratify vision. The designer added a very unusual sensorial quality of translucency to a material—marble—that in everyday experiences one cannot generally encounter. To anyone who interacts with the table, this end effect comes as quite a surprise.

24 Pieter Desmet, "Three Levels of Product Emotion," in the proceedings of *The Kansei Engineering and Emotion Research International Conference,* ed. Carole Bouchard et al. (Paris: Arts et Métiers ParisTech, 2010): 238–48.

25 Gaia Crippa, Valentina Rognoli, and Marinella Levi, "Materials and Emotions: A Study on the Relations between Materials and Emotions in Industrial Products," in the proceedings of *Design and Emotion Conference,* ed. Jamie Brasset et al., (London: Central Saint Martins College of Arts & Design, 2012).

26 Donald Norman, *Emotional Design* (New York: Basic Books, 2004).

27 Geke Ludden, Sensory Incongruity and Surprise in Product Design (PhD diss., Delft University of Technology, 2008).

Figure 3
'Biscuit' table by Patricia Urquiola for Budri, 2010 (©Studio Patricia Urquiola).

Key Issues Shaping Today's Materials Experiences

So far we have concentrated on the materials experience of *end users* but not of designers who are responsible for defining the intended materials experience of a product and who—on various levels—have the initial interactions with artifact materials. Thus, designers *and* users together are the principal stakeholders in the loop that joins intended and realized materials experiences.[28] Given the fundamental link between design (material) intent and realization, a helpful first inquiry is to consider the key issues affecting designers' material choices—or their design process when a particular material is pre-set—for the creation of intended user experiences. In the arena of product design, we observe two key issues that drive material decisions and applications and that, accordingly, trigger the emergence of new materials experiences: *sustainability* and *technology*. In the following section, we elaborate on these two key issues and suggest a number of emerging materials experiences falling under each issue.

Sustainability in Materials Experience

A study conducted before the emergence of materials experience reviewed pioneer books concerned with materials selection.[29] The review covered both industrial design and mechanical design and included books published between 1967 and 2005. Interestingly, in most of the pre–1996 sources, environmental (and later on

28 Owain Pedgley, "Influence of Stakeholders on Industrial Design Materials and Manufacturing Selection," *International Journal of Design* 3, no. 1 (2009): 1–15.

29 Elvin Karana, Paul Hekkert, and Prabhu Kandachar, "Material Considerations in Product Design: A Survey on Crucial Material Aspects used by Product Designers," *Materials and Design* 29 (2008): 1081–89.

sustainability) issues were placed at the bottom of the list of material requirements for designers and engineers to take into account. However, only a few years later, Mangonon organized material selection factors under three main topics: property profile, processing profile, and environmental profile.[30] He emphasized that selection based on an environmental profile covers multiple effects of a material: its inherent properties, its manufacture, its use, its reuse, and its disposal.

Today we see these collective effects under the wider umbrella of sustainability, with their recommended consideration moved considerably further up from the bottom of material selection criteria. So what crossovers can we identify between material experiences and sustainability concerns? The aesthetics of sustainability—or as named by others, "aesthetics of environmentally sensitive products,"[31] "total beauty,"[32] "green aesthetics,"[33] and "sustainable beauty"[34]—has emerged as an important factor when designing for sustainability. When looked at from the perspective of materials use, one of the aesthetic expressions discussed in the design for sustainability domain is whether a material of a sustainable product expresses "naturalness,"[35] in the sense that it comes from nature and goes back to nature.[36]

Alongside naturalness, we observe another aesthetic movement: that of imperfection. Products that fit into an imperfect aesthetic through material choices are aimed at gratifying people's senses through unique aesthetic features and sometimes through a resemblance to material effects that occur in nature. These products are intended to generate value for people through the characteristics of graceful aging. In such circumstances, people welcome the traces of life that a material can carry as part of its aesthetic beauty, as they inherently valorize imperfection as a unique aesthetic feature. Giving value to the imperfect condition leads to a reconsideration of the relationship that one has with everyday objects. Imperfect aesthetic qualities of materials can be endearing and help to create an experiential bond with users.[37]

Issues such as these, presented to designers' palettes through sustainability discourses, suggest a movement toward a new aesthetic for the materials of design—one that can be harnessed to elicit particular emotions (e.g., love, hate), encourage particular behaviors (e.g., to care for, to keep for longer), and impart high-level values (e.g., appreciation of the natural). A material ages with its user, matures in time, carries the traces of one's life span, facilitates the recall of memories, and relates one to the familiar and the usual. When discussed through a human needs perspective, we foresee great potential for these new material aesthetics in designing for experience of *relatedness* (i.e., a feeling that people have when in regular contact with others who care).[38]

30 Pat Mangonon, The *Principles of Material Selection for Engineering Design* (Upper Saddle River: Prentice-Hall, 1999).

31 Stuart Walker, "The Environment, Product Aesthetics and Surface," *Design Issues* 11, no. 3 (Summer 1995): 15–27.

32 Edwin Datschefski, *The Total Beauty of Sustainable Products* (Crans-Près-Céligny: Rotovision, 2001).

33 Yuriko Saito, *Everyday Aesthetics* (New York: Oxford University Press, 2007).

34 Lance Hosey, *The Shape of Green. Aesthetics, Ecology, and Design* (Washington: Island Press, 2012).

35 Krista Overvliet and Salvador Soto-Faraco, "I Can't Believe This Isn't Wood! An Investigation in the Perception of Naturalness," *Acta Psychologica* 136 (2011): 95–111.

36 Elvin Karana, "Characterization of 'Natural' and 'High-Quality' Materials to Improve Perception of Bio-Plastics," *Journal of Cleaner Production* 37 (2012): 316–25.

37 Valentina Rognoli and Elvin Karana, "Towards a New Materials Aesthetic Based on Imperfection and Graceful Ageing," in *Materials Experience: Fundamentals of Materials and Design,* ed. Elvin Karana et al. (Oxford: Elsevier, 2014): 145–53.

38 Hassenzahl, *Experience Design: Technology for All the Right Reasons.*

Technology in Materials Experience

In parallel to concerns about sustainability, the technological advancement of materials (e.g., having superior properties, such as conductivity, sensing, thermal stability, and mechanical resistance) and significant improvements in manufacturing technologies (e.g., additive manufacturing) have been essential for product development and have affected designers' material decisions. These technological developments inevitably influence (or will influence) how users experience materials, and how designers create material experiences. Hekkert and Karana explain this by demarcating meanings of materials into two categories: universal and learned meanings. They explain the universal material meanings as "...the material-meaning associations which are, by their sensorimotor nature, very robust and persistent and not very sensitive to cultural or individual differences." They offer several examples:

> Wood is literally warm to the touch and therefore perceived as inviting and cozy, whereas stone or steel is generally cold to the touch and thus tends to be perceived as more distant. Or, 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…. Yet, for many new materials with a much shorter history than, for example, wood or steel, the meanings still have to be learned....[39]

Our everyday experiences of materials are increasingly diverse, and the designer's opportunity both to build meanings into products and to create new meanings to be learned by societies through materials is wider but more complex. Accordingly, we recognize the emergence of two key opportunities concerning the interrelationship between technology and materials experience: *dynamic* materials experiences and *personalized* materials experiences.

In the opportunity for dynamic materials experiences, materials and technologies around us (particularly given the advancement in smart technologies) become increasingly reactive to external stimuli, originating, for example, from the environment or from human intervention. In this way, materials become a dynamic *creature* rather than a static *object,* giving different reactions in different times and places and for different individuals. Inspired by Chapman's "fuzzy interactions,"[40] we can suggest that these dynamic interactions might trigger fuzzy materials experiences, which introduces the wildcard element of unpredictability to otherwise traditional interaction scenarios. We suggest that fuzzy materials experiences have great potential to elicit *stimulation* experience (i.e., a feeling of plentiful pleasure and enjoyment) through the unpredictable reactions to materials when materials are properly applied in a carefully constructed context.[41]

39 Paul Hekkert and Elvin Karana, "Designing Material Experience," in *Materials Experience: Fundamentals of Materials and Design,* ed. Elvin Karana et al. (Oxford: Elsevier, 2014): 3–11.

40 Jonathan Chapman, *Emotionally Durable Design: Objects, Experiences and Empathy* (London: Earthscan, 2005).

41 Hassenzahl, *Experience Design: Technology for All the Right Reasons.*

We also see the opportunity for personalization as triggered by technological advancement. In an era where we are exposed daily to an abundance of new manufactured products, people seek ways to personalize their belongings, making them different from the identical objects possessed by other people. Advancements in technologies provide various ways that do not rely on the post-purchase personalization approach for users to personalize their materials experiences. Placing Hassenzahl's ideas in the context of product materials, we suggest that personalized materials experiences trigger experiences of *popularity*—as a feeling of being liked and appreciated, with influence on other people, through possession of unique personal belongings—as well as experience of *autonomy*, where one may experience having control and being the cause of one's own actions.[42]

A very stark effect of advancement in material technologies is that it (still) radically alters the meanings that once endowed materials with cultural and physical depth.[43] Take clay as an example. Craftsmen shaped clay for centuries with their hands, leaving signs of professionalism through the creation of unique artifacts. Industrial production demanded a shift in approach—not a shift from making to designing, but a shift in mindset, from creating the unique to creating the standardized, and to producing in large quantities with reproducible perfect forms and surface finishes. Although this approach represents the normality of mass production, it is not beyond question. We have witnessed a number of attempts by well-known designers to emphasize unique properties of materials, even though the artifacts in which the materials are embodied are shaped by industrial manufacturing processes. Hella Jongerius' B-Set tableware is a prime example in this regard. By firing the clay at a purposefully too-high temperature, each element of the tableware deforms slightly in a different manner, offering an industrially produced yet unique artifact each time. Technological advancement now gives designers immense opportunities through 3D printing to shape the clay (among other materials) in unique ways, forcing the limits of the material beyond the adage of "what the mind of a craftsman can imagine, the hands can shape." We suggest several questions for discussion in this environment: Can 3D printed clay elicit the same meanings with which traditionally formed clay has been endowed? Can we suggest new meanings or introduce new experiences through the use of 3D printed clay?

42 Ibid.

43 Manzini, *The Material of Invention.*

Conclusion

Designing meaningful materials experiences requires competence in materials that is tied not only to three experiential components (i.e., aesthetics, meanings, and emotions), but also to understanding the possible effects of various design aspects (e.g., form, process, finishing), user characteristics (e.g., gender, culture, age), and context of use on the resulting materials experience. Developing competence in these areas entails a critical assessment of the way we design, the way we select materials, and the way we teach materials in design. The guiding approach is essentially a merger between materials knowledge and user experience design principles. In generating this mix, we must reconcile diverse topics, including the balancing of functionality and expression through materials; ways of learning about material properties; and developing new tools and methods that are experientially based to complement well-established technical-based tools and methods.

In the context of education and professional training, several independent research projects have been conducted into how different experiential levels with materials can be nurtured and understood. These research projects have led to tangible outcomes in the form of material inspiration and selection tools. We maintain that understanding how materials are experienced is fundamental to designing meaningful artifacts and interactions. In this essay, we have suggested that a fruitful approach is to consider materials experience at three fundamental levels: aesthetics, meanings, and emotions. We have promoted a curiosity focused on finding out how these experiential levels interrelate and how other aspects, such as artifact application and user demographics, moderate them. Finally, we have identified the challenges concerning the *ultimate* materials experience and its relation to people's hedonic needs. We envision the emergence of a variety of prominent materials experiences in the near future, centralized on the issues of sustainability and technology. In conclusion, our hope is that on reading this paper, you will be left challenged and energized to bring a principally experiential perspective to materials decisions and will take it into future design projects, whether they are sustainability- or technology-driven.