# FORM, MATTER AND TECHNOLOGY

## A FORMATIVE RESEARCH REFERENCE IN INDUSTRIAL DESIGN EDUCATION

**Andrés Valencia-Escobar / Ever Patiño, Alejandro Zuleta, Diana Urdinola and David Torreblanca**
Industrial Design Faculty - Universidad Pontificia Bolivariana – Medellín - Colombia
andres.valencia@upb.edu.co / ever.patino@upb.edu.co, alejandro.zuleta@upb.edu.co, diana.urdinola@upb.edu.co and david.torreblanca@upb.edu.co

## 1. INTRODUCTION

The development of research projects that actively involve undergraduate students is a challenging activity. Formative research implies from its leaders the understanding of the scientific exercise and its results as a means and not as an end. The Experimental Morphology Research Line and its Morfolab study group, are part of the Design Studies Research Group of the Industrial Design Faculty of the Universidad Pontificia Bolivariana in Medellín, Colombia, and have been working for the last 14 years in strategies for linking and permanence for undergraduate students of Industrial Design with the aim of that they acquire investigative skills through their inclusion in scientific projects. A combination of research methodologies focused on presenting science as an input to the design process has allowed the development of projects in the four basic topics of the Line: Biomimetics, Non-Conventional Structures, Finding Form and Materials and Design. These themes have been present for more than 50 years in design education and design practice; however, all have been constantly renewed and strengthened from the inclusion of new ways of acting, new technologies associated with the materialization of ideas and new schemes for interpreting scientific results in terms of their application. The aim of this text is to describe three different industrial design formative experiences through research projects.

Initially it is important to mention that the constant updating of production technologies, research to propose new materials, morphological experiments and the development of various and unexpected design projects transcends the boundaries between different disciplines and installs new study scenarios that result unexplored, strongly attractive and innovative. Because of this, design deploys new combinations of tools, techniques, processes and methods that propose new paradigms. Among them, "Food Design" or "Design and Food" is presented as an emerging theme, which specifies three lines of study: design with food, design for food and design of food (Zampollo, 2015). In Food Design, the similarities between food engineering, gastronomic techniques and the methodologies used during the design process are mixed. Traditionally, design and gastronomy are disconnected both in the creative process and in the formative process, each with methodologies that are developed and taught in isolated courses and spaces, which does not encourage the encounter of connections and the visualization of their potential. However, this has been changing during the last years allowing both disciplines a productive interference between them.

On the other hand, the integration between biomimetics and morphological experimentation mediated by parametric design and Digital Fabrication Technologies (DFT) is an emerging area of research that has been structured in the last decade. Within the possibilities that nature offers, the texture of natural surfaces has become a highly relevant aspect for product design, as it not only provides the means to change or improve physical appearance, but also create different multi- sensory features to users who evoke from perceptions and associations, and in turn, give the user idea of quality or durability of the product. From this perspective, Janine Benyus (2012) affirms that the way in which nature generates new substances and energy, to build structures are an example of how humans can copy and imitate to survive and adapt to the ecosystem. This translation of principles, forms and patterns to be applied in human construction has commonly taken the name of Biomimetics. From the design, Biomimetics can be understood as that project activity in which it is taken as reference to the nature for the solution of human problems. This reference can focus on the identification, analysis and synthesis of principles or laws of operation, materialization or formal configuration of natural origin, which in some way provide support to the project. It is established that if an industrial object is designed from biomimetics, it can acquire a series of characteristics that will make it innovative and efficient (Vincent, 2006), (Jirapong, Krawczyk & Elnimeiri, 2002) and (Wen, 2008).

Finally, industrial design has impacted the material industry significantly since the beginning of the 21st century, among other reasons, because it has generated a trend of use and design of materials based on sensoriality. The understanding of the perceptual phenomena associated to the way in which a user relates to an object through its materiality, has generated that today the material industry sees in this a tool with high potential of innovation for the products. The interaction between the user and the object is closely related to the materials, which may or may not favor the user's desire to maintain a product after seeing, hearing, tasting, smelling and touching. This experience is experienced, in most cases, thanks to its surface because this is the most exposed part of the object and the place where the material ends to contact the outside world, this being the portion of the material the users interact with and by means of which the characteristics of a product are recognized (Manzini, 1993). The research on the subjects related to the surfaces of the materials and their relation with the users involves the qualification and quantification of the characteristics of an object (Picard, Dacremont, Valentin, & Giboreau, 2003; Zuo & Jones, 2005). It is necessary to approach the process of sensory perception of materials in a complementary way with the study of their quantifiable technical attributes. The relation between the technical and sensorial aspects allows to complement the teaching in the subjects related to the science of materials with a scheme that in essence is qualitative and very linked to the emotional (Karana, Pedgley, & Rognoli, 2013; Karana, 2009). This allows to generate radical changes in the way of designing products that, in addition to having functional benefits, offer, through its surface, a variety of possibilities for human interaction with matter.

## 2. METHODOLOGICAL APPROACHES AND RESULTS

### 2.1. DIGESTIVE FORMS

Under the objective of experimenting with the transformation processes used with edible physical supports -food- to reach pre-established forms and transferring them from the design area to the gastronomy and vice versa, the project "Digestive Forms", proposes a methodology that obeys to four instances in which observation and analysis are the guidelines to conclude in the experimentation and validate the result. The proposed instances are: deductive observation, deductive selection, controlled exploration and validation. These methodological instances, which are explained below, establish scopes that dialogue between forms that are considered conceptual morphological references and forms that obey functional objects. During the development of these instances, the students who participate in the project are advised by the teachers, who from their experience participate actively in all the activities proposed by the methodology. The team working on this project is made up of 2 teachers and 6 undergraduate students.

For Deductive Observation the materials and transformation processes are analyzed through analogies and comparisons (see Table 1). Non-edible materials and their manufacturing processes are compared with edible materials and their cooking/transformation techniques to find similarities and deduce processes for the generation of forms. Various experiments are carried out at this stage which becomes the process of sensitization and contextualization too. The initial point to begin the observation focuses on the intuitive characterization of the edible materials to be explored in order to use those foods that share properties. Some of the above-mentioned experiments can be seen in Figure 1a. It shows how the initial shapes are transformed as a result of the existence of constraints such as curvature, folds and other irregularities on the surface of the models. In the Deductive Selection we propose the selection of the edible material to be explored and the processing and transformation methods to arrive at the final morphology. The geometrical properties of the desired shape are also established. To continue the exploration process, it is necessary to recognize and analyze the results of deductive observation, thus identifying the possibilities that are there (see Figures 1b and 1c). For this reason the edible materials were subjected to various experiments regarding the cooking/processing process. For Controlled Exploration the methods of transformation propose the exploration by means of the change of state of the material, the analysis of the physical and chemical phenomena as well as the external agents in charge of generating the form. Figure 5 shows results with various edible materials, various cooking/transformation processes to arrive at a wrinkled surface as a final shape. These morphologies were obtained by depositing the material in a liquid state on molds made of crumpled paper, then the samples were subjected to low temperatures in the refrigerator to achieve solidification. Finally, for validation, the results obtained are submitted to a verification process involving the students and the teachers team (Figure 1e).

| ANALOGIES | | | | |
|---|---|---|---|---|
| **EDIBLE MATERIAL** | **COOKING TECHNIQUES** | | **NON-EDIBLE MATERIALS** | **MANUFACTURING PROCESSES** |
| Batter | Baking | ⇨ | Ceramics | Sintering |
| Jelly | Liquid Molding<br>Cooling | ⇨ | Polymers | Rotomolding<br>Injection molding<br>Thermoforming |
| Caramel | Liquid Molding<br>Cooling | ⇨ | Glass | Blowing<br>Injection molding |

Table 1. Examples of analogies worked in the "Digestive Forms" research project.


a


b


c


d


e

Figure 1a. Transformation during the baking process. Figure 1b. Wheat dough samples subjected to various cooking/ processing processes. Figure 1c. Samples of gelatin solidified in molds of various materials. Figure 1d. Experimental crumpled surfaces. Figure 1e. Process of validation of edible materials and morphologies resulting from the cooking/processing process.

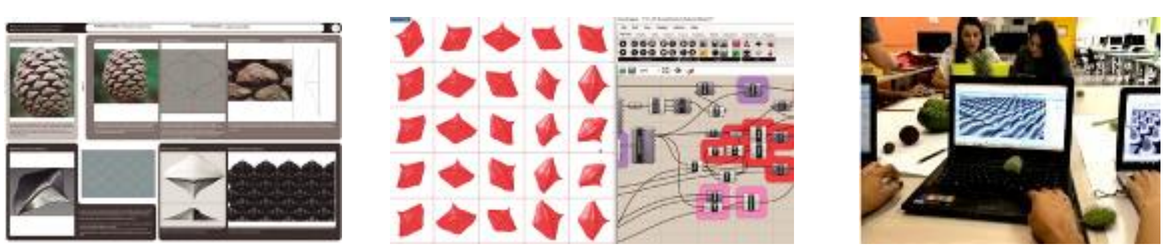
### 2.2. BIOINSPIRED SURFACES AND TEXTURES

In order to design a set of bio-inspired surfaces and textures for professionals in the Cultural and Creative Industry, the project "Repertory of bioinspired surfaces and textures, through morphological experiments with Digital Fabrication Technologies", is being developed. Its aim is to provide an online customizable open source catalog where designers and/or architects can extract the best solution for a specific problem in the field of surfaces and textures of objects, textiles and/or spaces. In addition, to realize the materialization with the DFT, with all the advantages that these technologies have: immediacy, precision, personalization, remote manufacture and representation of complex forms. For this purpose, it is proposed to characterize patterns of nature, specifically the plant kingdom of Medellín-Colombia, to experiment morphologically with Rhinoceros CAD software, and the Grasshopper parametric plug-in, to construct a repertoire of bio-inspired textures with DFT and finally to propose a project methodology for the transfer of natural surfaces and textures to artificial elements. At the time of writing this text, the project progresses within the first and second stages, so these will be the ones that will be exposed. The team working on this project is made up of 4 teachers and 10 undergraduate students. For the characterization of the patterns, the student team made a preliminary observation. Each of them registered 15 natural models, to which they were taken three different photos with scale change, obtaining 450 photographs of textures. This process of observation was recorded in two types of instruments such as those that can be seen in figure 2. In addition, it had a fundamental characteristic and was to generate a real and experiential experience in the middle of nature allowing learning by discovery and self -construction (Patiño, 2015).

a b

Figure 2a. Preliminary observation instruments for several natural patterns. Figure 2b Preliminary observation instruments for same natural pattern in several scales.

Subsequently, to make a systematic and orderly debugging of the information, the most representative photograph of each model was taken, manually cut, a photographic quality was reviewed and the best ones were selected. Then the models were grouped in relation to the shared and preponderant formal properties. This process yielded a new classification of six major categories of textures present in nature: basic, reciprocal geometries, reliefs, ramifications, folds and visual textures, each having its respective subcategories for a total of 23 clusters. Finally, to comply with the proposed characterization, the geometric abstraction of a natural model was performed by subcategory, which was previously selected according to objective criteria and determined by the research team. Figure 3a shows two examples of the abstraction instrument, in which bi and three-dimensional geometric analysis is visible and used to develop the digital models necessary to begin the subsequent stage of morphological experimentation with Grasshopper (Figure 3b and 3c). In this case they defined which formal properties should prevail to be imitated, and which should be discarded. It is important to mention that the biomimetic exercise was mediated by the characteristics of the research project and the proposed scope, giving greater importance to those properties that could be used in future design projects.



a b c

Figure 3a. Examples of instruments of geometric abstraction. Figure 3b. Start of the stage of parametric morphological experimentation. Figure 3c. Study group working in the stage of parametric morphological experimentation

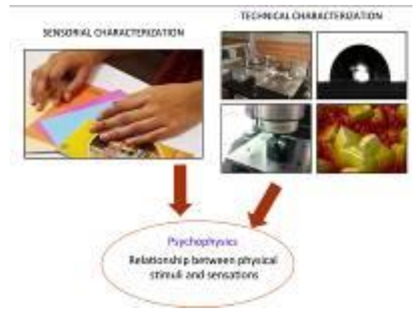
## 2.3. SURFACE MODIFICATION OF MAGNESIUM

With the aim to show how the interdisciplinary combination between the technical aspects, studied by the science of materials, and the study of the sensorial aspects, addressed by the industrial design, can provide relevant information that industrial designers can include in their creative processes, the project "Surface modification of magnesium with composite coatings", presented in colaboration with the Center of Research, Innovation and Materials Development (CIDEMAT) of the University of Antioquia, proposes a methodology that combines the science of materials and perceptual psychology. For this, the following methodology is proposed: *(i)* the preparation of the material, *(ii)* the modification of its surface, which includes the preliminary test of anodizing specimens using other materials as titanium (Figure 4), *(iii)* the characterization of the material by means of advanced techniques and *(iv)* the elaboration of a test for the sensorial characterization of the materials developed. For the latter we consider sociological aspects and sensorial aspects that are framed in four different dimensions: geometric, physicochemical, emotional and associative, according to the works carried out by Karana, et al. (Karana, 2009) (Karana & Hekkert, 2010), van Kesteren et. Al. (Van Kesteren, 2010) and Zuo et al. (H Zuo, Hope, Castle, & Jones, 2001).

Figure 4. Anodizing of titanium laboratory

The geometric dimension refers to the roughness (Figure 4b) of the sample, this because all have the same format. The physicochemical dimension involves properties such as temperature (hot/cold), hardness (soft/hardness), coefficient of friction (slip/slippery), contact angle (wet/dry) and color brightness (bright/opaque). The emotional dimension is related to the emotional aspects such as: nice, elegant, costs, modern, etc. And in the last dimension, the associative, deals with aspects that involve those ideas, concepts, situations or memories with which the materials are associated. The project focused on working with magnesium and the possibility offered by nanomaterials, specifically ceramic nanoparticles, to improve protection conditions and to alter in a controlled way the sensory properties of the material surface (Figure 4c). Among the characterization tests that have been carried out are the Knoop microhardness test, the wettability test with the contact angle measurement, the determination of the coefficient of friction and a colorimetric test to define the color intensity.

a



b

Figure 5. a: characterization of the roughness for texture analysis. b: The tactile characterization and its relation with the technical properties of the materials

## 3. REFLECTIONS REGARDING STUDENT PARTICIPATION

With the development of the mentioned projects, it was possible to verify that the multidisciplinary approaches offer an added value for the activities of formative research, since they allow the student to involve on the one hand varied concepts, and on the other, different visions before the same parameter in its thought structure. In addition, it can be said that these workspaces can be inscribed in strict research processes but their main objective is to foster the necessary investigative skills to face the resolution of a problem, question or design opportunity and establish an active and constructive relationship in the search and generation of knowledge (Patiño, 2015). For the industrial design, the concept of experimentation can mean something exploratory, free and open in methodological possibilities, nevertheless, through the scientific experiments the students are appropriated of a scheme of systematic work, with which, in turn, they manage to internalize each one of the stages of the research process as a possible combinatorial element for the development of a project that seeks to integrate the design with other disciplines that are opposed to the naked eye. In addition, it is observed how the performance of students increases and improves due to the voluntary participation in the projects, with which, the work dynamics change and different roles are installed between the students and the teachers. Research training through this type of project offers several advantages compared to the conventional processes within the classroom. First, it develops the autonomous ability to systematically search for information, to record it, organize it and analyze it, and thus self-provision of the tools to constantly update and organize knowledge. Second, it develops a permanent spirit of observation, inquiry and curiosity in the measure that motivates the student to move and seek information where he usually does not. And finally, since the direct application of the results in the design product is not at any time the objective of the research, the student must train the divergent thinking to generate speculative awareness and so that its horizon does not narrow in search of only applications (Bonsiepe, 2004).

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