

# Form-finding methodology as strategy for formative research in industrial design education

## *Experimental techniques for the early creative phases of the product design process*

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*The experimental work of Antoni Gaudí and Frei Otto have been the precedents of what is currently called form-finding, a methodology based on rules and physical forces of nature that promotes principles of transformation as a result of the relationship between form, material and structure. This text shows the first results of the research titled as Form-finding methodology as strategy for formative research in industrial design education, with an empirical-analytical approach through action-research based method and using collaborative-participatory tools. As a result of the analysis of different cases in the first stage of the research, a basic methodological proposal is made, this methodological proposal is aimed to find new research possibilities for the identification of morphological characteristics to be used in design projects in the early creative phases (ideation and experimentation); the methodological proposal stages are the following: selection of technique, design of the experimentation, experimentation, analysis and discussion.*

**Keywords:** *Form-finding, Experimental morphology, Industrial design education, Formative research, Action-research*

## INTRODUCTION

Jacob (2014) said that the organization of living systems obeys a series of principles, both physical and biological: natural selection, minimum energy, self-regulation, stepped construction, among others. The forms in nature are diverse and heterogeneous, they are the result of different forces that have shaped

them for millions of years in a constant, changing and unpredictable process; Sir D'Arcy Thompson in his book entitled On Growth and Form makes a study about the incidence of natural forces in the form of plants and animals, in that research he affirms that the form is a diagram of forces. But these constant changes and transformations occur in the context of

physical, geometric and material constraints, Wasenberg (2013) said that the world around us is diverse, creative and changing, but it exists in the context of restrictions and rules, because not everything can persist and remain in this reality.

Between the second half of the 19th century and the beginning of the 20th century, Antoni Gaudí, an innovative architect and artist, broke the paradigms in the process of architectural design, he proposed new methodologies using the forces of nature and constant experimentation with analog models as part of the process of creation-experimentation, proof of this is that the Catalan architect didn't use arcs with geometries resulting from the circle (half a point, pointed, among others), instead he used arcs of non-circular form called parabolic or catenary, using the force of gravity. The catenaries were exposed by Robert Hooke towards the year 1670, who argued that "in the same way that the flexible thread hangs like this, but inverted, the rigid arch will be held." Later the German architect Frei Otto focused

his work on a set of experiments and methodologies around the forms generated in nature in response to forces, such as gravity, surface tension and atmospheric pressure, the results of those experiments with qualities of self-formation and self-organization, these last ones present in nature in living and inert beings.

The experimental work of Gaudí and Otto have been the precedents of what is currently called form-finding, a methodology that uses physical forces of nature, for the generation and transformation of form, integrating analog and digital techniques determined by different restrictions. Patiño (2018) proposes the following definition: form-finding techniques are strategies based on rules and physical principles that promote principles of transformation, based on the relationship between form, material and structure, these rules are usually algorithms formed by an input, a controlled process of variables and an output or results. This idea can be seen in figure 1.

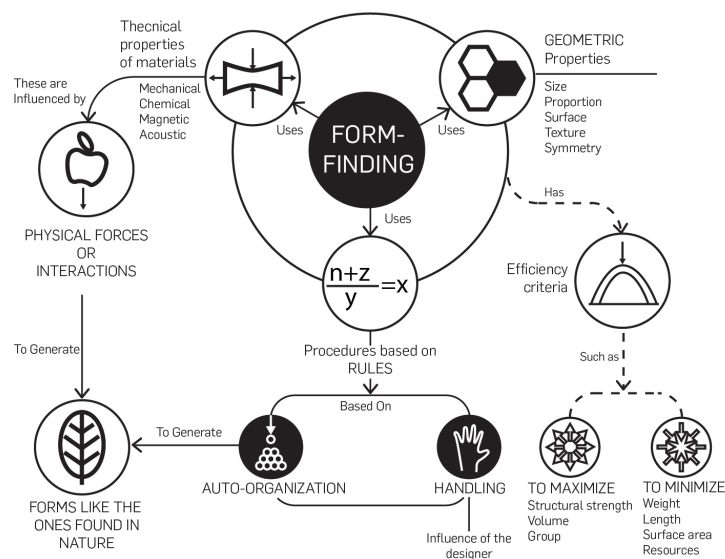
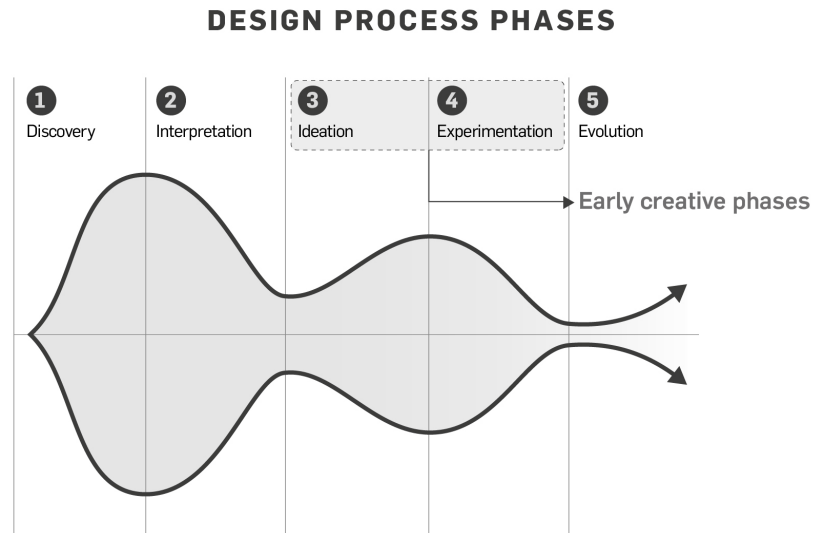


Figure 1  
Form-finding  
schema, Patiño  
(2018).

Figure 2  
Design process  
phases based on  
Design Thinking  
process for  
educators (IDEO &  
Riverdale, 2012).  
Drawing by Catalina  
Grellet De Los  
Reyes.



Form-finding techniques have been used mainly in architecture, in professional and academic areas, but the use of Form-finding techniques has been scarce and only occasional in industrial design, Nordin, Hopf & Motte (2011) mention that, compared to architecture, in industrial design there are few references of these methodologies and the experiences that have been done, but are not documented or published.

On the other hand, the early phases (ideation and experimentation) are important stages in the product design process, because each one concentrates a high level of creativity and it's the moment in which the form is generated. In this phases, a large part of the creative level of the design proposal emerges, because the designer's understanding of three-dimensional geometries intervenes in visual reasoning, in the cognitive level of concluding and inferring information based on visual data of the drawing or the model observed (Egenhofer, 2015). The creative process goes spontaneously from analytical to associative thinking (Gabora, 2010), agile

and constant feedback loops are generated, so that the designer can generate a large number of internal representations in short periods and with a low cognitive effort. In figure 2 it's possible to see the design process phases, and early creative phases proposed by IDEO & Riverdale (2012).

As a result of the analyzed antecedents, the Research Line in Experimental Morphology (Morfolab) of the Industrial Design Faculty of the Universidad Pontificia Bolivariana proposes a research with the goal of developing a methodology to use analog and digital form-finding techniques to explore new research ideas, discovering new research possibilities about the identification of morphological characteristics with possibility of being used in design projects, especially in the early creative phases, in the context of formative research in industrial design program. This methodology as a result of the analysis, understanding, and systematization of the experiences and methods carried out by the research line during 20 years of experience in the Faculty of Indus-

trial Design. The Research Line in Experimental Morphology has proposed different strategies to transfer the knowledge and experiences of the research projects to the industrial design students, this with the goal to build their research and design skills, propitiating an active and collaborative interaction with an empirical-experiential emphasis. The research line has done research projects in the field of morphology around four main themes: biomimetics, non-conventional structures, form-finding, materials and design. At the same time, cross-cutting themes are proposed: food design, digital fabrication technologies, parametric-associative and generative design.

This text shows the first results of the research project titled as Form-finding methodology as strategy for formative research in industrial design education, focused on developing a methodology to use analog and digital form-finding techniques in the context of formative research in industrial design, at Universidad Pontificia Bolivariana in Medellín, Colombia.

**METHODS**

Research project has been proposed with an empirical-analytical approach through action-research based method and using collaborative-participatory tools. The research proposal is based on the understanding of the phenomenon through direct participation in the experience, with emphasis on practical activities, in a dynamic interaction between professors-researchers and students of industrial design, also promoting an active learning process.

The figure 3 shows the stages of research project, the phases are the following: Identification of techniques, stages and variables, analysis and synthesis of information, methodological proposal, validation of the methodology, analysis and evaluation.

The research has been developed in different subjects of research in morphology in the Industrial Design program. Initially groups of students are organized, led by a multidisciplinary team of professors-researchers, who work collaboratively, first to define the type of experimentation, selecting the technique, the materials, processes and require-

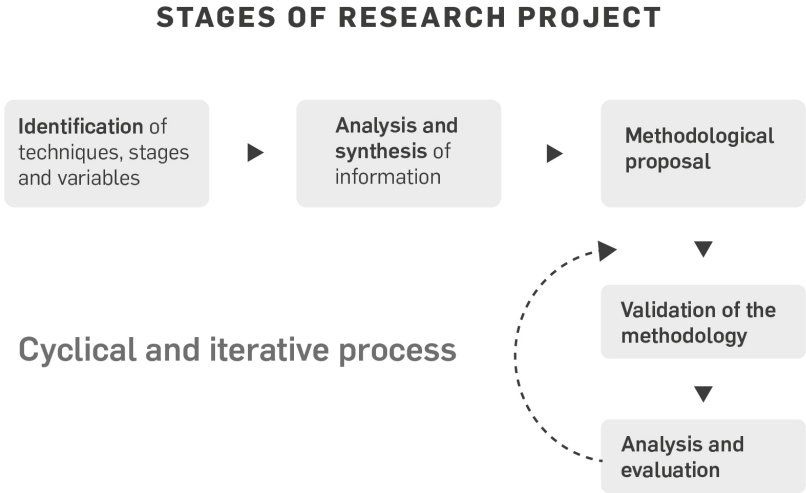
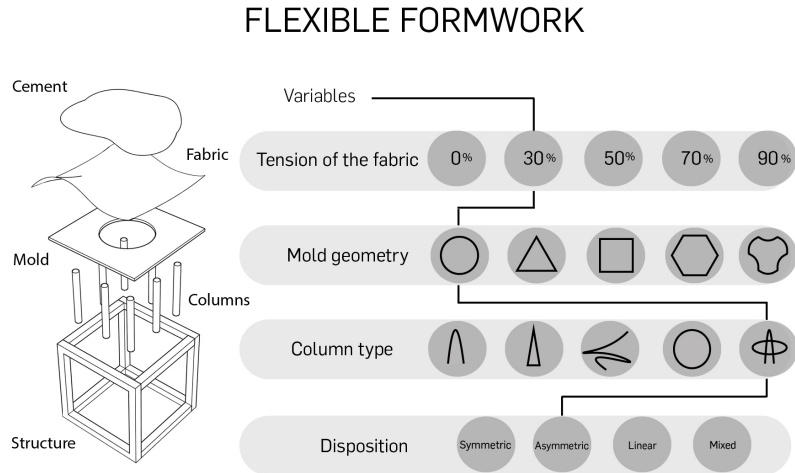


Figure 3  
Stages of research projects, idea proposed by the authors. Graphic design by Catalina Grellet De Los Reyes.

Figure 4  
Flexible formwork  
schema by Camila  
Aguirre, industrial  
design student.



ments involved, then the experimentation is carried out, with a photographic and written record of what happened. Finally, professors and students together analyze the results of the experimentation and synthesize the information obtained in order to identify stages, problems, variables and research opportunities that the technique showed. It's planned to analyze different cases to propose and improve continuously a methodology to be used systematically in formative research in the industrial design program.

### RESULTS

Currently the research project is in the first stage, several case studies have been analyzed that have allowed an initial methodological approach. For this text we have selected highlighted cases, because their results have allowed to identify stages, variables, problems and key factors for the methodological approach, the selected cases are explained below.

**Case 1: Flexible formwork technique (Iwamoto, 2013; Rojo, 2013; Swackhamer & Satterfield, 2013)**

The goal was to generate solids with double positive curvatures through the use of elastic membranes

and concrete, whose main property is to maximize the volume with the minimal surface. The sequential stages were to build the rigid structure, select the type of membrane in relation to its percentage of elongation or elasticity, put the molds and distribute the columns in the structure and deposit the concrete. The experimental variables were the membrane tension, mold geometry, column type, position of the columns. A family of organic forms with potential to be used in facades and floors was obtained, however it's difficult to control the elasticity of the membrane, see figures 4 and 5.



Figure 5  
Flexible formwork,  
photography by  
José Agudelo,  
industrial design  
student.

## SOLIDIFICATION OF MEMBRANES AND GRAVITY

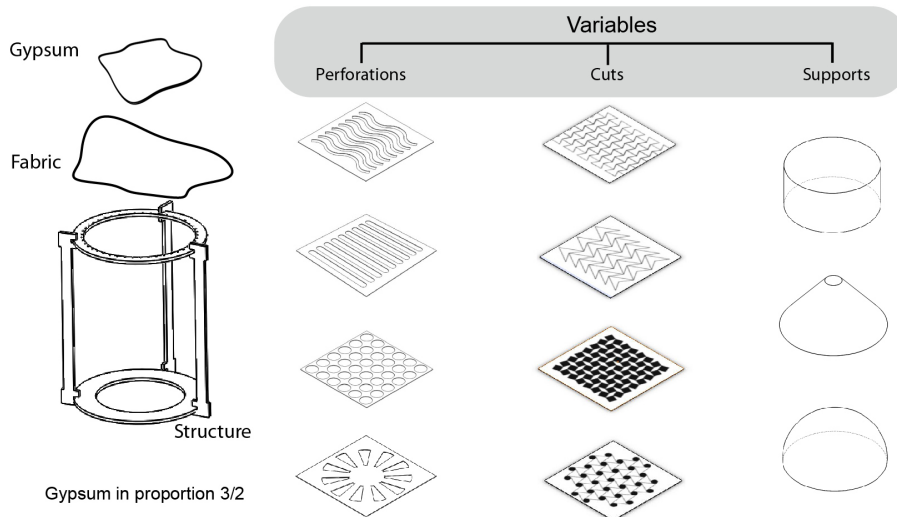


Figure 6  
Solidification of membranes and gravity schema by Juliana Vélez, industrial design student.

### Case 2: Solidification of membranes and gravity technique (Bletzinger, 2001; Jannasch, 2016; Dickson, 2003)

The goal was to find surfaces generated from catenary curves that when are solidified and inverted maximize their capacity to resist loads under compression. Firstly, the structure was built, the fabric was selected and cut, and the gypsum was prepared; then the fabric was immersed in the gypsum and these were hung on the structure. After the cast solidifies, the result is inverted and analyzed. It was observed that the cuts and perforations of the fabric are also influenced by gravity, which produces curvatures similar to the catenary. Although this kind of technique has been used frequently in architecture, in industrial design it hasn't been used; it's necessary to search applications where the resistance to compressive loads must be increased, see figures 6 and 7.



Figure 7  
Solidification of membranes and gravity, photography by José Agudelo, industrial design student.

Figure 8  
Flexible molds  
schema by José  
Agudelo, industrial  
design student.

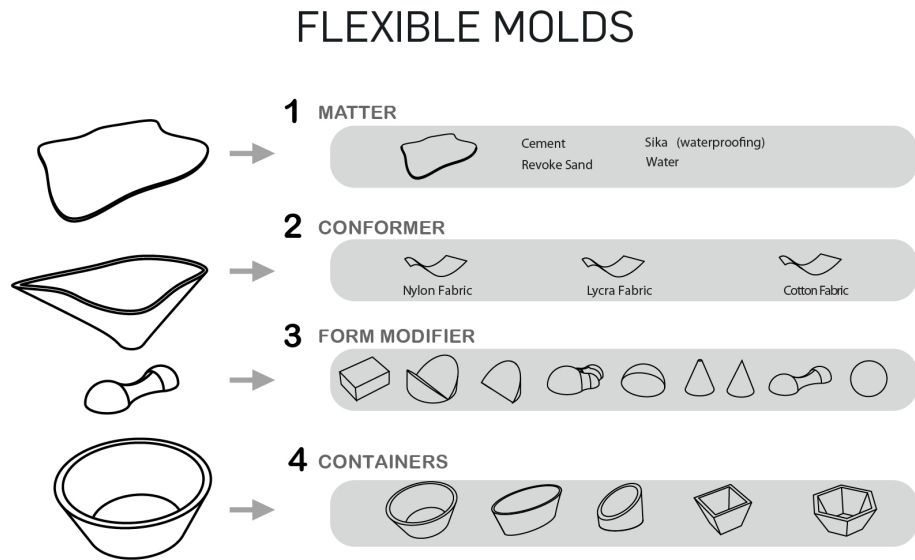


Figure 9  
Flexible molds,  
photography by  
José Agudelo,  
industrial design  
student.

**Case 3: Flexible molds technique (Manelius, 2012; Concretecanvas, 2015)**

The goal was to generate concrete volumes with low cost molds, flexible and with irregular forms. The experimental stages were to prepare the containers, the form modifiers, the conformers (fabrics) and the concrete, the concrete must be prepared with low water content to ensure that it fits in the containers. The experimental variables were types of containers, modifiers and conformers (fabrics) that will influence the finish of the volume. It was observed that irregular volumes are generated as a result of the wrinkles originated from the interaction of the variables. The irregularity of the results makes it difficult to search for applications, see figures 8 and 9.



### Methodological proposal

As a result of the analysis of different cases in the first stage of the research, a basic methodological proposal is made; the methodology has two goals, firstly it allows to systematize the perform and repetition of that kind of experimentation, secondly it's aimed to explore new research ideas about the identification of morphological characteristics with possibility of being used in design projects, especially in the early creative phases, in the context of formative research in industrial design. The figure 10 shows the sequential stages of the methodological proposal.

The methodology stages are the following: selection of technique, design of the experimentation, experimentation, analysis and discussion. The different stages and variables involved are explained below:

1. Selection of technique: firstly, it's necessary

to select a technique and consequently to select a material and a physical principle, besides the technique can be analog, digital or mixed, such as: flexible formwork, solidification of membranes and gravity, flexible molds, inflated structures, minimal surfaces, tensegrity systems, catenary pottery, flexible wood, reciprocal structures, shells, bubbles, among others. The research line has been mainly worked with analog techniques, the use of digital techniques is just beginning to be proposed, through the use of the Rhino's plug-in named Grasshopper and Kangaroo to make physics simulations. It's important to emphasize that the experiences with analogical techniques allow to develop the basics for future digital applications.

2. Design of the experimentation: secondly, the experiment must be designed for professors-

## FORM-FINDING METHODOLOGY

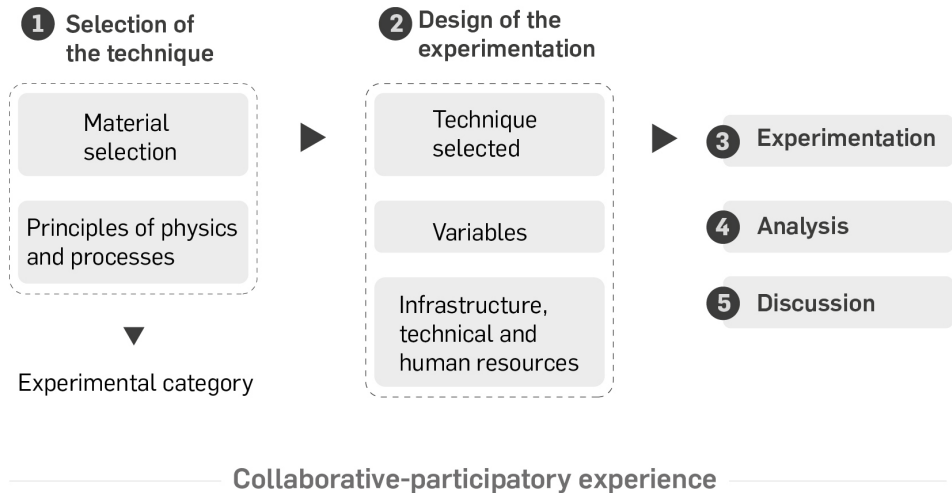


Figure 10  
Form-finding  
methodology  
proposal, idea  
proposed by the  
authors. Graphic  
design by Catalina  
Grellet De Los  
Reyes.



researchers in collaboration with students, must be considered the selected technique, the variables, the infrastructure, technical and human resources.

3. Experimentation: this is the most important stage, the core and the main experience, in this stage students and professors-researchers carry out the processes of transformation of materials involved in the chosen techniques, in a collaborative-dynamic interaction in an active learning. In this stage, the photographic record is highly relevant and also a written record in the field diary, in order to identify different stages, variables, key factors, problems and opportunities; different formats have been developed to record the experimentation.
4. Analysis of results: the results are analyzed in order to identify stages, variables, and morphological characteristics or principles; It's also important to identify problems and unforeseen events. The analysis can be done through qualitative, quantitative and mixed methods.
5. Discussion phase: in the last phase professors and students discuss collaboratively about the experience and results. The results are analyzed to identify stages, variables and characteristics of this type of experimentation, as well as the problems and unpredictable situations. On the other hand, it's expected to find morphological principles with possibilities of being used in the first stages of the product design process, these analyzes open new possibilities of research in the industrial design program.

## DISCUSSION

As a result of the first stage of research and lived experience, it's possible to outline the following ideas and conclusions:

The analysis of the case studies has allowed to identify different experimental categories, the

stages, variables and key factors for the first methodological approach. In synthesis, the stages of the methodological proposal are selection of the technique, design of the experimentation, experimentation, analysis of results and discussion.

The methodological proposal aims firstly to systematize the perform and repetition of each kind of experimentation, secondly to explore new research ideas about the identification of morphological characteristics with possibility of being used in design projects, especially in the early creative phases, in the context of formative research in industrial design.

The research group have mainly used analog form-finding techniques and have just started to use digital techniques, however the experiences with analogical techniques allow to develop the basics for future digital applications; also analog techniques are important because they propitiate direct contact with materials and transformation processes, this can improve the ability of the students to understand. On the other hand, the use of digital techniques shouldn't exclude analog techniques, on the contrary, analog and digital techniques are complementary.

The methodology reveals a cyclic and iterative sequence, in which experience is the core of the process, the trial and error, doing and doing it again are important parts of the experimental process. It's expected to refine the proposal through the future analysis and experiences in a dynamic process with a collaborative-participatory interaction between professors-researchers and industrial design students in order to increase creative results. This methodological proposal will be part of the different formative research strategies at the Industrial Design program at Universidad Pontificia Bolivariana in Medellin, Colombia.

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